Microdevelopment

Transition Processes in Development and Learning

edited by

Nira Granott and Jim Parziale

CAMBRIDGE
UNIVERSITY PRESS

2002

10 Notebooks as windows on learning: The case of a science-into-ESL program

Rochel Gelman, Laura Romo, and Wendy S. Francis

Introduction

Our efforts to study the acquisition of new knowledge, especially in the areas of mathematics and science, take advantage of a combination of methods. These include experiments, controlled training studies, and qualitative analyses of videotaped classroom learning. In addition, we have been developing ways to treat the classroom as an in situ learning laboratory. Here we focus on a particular example, a science-into-ESL (English as a Second Language) classroom that functioned as a concept and language learning laboratory.

A key research goal was to gather "on-line" data on whether students moved on to and along relevant learning paths during the course of a semester. Given the classroom setting, we wanted these to be inconspicuous "probes" rather than more traditional learning test trials. Our solution shares important aspects of the microgenetic method, the topic of this book. We requested that students keep notebooks and make regular entries that could function as learning experiences for them and probes as to whether learning was happening over time. Notebook entries are a common feature of how scientists work, especially when it comes to trying to keep track of experiments and evolving ideas. They also have served historians of science as documents for analyzing the conditions of conceptual change. As we shall see, notebooks have the potential to serve researchers' efforts to obtain on-line information about students' progress in a non-intrusive manner. Thus, they can function both as a

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An early report of the Science-into-ESL project was presented in a master's thesis by Romo (1993). The work covered here was supported by several funding sources, including grants from the Linguistic Minority Research Institute, University of California; the US Office of Education; and an NSF LIS grant entitled "Learning in Complex Environments by Natural and Artificial Systems." Correspondence about the chapter can be addressed to Rochel Gelman.

This chapter is dedicated to Anne Brown. She and her husband Joe Campione were ever-present conversationalists and cheerleaders from the very outset of the science-into-ESL project.

learning opportunity for students and as a research tool for investigators of concept and language acquisition.

Our commitment to a constructivist theory of concept acquisition motivated us to achieve on-line peeks at students' accomplishments (or lack of accomplishments) as their term progressed. Since learners are active participants in their own conceptual development, we cannot assume that they and their instructors will share a common interpretation of the lessons and related learning exercises. The knowledge and language skills they bring to a given subject influence what they attend to and how they interpret offered data. When the to-be-learned material is not readily related to what is already known, there is a risk that the inputs are ignored or even misinterpreted (Bartlett, 1932). Hence, it is critical to have ways to peek regularly at what, if anything, about the curriculum is being learned.

The science-into-ESL program featured here was developed by a team of high-school ESL and science teachers in collaboration with members of our university research team. A major goal of the program was to move ninth-grade students (fourteen and a half to sixteen years of age; median fifteen years) far enough along in their use and understanding of science in English so that they could take regular tenth-grade science classes, even though they had not completed their ESL course sequence. Of course, the program also had to increase students' overall English proficiency. At the time of study, ESL students at high schools in the Los Angeles Unified School District (LAUSD) were required to finish at least four semesters' worth of ESL instruction before starting science classes. This had the effect of limiting their opportunity to take enough years of high-school science courses to meet admission requirements to many colleges and other advanced levels of training.

The science-into-ESL curriculum used many of the lessons of cognitive science (see Bransford, Brown, & Cocking, 1999; Gelman & Gattis, 1995, for reviews). Every effort was made to ensure that students were active participants in their own learning, and that they engaged in guided discovery (Brown & Campione, 1996). In addition to being able to read newly prepared reading text materials about science topics, the students had opportunities to do collaborative experiments, make entries in their science notebooks, interpret data, talk and write about science, use computers, and interpret the course materials. Further, a group of bilingual UCLA undergraduates were present during voluntary after-school periods. Not only did the notebook requirement allow us to build in non-evaluative exercises that we could use to monitor students' learning over time, but it also fit with one of the desiderata of the course, this being that the students be able to do science and communicate about what was covered in readings and classroom lectures.

