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Comparing and contrasting methodologies
A commentary

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A short overview
The term 'methodology' is discussed before we consider the methodological contributions of each team of chapter authors (Cobb, Gresalfi & Hodge; Nathan, Eilam & Kim; and Saxe, Gearhart, Shaughnessy, Earnest, Cremer, Itakbhan, Platas & Young) and examine links between them. We generate questions arising from our analyses of the three chapters in this section and formulate views on classroom learning in mathematics that could be researched through complementary analyses. The subsequent discussion of data-collection instruments appropriate to further analyses is informed by our own research perspectives. This commentary concludes with a summary of what we have learnt through comparing the three methodologies and how simultaneously focusing on data from different theoretical perspectives might help to show the way forward in researching the richness of learning in classrooms.

'Research methodology': what does it mean?
Background theories determine the kind of research questions that can be investigated and the kind of methods that are suitable. They provide the frame of how research objects are shaped and what kind of aims are followed (Mason & Waywood 1996; Bikner-Ahsbahs & Prediger 2006). Seiffert & Radnitzky (1989, p. 465) describe a methodology as a technology for epistemological progress that should not merely be regarded as a set of algorithms; rather it comprises quite vague rules which allow a researcher to handle methods in a creative way. Such creative ways of handling methods are described in the three methodology chapters in this section.

The methodology of a research study cannot simply be reduced to the set of methods. Methods control the way of coming to know and a methodology controls the choice of methods. The methodology's normative rules tell us how research results can be valued and applied and how they are related to the empirical world. Therefore it has to fit the background theory and paradigm in which research is conducted. Research results might not be compatible due to incompatible assumptions. That is why researchers should feel an obligation to make explicit their normative rules for their choice of methods. Reflecting on the topics of the three studies and their connections to their views on learning,
research objects, observation tools, situations of investigation and their aims, we will illustrate the notion of 'methodology' in more detail.

All three research teams use a study on learning mathematics to inform their methodologies. Cobb and colleagues describe what design research means methodologically using a concept of a pair of situational subject-based identities developed in a statistics classroom. Saxe and colleagues outline a methodological frame for investigation of the travel of ideas which they illustrate by a fraction lesson shaped as inquiry learning. Nathan and colleagues present the analysis of a dialogical learning situation with a focus on developing intersubjectivity and consider methodological issues.

Learning mathematics, which is at the centre of all the three chapters, has different meanings for different authors. Nathan and colleagues speak of 'socially mediated learning' which implicitly indicates an individual concept of learning. Saxe and colleagues focus on the travel of ideas that shape learning as a social process that is interrelated to individual learning mediated by participation in the travel of ideas. Cobb's more dialectical view considers the co-development of two identities, one on the social level and the other on the individual level; learning mathematics takes place as co-constructions of both of them.

Concerning the concepts of learning, the three authors require different kinds of observation tools in their empirical research. Dialogical learning environments (Nathan et al.) are especially effective for investigating learning as part of a discursive process with tools that grasp the specificity of the dialogue and its impact. For inquiry learning the core idea is the production of mathematical ideas which Saxe and colleagues investigate through the change of forms and functions in the ideas that travel.

Classroom learning takes place within a class as a result of teaching and the teacher's philosophy of teaching and learning. Therefore research on learning mathematics in the classroom must also take into account the situation under investigation and this can be regarded at different levels, e.g. at the level of microgenesis, sociogenesis and ontogenesis of inquiry-learning processes in the class (Saxe and colleagues) or at the micro-, meso- and macro-level of a dialogical process within one lesson (Nathan and colleagues).

Methodological considerations taking into account all these aspects show how choices of methods and techniques are to some extent predetermined. However, the choice of methods is also influenced by the nature of the results that are of interest; for example, Saxe and colleagues and Cobb and colleagues use a recursive method of investigation because research is done for the purpose of curriculum development or design.

We conclude that a good methodology relates all the important research aspects to each other and to the theoretical background leading the researcher to well-grounded choices about methods, tools and techniques that capture just what the researcher wants to observe before and during the research conducted. An illustration that deepens our understanding of such connections between analysis tools and theory is presented by Hershkowitz in this volume.
Some questions arising from these methodology chapters

These chapters stimulated the following reflections and questions for us:

1. Saxe and colleagues have investigated the travel of ideas. Understanding the kinds of participation in the travel of ideas seems to be crucial to examining how mathematical understanding develops. We want to know more about this, including: What kinds of participation were observed? What kinds were found productive? If changes of forms and functions indicate learning, do some kinds of forms and functions occur before others? When and why are students satisfied to know only how (described as procedural)? What kind of conditions support asking why (described as normative)? The authors stated: 'Mathematical ideas travel as students make sense of them'. To what extent is sense making captured through the research design? For example, Annabelle realized that adding further intervals (geometric representation) gave the same answer as 'doubling (the numerator and denominator of) the fraction'. Did she only see a pattern linking these representations or did she know why the pattern existed?

2. Is Saxe and colleagues' focus on the change of ideas sufficient to examine the learning that occurred? Change of ideas need not indicate making progress, and change of forms and functions might not be enough to describe learning. For example, adding an idea to one's own ideas is a learning step but need not result in a change of form and function. Transforming an idea into one's own view could be a change of form and function but need not be a step in progress. Linking to Cobb and colleagues' chapter, how can student participation in the travel of ideas be improved?

3. Saxe and colleagues collect data on 'influences' on learning by asking students whose ideas influenced them most. Students tended to select one of the three students who presented their work to the class rather than a member of their own groups. Given previous research on how much students can learn from each other in groups, a closer examination of how students interpreted the term 'influence' is required. In making their decisions, did these students use a criterion like the 'amount of time spent listening'? Or did they make their selection on the 'significance of the change in ideas'?

