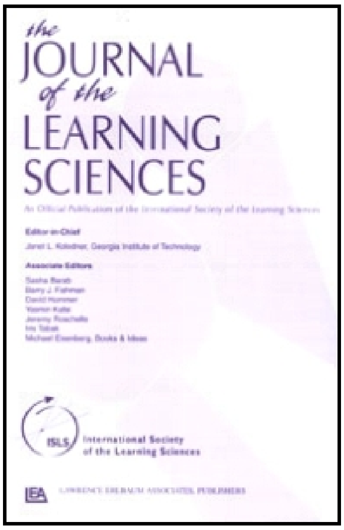

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Expanding the Disciplinary Expertise of a Middle School Mathematics Classroom: Re-Contextualizing Student Models in Conversations With Visiting Specialists

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Expanding the Disciplinary Expertise of a Middle School Mathematics Classroom: Re-Contextualizing Student Models in Conversations With Visiting Specialists

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This article examines how conversations during design reviews in which 8th-grade mathematics students shared population models with visiting specialists expanded the disciplinary expertise of the classroom. *Re-contextualizing* is a conversational exchange that visiting specialists initiated to invite groups to consider their models in novel contexts. Analysis of 14 design reviews in 2 classrooms showed that re-contextualizing resulted in both the elaboration of ideas students already understood and new contributions to students' understandings of mathematical aspects of population modeling. This article presents case studies of 2 groups that differed in terms of their interest in the curricular task and the level of conceptual integrity of their population models. Despite these differences, the re-contextualizing exchanges that emerged in their design reviews led to new insights for both groups and provided them with opportunities to try on ways of thinking and acting like population biologists.

During a review of Derek, Mike, Liam, and Brendan's guppy population growth model, Mark, a visiting biology graduate student, asked a question about a situation the students

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had not considered in their model: “Say one year there’s a huge boon of guppies *but* it’s not in the breeding pool; *instead* it’s in the rice areas?” (emphasis added)

This was not the kind of question these middle school math students typically heard in their classroom. The questions their teacher, Ms. Douglas, usually asked focused on topics they had worked on and had a chance to mull over individually or in groups. Up until this point in the presentation of their model, students talked about what they chose to display on the poster they created expressly for this design review. Mark’s question shifted the group’s focus from the familiar to the unknown, from their usual middle school mathematics classroom practices of talking about finished work into a practice in which a population biologist seriously yet playfully entertained the hypothetical.

In response to Mark’s question, Derek cocked his head in surprise at what the visitor was asking his group to consider—a situation they had not modeled prior to this presentation. Derek regained his sense of composure and responded in a way that suggested Mark’s question was irrelevant to the situation the group modeled, as it was presented in a scenario given by their teacher. Mike backed Derek’s position by describing the scenario they modeled in more detail. Despite the students’ reluctance, Mark persisted in his questioning but took a different tack. He turned the discussion to the assumptions of the software program they used and finally managed to get the students to open up their model so they could consider how it worked and how it might work differently.

This scene makes evident the challenges and promises of bringing the mathematical practices of disciplinary specialists into contact with middle school students. The above exchange took place during a “design review” in which eighth graders presented their analyses of population-modeling scenarios to visitors with expertise in biology.

In this exchange, the visitor faced resistance from students who not only were unused to being asked to think about mathematics on the spot, but were also unaccustomed to having the whole context of a problem they had considered shifted in the course of one question. For scientists, the kind of “thought experiment” (Hammer, 1995; Kuhn, 1964) Mark proposed is a common and often productive way of investigating scientific phenomena and ideas (e.g., Einstein’s famous thought experiment comparing falling bodies in an elevator on earth and in space). The students drew on resources with which they were familiar from school; in this case, they attempted to refuse a question that violated the basic assumptions guiding their original work (e.g., complete the given assignment and exchange the work for a grade). Because of Mark’s persistence and his way of asking questions that invited students to play with ideas rather than provide definite answers, he managed finally, though briefly, to get the group to consider the assumptions built into the software they had used to create their model. In this way, the visiting disciplinary specialist helped the students take a more sophisticated view of how models selectively represent real-world situations.

In this article, we consider students' and visitors' exchanges during a set of design reviews that took place in two eighth-grade mathematics classrooms toward the end of a project-based mathematics unit focused on modeling fish population growth (Middle School Mathematics through Applications Project [MMAP], 1997). The main question that guides our analysis in this article is the following: How does the interplay between the professional practices of biologists and the classroom practices of middle school mathematics students working on a population-modeling project support learning? To answer this question, we examine how the questions the visitors asked during the design reviews reveal aspects of mathematical modeling that are relevant to adult practitioners of biological modeling.

