Microgenetic Learning Analysis: 
A Distinction without a Difference

Commentary on Parnafes and diSessa

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Parnafes and diSessa [this issue] present a useful description of the process of doing microgenetic analysis of qualitative data and report interesting findings about how students’ reasoning changes as they gain relevant experience. We are pleased that microgenetic approaches are being applied to educational issues and agree with the authors that new knowledge can be gained by closely examining changes in students’ thinking over time. Conceptual change is a topic that has been mostly overlooked in the microgenetic literature [for exceptions, see Amsterlaw & Wellman, 2006; Opfer & Siegler, 2004; Schoenfeld, Smith, & Arcavi, 1993]; yet it is an area where close observation of changing behavior is likely to yield large theoretical gains.

In our view, however, the microgenetic learning analysis (MLA) described by Parnafes and diSessa is indistinguishable from microgenetic analysis more generally. The authors state that ‘it is not obvious, at first blush, that MLA is anything other than the use of general microgenetic methods applied to an area (conceptual learning) that has been somewhat neglected in the microgenetic literature’ (p. 10). We agree, and after reading and thinking about the article, we continue to believe that MLA is simply microgenetic analysis applied to conceptual change. Below, we provide the definition of microgenetic analysis that we have been using for more than 20 years [Siegler & Crowley, 1991] and discuss why we concluded that MLA is simply a form of microgenetic analysis.

The Microgenetic Method

The microgenetic method is defined by three properties: (a) observations span a period of rapid change in competency; (b) the density of observations is high relative to the rate of change; and (c) the observations are subjected to an intensive, trial-
by-trial analysis to infer the processes that give rise to change. The MLA case study presented by Parnafes and diSessa fits all three of these criteria. Pairs of children are observed as their understanding of simple harmonic motion is rapidly changing, the density of observations is high, and the authors intensively examine the data to determine how learning occurs.

The changes that Parnafes and diSessa documented can be categorized into the same five dimensions that have proved useful in microgenetic studies in general [Siegler, 2006]: the source, path, rate, breadth and variability of change. The source of change refers to the events that set the change in motion. The path of change is the sequence of knowledge states that the child passes through while gaining competence. The rate of change refers to how quickly the change occurs. The breadth of change involves the range of extensions of new approaches to novel contexts. The variability of change refers to the variability between children on the other four dimensions and to within-child variability in the strategies used to solve a problem.

For the children studied by Parnafes and diSessa, Rachel and Debbie, the source of change is their interactions with the computer representation. At a more fine-grained level, the source of their improved understanding is the graph in the computer representation that represents the period. Noticing this aspect of the graph sets in motion the processes that lead to conceptual change. For the path of change, consider Rachel and Debbie’s understanding of pendulum speed. They began by thinking that the greater the distance that a pendulum travels, the faster it must be traveling. After noticing the period of the pendulum on the computer representation, they modified their beliefs and began to pay attention to both period and distance traveled when determining speed. Notice that this is not the only possible path of change. Debbie and Rachel could have started using only the pendulum’s period when determining speed, but instead they used both the period and the distance. The rate of change is unclear from the data presented, but examination of the data would allow the authors, if they wanted to do so, to determine how quickly Debbie and Rachel modified their understanding of speed. The breadth of change is also currently unclear but is discoverable from the data set. One could examine, for example, whether Debbie and Rachel used their new understanding of period when dealing with springs as well as pendulums or if the new knowledge is limited to pendulum motion. Finally, Parnafes and diSessa provide evidence for the variability of change within their study. The authors identify four mechanisms of change that explain why the children modified their concepts. Presumably, different pairs of children would vary both in the frequency that the different mechanisms occurred during the study and in which mechanism produced each change. For example, Debbie and Rachel’s new appreciation of period was prompted by the reapplication mechanism. For another pair of students, the same transition might have been prompted by the challenge mechanism.

**Theory Development**

The authors distinguish between MLA and microgenetic analysis by stating that microgenetic analysis does not create theory. It is true that grand theories such as information processing theory and Piagetian theory were not developed due to microgenetic methods. However, the results of microgenetic studies have motivated
theories of how development occurs. Just as Parnafes and diSessa suggest that multiple MLA studies will gradually contribute to theory development, multiple microgenetic studies have contributed to creating psychological theories.

A prototypical example is Siegler’s overlapping waves theory [Siegler, 1996]. The theory suggests that development is a variable process with children processing multiple ways to solve a problem at any given time point and that the relative frequency of any given choice will change with development. As shown in figure 1, children process multiple strategies for solving any given problem and, through development and experience, the relative frequency that each strategy is used will change. For example, some strategies are initially popular and then fade away (strategy 1), some become frequent before being replaced by other strategies (strategy 2), some are used occasionally but never frequently (strategy 3), and others are rarely used initially before becoming dominant later in development (strategy 4). The overlapping waves theory was developed based upon the results from microgenetic experiments in a wide range of areas, including development of perceptual and motor capabilities, conceptual understanding, problem solving, and academic skills [e.g., Adolph, 1997; Karmiloff-Smith, 1984; Shimojo, Bauer, O’Connell, & Held, 1986; Siegler, 1995; Siegler & Jenkins, 1989] and had been used as a theoretical framework for many other studies in domains such as arithmetic [Robinson & Dube, 2008; van der Ven, Boom, Kroesbergen, & Leseman, 2012], attention [Lavelli & Fogel, 2005], counting [Camos, 2003; Chetland & Fluck, 2007], numerical magnitude understanding [Nuerk, Kaufmann, Zopoth, & Willmes, 2004; Opfer & Siegler, 2007], reading [Lindberg et al., 2011], spelling [Kwong & Varnhagen, 2005; Rittle-Johnson & Siegler, 1999] and tool use [Chen & Siegler, 2000].