4. Mathematical ideas can be considered at the level of content, and at a meta-level. Dreyfus, Hershkowitz and Schwarz (2001) describe a meta-level change in ideas that occurred when a student pair realized algebra could be used as a tool to develop an argument. Meta-level change in ideas might not be easily observable. Do these types of meta-ideas 'travel'? And if so, how? Can the data-collection instruments used capture this?

5. Cobb and colleagues investigated two mutually dependent concepts of identity. We would have liked to see illustrative examples of the enactment of normative and personal identity, and students' responses to questions about their perceptions of competence in these classrooms. This would have provided opportunities to consider the nature of the methodology in more detail and to retrace results from data. We wonder what such illustrations would have 'looked like'?
6. Have Cobb and colleagues found that normative and personal identity depend on the mathematical topic and the aims of the lesson or do they reflect a special kind of engagement no matter what kind of mathematical topic the students work on? For example, do they consider that preparing for a test requires another kind of normative identity than discovering a pattern, or developing a concept?

7. In what ways could simultaneous study of the work on identity by Cobb and colleagues and Sfard and Prusak (as cited in Cobb and colleagues) inform our understanding of mathematics learning? Complementary analyses of a situational and a stable concept of pairs of identity might shed light on the question of how a learner creates a specific relationship to a mathematical content, as well as the conditions that support and hinder this process.

8. Nathan and colleagues have found that a dialogical process leads to more standardized practices and have employed intersubjectivity as a way to study this process. What differences were there in the nature of the developing intersubjectivity displayed towards the beginnings and the ends of exploratory intervals? Answers to this question could lead to further insights into the quality of learning mathematics in dialogical settings and into how the nature of the dialogue can influence the process of knowledge development.

**Interest: origins and fluctuations**

A theme that permeates all three research studies is student interest and fluctuations in interest over time.

**Fluctuations in interest**

The episodes described by Saxe and colleagues and Nathan and colleagues were not uniform with regard to the degree of interest displayed by the students. Fluctuations in interest can be considered in terms of what Bikner-Ahsbahs (2005, 2003) has called 'interest-dense situations'.

In interest-dense situations, the students experience what it is like to learn mathematics with interest, and participate in an epistemic process that requires students to take responsibility for their own learning processes. In a socially supportive learning environment, students begin to value mathematics and experience positive affect in class. Without being forced to, they become involved in the activity of constructing mathematical meanings which often appear as an evolution of mathematical ideas within a dialogue. This way, they develop a feeling of competence, and experience autonomy and social relatedness. Such interactions are evident in the research described by Saxe and colleagues and Nathan and colleagues. Repeated experience of interest-dense situations increases the chance to develop a fruitful and interest-based relationship to mathematics (Krapp 2003).

Taking Cobb’s normative view of identity, interest-dense situations build a normative identity that describes a mathematically interested student experiencing competence, autonomy and social relatedness (Deci 1998). Such an interest-based identity can lead to seeing mathematical structures and valuing
mathematics highly by creating mathematical ideas, building concepts and inventing, discovering and checking mathematical patterns. Interest-dense situations offer increased opportunities to affiliate with mathematics and to participate in doing mathematics in a creative way. The extent to which a student identifies with such a normative identity or with parts of it provides evidence of situational interest (Mitchell 1993). According to self-determination theory (Deci 1998), this kind of interest is not far away from a more stable kind of interest which is called personal interest (Mitchell 1993).

Personally interested students are already affiliated with mathematics before the lesson begins. They bring their interest with them into the class and influence the building of a special kind of normative identity through their involvement in the activity. How do Cobb and colleagues capture this kind of phenomenon since personal identity is a situational concept which does not seem adequate to grasp stable features? Sfard and Prusak’s construct of identity (in Cobb et al.) might provide this complementary view.

Within interest-dense situations the students participate in a ‘travel of ideas’ that leads to seeing mathematical structures. The teacher may support this process by abstaining from her/his own content-specific expectations. At the same time the students take over the responsibility for their learning process following their own and their classmates’ process of producing ideas while considering them to be mathematically valuable. Saxe and colleagues’ concept of learning is restricted to the change of ideas according to their forms and functions. To what extent do they include the quality of learning mathematics as it is part of interest-dense situations? Some progress of learning mathematics is described in their results in distinguishing between normative, procedural, partial and non-normative functions. Do the authors want to find out what kind of progress is observed in the travel of ideas? If so, why do they only distinguish between arithmetic and geometric forms and gather all the other forms into the category ‘other’? Changing real-world forms, such as pizza cuts, into arithmetic forms may not occur in this way. Former experiences such as decimals, percentages or pizza cuts and how they link with fractions might influence the way the students ‘catch ideas’. New ideas can have the function of structuring a group of ideas to build a rule, for example expanding a fraction with the natural numbers 2, 3, 4 or ‘any natural number’ (Bikner-Ahsbahs 2005). In addition, interest can have a significant effect on the travel of ideas. How do the authors grasp these kinds of phenomena?

The last example in Nathan and colleagues’ chapter about pie cuts shows that the interest-dense situations can break down when the flow of ideas begins to dry up. This happens because complicated representations are difficult for the students to understand and the teacher does not intervene; therefore, ideas cannot be grasped and situational interest decreases. Do Saxe and colleagues investigate what conditions prevent students from grasping ideas? This would inform research on fluctuations in interest.

Nathan and colleagues show that, in a dialogical environment, there is a ‘convergence on standards for representing ideas’. This convergence seems to be a natural phenomenon if learning through dialogue is experienced because understanding the other is essential for this kind of lesson. However, does this lead to