We describe the conversations and activities that took place during the design reviews as *hybrid interactional practices* because they intentionally combined diverse discourses to further students' understandings of mathematics and ways of modeling biological processes involved in the growth of populations. The exchanges between the students and the visitors were hybrid in that they involved different ways of knowing and talking about mathematical aspects of modeling population growth; they invoked roles and power relations between adults and youth that varied from those that were typically available in these classes; and the exchanges routinely involved using representational resources such as graphs in ways that differed from their usual use in the classroom. Based on our analysis of these exchanges, we found that although these hybrid interactional practices were at times uncomfortable for students, they created open-ended environments for finding out new things about students' population models and the process of modeling. In this sense, the design reviews were consequential as a form of authentic assessment and as opportunities to expand the disciplinary expertise of the classroom.

CONCEPTUAL FRAMEWORK

Much of school mathematics aims at transforming students' everyday experiences of number and quantity through participation in activities that are thought to resemble the mathematical practices of a narrowly targeted group of adults, usually professional mathematicians. From this perspective, students' everyday uses of mathematics are something to be built on or replaced as they learn discipline-specific ways of perceiving and acting. Rarely are adults (other than teachers) or actual members of targeted professional practices involved, other than as advisors in the process of writing state-adopted textbooks or external assessments. Rather than approaching the boundary between school and professional practices as something that can be settled by ever more intense simulation (see Beach, 1999, on "mediational" transitions), but also mindful of infrastructural differences between school and professional settings (see Lynch & Macbeth, 1998, on differences of scale, safety, division of labor, and organizational competence; see also Becker, 1972; Stevens, 2000), we have simply attempted to put these different worlds into direct contact over students' in-progress modeling efforts. We think it is possible, with relatively minimal levels of coaching either for students or visiting reviewers, to create hybrid interactional practices that provide rich opportunities for learning mathematics and modeling.

Our analysis of how the boundary between school and professional practice can be structured to provoke learning draws on research from a sociocultural perspective, which views learning as deeply integrated with culture, identity, and changes in what one can do and know (Engeström, 1999; Rogoff, 1990; Vygotsky, 1978). Researchers studying learning from this perspective have suggested that creating hybrid spaces or interplay between social practices (e.g., community-based literacy and school-based literacy) can expand learners' understandings of academic content and create bridges across different kinds of thinking practices (Cole, 1996; Ford & Forman, 2006; Gutiérrez, Baquedano-López, & Tejeda, 1999; Lee, 1995; Moje et al., 2004; Saxe, 1991). For example, Saxe and Bermudez (1996) described how they productively combined aspects of school and street mathematics in the form of a board game. The interplay between these social practices, which varied in terms of recurring goals, the organization of social interaction, use of artifacts, and cognitive functions, was shown to further children's understandings of mathematics. In the context of playing the game, children collaboratively developed new goals and methods of using mathematics that helped them solve emergent problems with currency, place value, and planning.

As a way of extending the mathematical and modeling expertise of an eighth-grade mathematics classroom, we developed a classroom participant structure (i.e., a design review) that purposefully created an interplay between the mathematical modeling practices of the classroom and those used by adult practitioners of population biology. In brief, the students in the classrooms we studied were engaged in extended design projects in which they used mathematical functions to model changes in a fish population over time and under various circumstances; students presented their analyses in design reviews where visitors with disciplinary expertise in population biology critiqued and questioned their models. The academic task structure (Erickson, 1982) of the design reviews was unlike that of typical classroom presentations where students present a final product and engage in conversations oriented toward the closure of ideas. Rather, we designed these presentations so visitors could use the students' work as a jumping-off point for conversations that might further students' understandings of mathematical aspects of modeling biological processes. The focus of our analysis is on how this interplay between social practices (i.e., classroom and professional practices) was achieved in episodes of talk in which disciplinary experts drew on their knowledge of and background in population modeling to further students' understandings of mathematical modeling. One way this was accomplished in the design reviews was through a participant framework we call

TABLE 1
Demographic and Achievement Data
for Hill Middle School

Variable	*Value*
City population (1998)	17,650
Median household income (1990)	$34,836
School size (all grades; 1997–1998)	677
Ethnicity (all grades; %)	8.0
African American	30.0
Asian/Pacific Islander/Filipino	8.0
Hispanic	53.0
White	
SAT-9 math (1998, Grade 8, percentile)	80
SAT-9 language (1998, Grade 8, percentile)	73

re-contextualizing. In the two cases we present in this article, we look closely at the interactional structure of re-contextualizing.