Monitoring learning in a classroom, given a constructivist perspective

Learners, be they infants, children, or adults, are not passive recipients of their environments. We all contribute to our own conceptual development by virtue of the fact that we use existing knowledge structures, no matter how skeletal they might be. Mental structures both require and contribute to epigenetic interactions with their environment. Without conscious effort, we more readily notice and remember those aspects of the environment that are related to available mental structures. Our ever-present tendency to assimilate data that are related to existing conceptual structures is often a good thing. Domain-relevant paths lead learners to inputs that are consistent with the structure of the domain to be learned; domain-irrelevant paths do not. Thus, existing structures of mind help novices move on to learning paths that are domain-relevant rather than domain-irrelevant.

There is a potential downside to the constructivist nature of our minds, namely, that it is always possible that beginning and novice learners will ignore and/or misinterpret their environments. Where mental structures have to be acquired de novo – as is surely the case for topics such as Newtonian mechanics, the theory of evolution, the stock market, etc. – learners have to acquire domain-relevant structures in addition to content (see Brown, 1990). Efforts to provide instruction in these domains must recognize and overcome a crucial challenge: learners may assimilate inputs to existing conceptual structures even when those inputs are inconsistent with existing structures and intended to force accommodation and conceptual change (Slotta, Chi, & Joram, 1995; Gelman, 1993, 1994). For this reason, students are often at risk of failure to learn mathematics or science. If we leave them to their own devices, they are biased to assimilate classroom inputs about fractions to their counting-based number theory. For example, they are likely to assume that 1/56 is less than 1/75 because 56 is less than 75.The risk of a mismatch between our intended inputs and what the learners take on is much increased when what is to be learned does not share structure with what is already known (Gelman, 1994; Gelman & Williams, 1998).

If the to-be-learned data do not map to an existing structure, the conditions are conducive for them to be regarded as irrelevant and therefore ignored (Stigler & Fernandez, 1995), or misinterpreted as relevant to an existing knowledge structure (Hartnett & Gelman, 1998). In the former case, learners fail to move on to the target learning path. In the latter case, they might even move on to the wrong learning path, one that encourages the development of misconceptions. These considerations highlight the need to have tools to determine whether learners move on to relevant learning paths when they are offered inputs meant to nurture new learning.

There is growing evidence that microgenetic studies – ones that probe for the kinds of hypotheses, language, and strategies children use at different points in the course of acquisition – contribute to efforts to understand concept development (e.g., Karmiloff-Smith & Inhelder, 1974/75, as well as the chapters by Goldin-Meadow & Alibali, Granott, Kuhn, Siegler, and Parziale in this volume). They are especially suited to gaining insight about the initial and changing nature of children's interpretations of inputs for learning. We had this advantage in mind when we set the goal of developing a version of such microgenetic analyses to chart learning paths in a school setting over the course of a semester. To do so we had to deal with three challenges.

The science-into-ESL materials were likely to be rather novel for many in the class. Therefore, despite extensive efforts to achieve a superb curriculum, it was not reasonable to expect the students to achieve learning with full understanding in a ten-week term. Mastery of the scientific concepts taught in high school can take many years. Acquisition of what Gelman and Williams (1998) dub "non-core domains" requires the assembly of new conceptual structures as well as the domain-relevant knowledge, and lengthy formal instruction is often required (see for example Bransford et al., 1999; Carey, 1991; Chi, 1992; Chi, Glaser, & Farr, 1988; Kuhn, 1970). We knew it would be foolhardy to expect the students to achieve learning with understanding. Therefore, we needed a design plan that differed from those microgenetic studies that track the evolution of strategy preference and deployment as learners converge on an endpoint, a correct solution, or a target learning plateau. The challenge then was to have ways to monitor whether students were at least attending to, and beginning to learn about, their lessons. A second challenge was to find a way to deal with the fact that, compared to most microgenetic studies, the time frame of our study was much expanded, indeed, to a full academic term. Finally, we knew that we could not achieve the level of experimental control that is a key feature of microgenetic studies. Still, our variant of the microgenetic method had to allow us to monitor whether or not students were moving on to and along relevant learning paths. Our search then was for a method that would provide a window on whether students were traversing learning paths which led toward science-relevant knowledge and language. As indicated, we responded to these challenges by taking advantage of a central feature of the science-into-ESL curriculum we were involved with – the students kept scientific notebooks. This was part of the plan to engage students in doing, talking, and reporting science.