The overlapping waves theory is not the only theory to have been developed based on microgenetic methods. The dynamic systems approach popularized by Thelen and Smith [1994] was also developed based in large part upon results from microgenetic experiments [e.g., Thelen, Corbeta, Kamm, & Spencer, 1993; Thelen

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**Fig. 1.** The overlapping waves model.
In addition, Goldin-Meadow’s influential idea regarding the meaning and effects of speech-gesture mismatches was also developed in large part from a series of microgenetic experiments [e.g., Alibali & Goldin-Meadow, 1993; Goldin-Meadow & Alibali, 2002; Goldin-Meadow, Nusbaum, Garber, & Church, 1993]. Finally, multiple microtheories of how knowledge develops within specific domains have been developed based on microgenetic methods including: changes in arithmetic strategy use [Siegler & Jenkins, 1989; Siegler & Shrager, 1984], word learning [Gershkoff-Stowe & Smith, 1997], number conservation [Siegler, 1995], theory of mind [Amsterlaw & Wellman, 2006; Flynn, 2006; Flynn, O’Malley, & Wood, 2004] and concepts of living things [Opfer & Siegler, 2004].

Concepts versus Strategies

A second contrast that Parnafes and diSessa make between MLA and typical microgenetic studies is that MLA deals with the development of concepts whereas microgenetic studies deal with the development of strategies. It is true that many, if not most, microgenetic studies have dealt with the development of strategies but only because strategies are a behavioral marker for children’s internal concepts, beliefs, and understanding of problems. For example, the behavioral choices that children make while designing an experiment reflect their underlying concepts of what makes a good experiment. If a child understands that good experiments vary only one aspect of the design at a time, then he or she will use the strategy of changing only one variable. If, however, the child’s concept of a good experiment does not emphasize the importance of changing only one variable, then his or her behavior will reflect that belief. The authors correctly surmise that we believe that the development of strategies is the development of concepts, stating that ‘Siegler … sees concept learning as only incidentally different from strategy development’ (p. 16).

It is unclear why Parnafes and diSessa believe that ‘the development of routine strategies is a different intellectual regime compared to learning complex concepts’ (p. 15). They suggest that strategies appear on a single trial while concepts develop slowly. It is true that a new strategy can appear suddenly, but that does not mean that the development behind that novel strategy was also rapid. Rather, the child’s knowledge, concepts and beliefs may have been slowly changing, allowing that new strategy to appear. Moreover, children often use transitional strategies for a brief period of time that reflect partial or inchoate understanding of a concept [e.g., Siegler, 1995; Siegler & Jenkins, 1989]. Furthermore, like concepts, strategies can be unreported. Children sometimes use a strategy to solve a problem but are not able to accurately report what they did, much less why they did it [Siegler & Stern, 1998]. Parnafes and diSessa themselves state that student’s concepts can be determined from their behavior, further blurring the line between strategies and concepts. The child’s concept is often inferred from the strategy he or she uses to solve the problem.

As noted earlier, it is inaccurate to say that microgenetic methods have not been used to study children’s learning of concepts [e.g., Chinn, 2006; Nuthall, 1999; Opfer & Siegler, 2004]. In one such example, Opfer and Siegler [2004] examined preschoolers’ concept of ‘living things’ to determine how children come to believe that both plants and animals are living. Children who were shown that both plants and animals were capable of goal-directed movement quickly modified their ‘living things'
concept to include both plants and animals. However, contrary to previous hypotheses [Inagaki & Hatano, 1996, 2002], learning that both plants and animals needed water did not lead to a revision of the concept. These findings led Opfer and Siegler [2004] to conclude that capability of goal-directed movement is central to children’s concept of living things.

Conclusions

Parnafes and diSessa present a detailed account of how to conduct a microgenetic study of conceptual change using qualitative data. Although we disagree with the authors about whether this is a new method or simply an extension of microgenetic analyses, we agree that detailed examinations of children’s behavior while change is occurring often leads to large increases in knowledge about how conceptual change occurs.

One aspect of Parnafes and diSessa’s method that we think is particularly important is their attention to what they call ‘readout strategies’. Typically labeled ‘encoding’ by Siegler and colleagues, these readout strategies recognize that two children looking at the same display may not notice the same elements. Further, the elements that children do or do not notice can have large effects on what they learn from a task. In the current study, Debbie and Rachel’s concepts of speed only begin to change after they notice the period in the computerized representation. Similarly, on a balance scale task, Siegler and Chen [1998] found that children only began to realize the importance of a weight’s distance from the fulcrum if they encoded distance when viewing the problem. One of the benefits of the microgenetic method is that it allows researchers to notice these differences in encoding or readout strategies among participants.

Overall, we believe that Parnafes and diSessa have conducted a very interesting and important study, one that illustrates the value of microgenetic methods for studying conceptual change. We hope that other researchers will use their paper as a guide and that we will see more microgenetic studies within educational settings in the near future.

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