RESEARCH CONTEXT

School

We conducted this study at Hill Middle School, the only middle school in a well-equipped and highly regarded urban public school district in the East Bay area of Northern California. Hill is located at the edge of a family housing project for the University of California, Berkeley, and serves children of graduate students who attend the university as well as children from the surrounding community. Students at Hill come from relatively homogeneous, middle-class backgrounds, with more White and fewer African American and Hispanic students than the neighboring city of Berkeley (see Table 1for data reported by the school). We studied two eighth-grade mathematics classes at Hill (there were approximately 28 students in each class) taught by the same teacher, Ms. Douglas.

Teacher

At the time of our study (1998–1999), Ms. Douglas had been teaching for more than 15 years, was the head of her math department, and served as a master teacher for students in credential programs at the University of California, Berkeley. As a member of the Math at Work research team,[1] Ms. Douglas taught two extended

[1]The Math at Work project was a 4-year ethnographic study that compared the organization of mathematics in school and in workplaces where design was a leading activity (Hall, 1999).

curriculum units that had the same basic structure but different topics: The first focused on mapping urban environments, and the second, discussed in this analysis, centered on population modeling (the "Guppies" unit). Throughout the school year, Ms. Douglas took part in after-class debriefing sessions with the three researchers (who filmed the activities in her class during the design units[2]) and attended weekly research meetings in which the research team discussed curricular activities and assessments, redesigned activities, and analyzed videotapes of classroom interaction. Ms. Douglas had primary responsibility for daily instruction, and our research team remained largely in the background except during the design reviews.

Curriculum Project

The fictional premise of the Guppies unit is that students have been hired as biological consultants who need to provide advice about how to maintain a population of guppies that has been rescued from a polluted pond in Venezuela. In groups of four, students were asked to model relations between fish populations under different habitat conditions by using a collection of dynamically linked, computer-based tools (see Figure 1). After exploring the population dynamics of a single fish population in a closed (tank) environment, groups were asked to serve as biological consultants to fictional clients (farmers in Venezuela) who managed fish populations as part of their agricultural production. We provided the students with three "extension scenarios" in which the guppy population faced various challenges from predators, pollution, and harvesting farmers; groups selected one extension scenario to investigate (see the Appendix for the handout on the extension scenarios). Following their analysis and efforts to model the extension scenario, student groups created posters that displayed their findings and working hypotheses. They presented their posters and analyses in a design review where disciplinary specialists in biology (i.e., graduate students studying biology), their teacher, their peers, and the classroom researchers questioned them and critiqued their models and approaches.

Modeling in the context of this curriculum unit was exploratory, involving predictions about the relative size of populations over time and under different event histories, rather than confirmatory (in the sense of data fitting). As intended by the curriculum[3] (Greeno & MMAP Group, 1998), learning mathematics with concep-

[2]The three classroom researchers (Rogers Hall, Susan Jurow, and Tony Torralba) focused on three focal student groups in each class. On occasions such as the design review or other presentations to the class, we decided ahead of time who would focus on what aspects of the interaction (e.g., whole-class interactions, teacher interactions, the activities of a particular student group).

[3]Our extension scenarios were added to the original MMAP units in order to give students a chance to use what they had learned about modeling fish populations in substantially more challenging, open-ended problems. We also wanted student projects to be complex enough to interest visiting specialists (in this case biologists) whom we had been following in parallel studies of using and learning mathematics at work (Hall, 1999).