Writing: A window on conceptual and language learning paths

The acquisition of scientific language and scientific concepts constitutes two sides of a coin; each is integrally dependent on the other (Kuhn, 1970; Halliday & Matin, 1993). When it comes to learning about technical domains, it is not stretching matters too far to treat science language learning as a form of second language learning. It is not just that the languages of science and mathematics are filled with specialized terms that derive their meaning from the domain within which they operate. There is also the problem that some everyday terms have completely different meanings. For example, the word "conductor" refers to the leader of an orchestra when used in everyday English. However, in the language of science "conductors" are substances or bodies that have the capacity to transmit or carry heat, electricity, etc. Within mathematics terms like "multiply" and "add" are more like false cognates; they do not have the same meaning in mathematics as they do in the natural language. They do not always mean "increase" or "get bigger," as shown in the result of multiplying two fractions or adding two negative numbers. Things are equally tricky when we consider the meaning of "add" when liquids are being combined. When one adds two cups of water to three cups of water, the result is five cups, but when one adds a 10 °C cup of water to another 10 °C cup, the resulting temperature is 10 °C. These examples illustrate that terms cannot always be treated as equivalent across different domains. Bransford et al. (1999) offer many further examples of the fact that learning about concepts and the specialized language (and notational system) of a domain go hand in hand. Such considerations reinforced our view that we would be able to probe whether students were moving on to and along a learning path that was related to the learning activities, by looking at their developing use of the domain-relevant scientific language.

Our decision to encourage students to write and ask questions about what they had been taught was also motivated by the finding that the study of explanations has provided researchers with a window into transitional states of students' mathematical and scientific understanding (Gelman, 1991; Hartnett & Gelman, 1998; Siegler & Jenkins, 1989). In addition, as individuals acquire knowledge about a topic, their ability to communicate and write about that topic progresses. For example, Siegler & Jenkins (1989) found that as children discover new strategies for addition problems their explanations are less articulate, that is, they use incomplete sentences, pause more often while talking, and engage in multiple starts and stops. These are taken to be indications that they are thinking about new and old strategies simultaneously. Related findings are provided by

Goldin-Meadow, Alibali, Church, & Breckinridge (1993). When children are in a transitional state of learning, the hand gestures that they use to describe their understanding of a math problem are often incongruent with their speech. This is because one kind of math strategy is being conveyed nonverbally while another competing strategy is conveyed through their verbal communication (Goldin-Meadow et al., 1993). Gelman and her colleagues have also illustrated the power of having students write about their understanding of to-be-learned concepts at different points in the learning process. Fourth- and fifth-grade children (nine- to eleven-year-olds) who were at different ability levels provided qualitatively different written answers when asked "why are there two numbers in a fraction?"

The foregoing examples illustrate another important point, this being that both mathematical understanding and language use differ as a function of how much students know about math. The same is true for learning about science. For example, Anderson and Shifrin (1980) demonstrated that when students acquire organized knowledge about spiders, they both understand and recall the salient features of a passage after reading it. Those who do not know about spiders recall poorly and have little understanding of the text.

Bransford et al. (1999) also review the growing evidence that teachers can benefit from clues about students' evolving and changing interpretations and understandings of the material being taught. An example of this comes from Stigler's analyses of video-taped lessons of elementary school mathematics teachers in Japan. The teachers made extensive use of students' changing explanations within and across lessons as a way to monitor students' progress. Stigler and his colleagues' characterization of the students' evolving solutions to problems brought out the fact that the students in the class often started out with different kinds of answers that covered a variety of areas. Over the course of classroom discussions, the teacher explored students' errors with them. Teachers then used these errors to guide students towards correct solutions and, from our point of view, move them on to relevant learning paths. (Stigler & Hiebert, 1999).

Aims and setting of the present study

As indicated, the curriculum was designed to embed science instruction into a ninth-grade ESL class in a public high school in the Los Angeles area. The high school which served the students in this study accommodates approximately 3,000 students, 20% of whom are designated as "Limited English Proficient." The school is in relatively good condition and has good sports fields as well as outdoor spaces. The great majority of the students in the school's ESL program speak Spanish, having come primarily from Mexico and El Salvador. Korean-speaking students comprise the next largest group; however, the program also serves students who speak Russian, Persian, Armenian, Tagalog, Vietnamese, Hebrew, Thai, Cantonese, and Mandarin. Many of the students traveled long distances from their homes on LAUSD school buses that picked them up at their neighborhood school. The data presented in this report were collected in an intermediate-level ESL2 class during the first semester in which the Science-into-ESL program was implemented.

Every effort was made to take into account the emerging views on how to apply the findings about the nature of conceptual learning to the design of classroom instruction. An effective program for preparing students with the relevant background for learning new science concepts requires more than just having them memorize terms or lists of facts (e.g., Beck & McKeown, 1989; Carey, 1988; Dooling & Lachman, 1971; Glynn, Yeany, & Britton, 1991). The ability to repeat the definitions of terms does not guarantee a correct understanding of the concepts (e.g., Osborne & Cosgrove, 1983; Stepans, Dyche, & Beiswenger, 1988). Therefore, it is important to attempt to relate classroom reading and other instruction materials and tools around a plan to develop into class an organized knowledge base of related concepts. It was agreed that the program would do well to concentrate on a limited number of topics in some depth. Topics from the biological and physical sciences that met school system guidelines, including those in the *California State Board of Education Science Framework* (State of California, 1990), were organized into a ten-unit program that focused on the conceptual themes of variability, energy, interdependence, and change. These were featured in the reading materials prepared for the classes (Meck & Gelman, 1992).

Materials were ordered to have latter lessons build on earlier ones. When it seemed warranted, several units were devoted to a topic. The titles of the initial ten units were: 1. Sun; 2. Photosynthesis; 3. Respiration; 4. Local Winds; 5. Temperature and State; 6. Buoyancy and Density; 7. Water Cycle; 8. Food Energy; 9. Organs and Organisms; 10. Interactions and Ecosystems. Each unit consisted of:

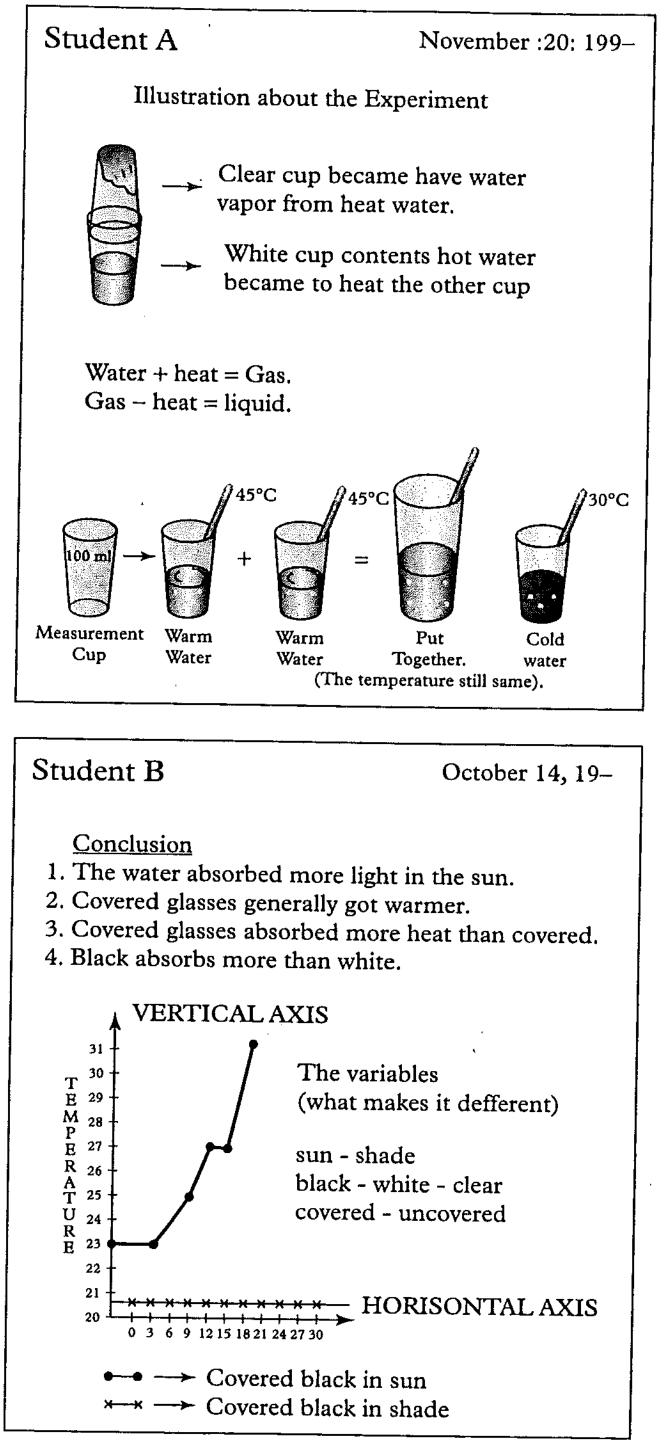
i. an *initial reading* designed to focus the student on the core concept(s) of the unit and to provide the linguistic means to respond appropriately to a short pretest for that unit
ii. a short *pretest* of a representative core concept presented in the initial reading; for the teachers, a *listing of the core concepts and vocabulary* around which each of the units was built

iii. a *main reading* that incorporated the core concepts and vocabulary into a text. This was paired with reading comprehension and second language development exercises
iv. a *laboratory exercise* focusing on the core concepts and including both demonstrations and experiments that the students did in groups, using inexpensive materials brought from home or a grocery. For each laboratory exercise, there was a teacher-oriented set of instructions
v. a *review* involving language and concept development exercises
vi. a short *follow-up test* to complement item ii, the short pretest
vii. a *journal notebook* for students to keep track of their classwork (see below)

Given the findings that opportunities to do science improve the likelihood of learning science (Brown & Campione, 1996), we created groups of "experimenters." Students were assigned to groups for conducting experiments, talking about them, and recording their observations. These groups also prepared their findings to report to the class, and the teacher was encouraged to engage students in guided question-answering opportunities. Also, as indicated, notebooks were an integral part of the students' participation in the class. They were used to make notes about a variety of learning experiences, including the preparation of graphs and other scientific figures, record keeping and analysis of experimental data, lessons on science vocabulary, reviews, and question-asking. Two examples of the kinds of notebook entries students made to record their experiments are show in a schematized version in figure 10.1. Figure 10.2 illustrates the kind of writing activities that were part of the review sessions that ended a unit.

The review session for a unit started with a group discussion during which the group generated a list of ten to twenty science terms relevant to the unit's theme. After the class agreed on the list of relevant terms, students were given approximately fifteen minutes to construct concept maps in their notebooks. In this exercise, students drew lines to link concepts that they thought to be related to each other. Subsequently, they were given fifteen minutes more to write up to ten sentences to describe how they had inter-related the concepts in their concept maps. The sentences that students did write became the focus of our analyses of whether students' knowledge of the concepts and language of science had indeed moved on to a learning path by the end of the second half of the course.

We turn to an extended consideration of the kinds of analyses we did with the review sentences. We also present some standard outcome measures. However, evaluation of the curriculum itself is not the main focus



Student A November :20: 199–

Illustration about the Experiment

Clear cup became have water vapor from heat water.

White cup contents hot water became to heat the other cup

Water + heat = Gas.
Gas – heat = liquid.

(The temperature still same).

Student B October 14, 19–

Conclusion

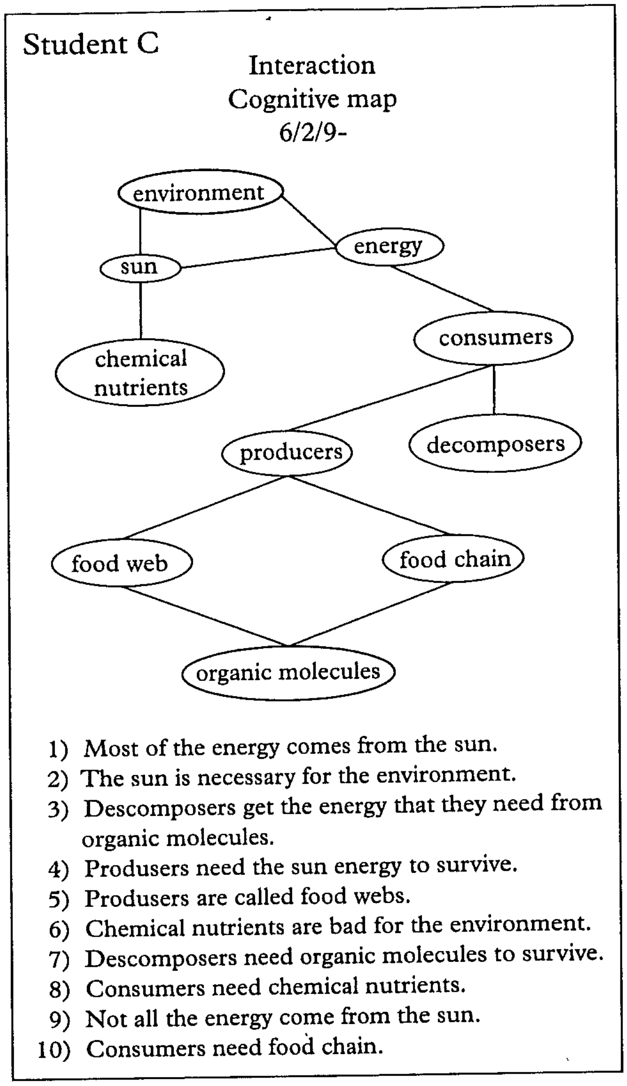
1. The water absorbed more light in the sun.
2. Covered glasses generally got warmer.
3. Covered glasses absorbed more heat than covered.
4. Black absorbs more than white.

The variables
(what makes it defferent)

sun - shade
black - white - clear
covered - uncovered

●—● → Covered black in sun
×—× → Covered black in shade

Figure 10.1 Redrawn examples of the kind of notebook records that Students *A* and *B* made for the experiments they did to accompany their reading. (Students' spelling and grammatical errors have not been corrected.)



Student C

Interaction
Cognitive map
6/2/9-

1) Most of the energy comes from the sun.
2) The sun is necessary for the environment.
3) Descomposers get the energy that they need from organic molecules.
4) Produsers need the sun energy to survive.
5) Produsers are called food webs.
6) Chemical nutrients are bad for the environment.
7) Descomposers need organic molecules to survive.
8) Consumers need chemical nutrients.
9) Not all the energy come from the sun.
10) Consumers need food chain.

Figure 10.2 A redrawn example of a notebook entry for a given review session. (Students' spelling and grammatical errors have not been corrected.)

in this chapter. It is instead to show that investigators can use students' notebooks to accomplish some of the key advantages of the microgenetic method, namely, that notebooks are windows into which to regularly peek at "on-line" learning (or non-learning) over an extended period of time and in a regular classroom setting. The kinds of on-line measurements that we have been developing need not be tied to a particular instantiation of a programmatic effort to embed relevant science learning materials into an ESL program.