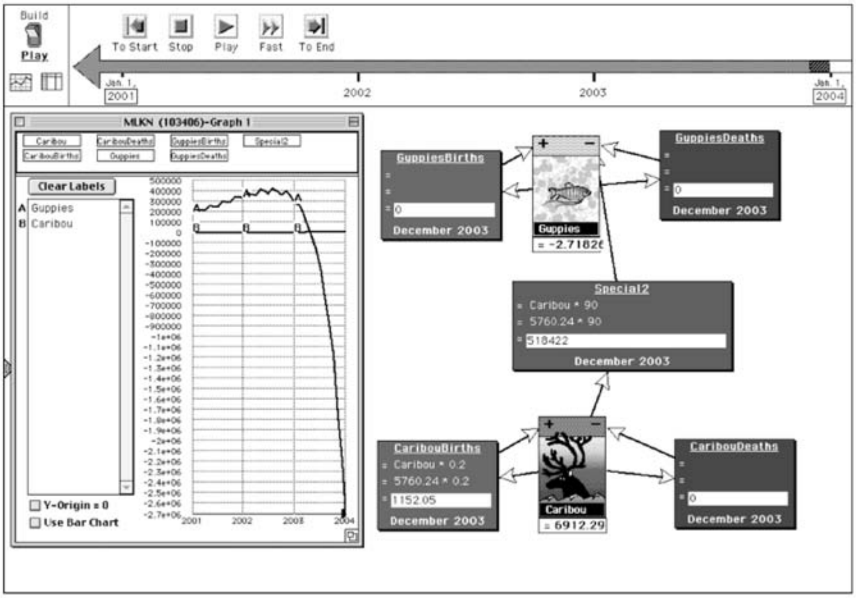

FIGURE 1 A Habitech© network model of a predator/prey scenario. The graph (left) shows an extinction crisis for the prey (guppies) after 2 years in a closed stream with an exotic predator (wolf-fish, represented as caribou in the net and graph). Special2 (middle of network) is a predation function that links together guppies (above) and predatory caribou/wolf-fish (below). Each wolf-fish eats 90 guppies per month (i.e., caribou * 90, or 3 guppies per day).

tual understanding was to become relevant in the practical work of building, tuning, and talking about population models.[4] In this sense, mathematical concepts would be learned within a larger, purposeful context (building and asking questions about models), rather than as ideas or procedures used to complete and review problem sets typical in conventional mathematics classrooms. These concepts included a comparison of linear and nonlinear functions defined as difference equations to model changes in population size (i.e., population at time $t+1$ as a function of population at time t), the implementation of these functions in con-

[4]We also studied teaching and learning in MMAP curriculum units with a substantive design focus both in architecture and in cartography. These MMAP curriculum units also were designed to have students build, evaluate, and refine computer simulations of objects typical in professional practice (e.g., a live/work structure for scientists wintering over in Antarctica, a multilayer Geographic Information Systems (GIS) map tailored to the particular interests of a client; see Jurow, 2005, and Stevens, 2000, for analyses of these classroom environments). For another curriculum effort using design as a context for teaching, see Kolodner et al.'s (2003) Learning by Design curriculum.

straint networks that defined particular animal populations and relations between these populations (e.g., predator/prey relations), the conducting of simulated runs of the model by setting and playing a "timeline" to see how populations changed over time (top of Figure 1), and the selective use of tables and graphs to interpret and evaluate model behavior. Typically, as student groups were developing their scenario models before the design reviews we analyzed, they worked through several cycles of model building, simulation, and revision. For analyses of student learning in these design cycles that follow groups of students working together over time, see Jurow (2005) and Stenning, Greeno, Hall, Sommerfeld, and Wiebe (2002).

The project-based instructional environment we created had much in common with other recent studies of teaching for conceptual understanding in mathematics and science classrooms, particularly those in which investigators try to engage students in authentic scientific or mathematical practices (Brown, Collins, & Duguid, 1989). Like in Polman's (2004) analysis of high school students working on projects in CoVis classrooms (Pea, 1994), we designed recurring activity structures at different timescales to support students and teachers in pursuing questions or problems that lasted over several weeks (e.g., cycles of model construction, evaluation, and refinement). Like Tabak and Baumgartner's (2004) analysis of symmetric forms of participation in inquiry science teaching, we were concerned with how teachers and students talked about project work and whether students experienced these activities as places where they could make legitimate contributions to shared knowledge (see also Boaler & Greeno, 2000; Engle, 2006; Engle & Conant, 2002; Hall & Greeno, in press).

As these and other studies have documented, it is difficult to create classroom activity and discourse structures in which students work with teachers on genuinely open-ended problems and are able to make self-directed progress. For example, the study by Polman (2004) focused on a single, exceptional teacher, Rory Wagner, with a graduate degree in geosciences and, by the author's own description, an atypical ability to create authentic scientific activity in the classroom. Similarly, in the study reported by Tabak and Baumgartner (2004), only one of five project teachers regularly produced the kinds of "partner" conversations that appeared to allow students to see and appropriate ways of structuring data to make credible scientific arguments. We turn now to a strategy we used in our classroom studies to expand the set of discursive resources available in typical classrooms: the use of design reviews with visiting disciplinary specialists. These design reviews are similar in some respects to the use of "tele-mentors" in the CoVis project (O'Neill & Polman, 2004; O'Neill, Wagner, & Gomez, 1996; Polman, 2004), but the involvement of specialists in our case was shorter in duration (i.e., a single design review vs. multiple weeks of e-mail exchange), we did not expect specialists to provide data or other substantive resources for student work (i.e., the leading activity was to review students' in-progress work), and specialists were available to students in face-to-face interaction over models that could be manipulated in conversation. We describe the details of particular reviews analyzed in this article first, and then we return to proposals for more general design principles in the Discussion.

Design Reviews

As part of the design reviews, student groups created posters that included at minimum a description of which scenario they chose to model, what they predicted would happen to the guppy population, and graphs and tables showing what did happen to the guppy population based on their modeling efforts. Ms. Douglas suggested a structure for the groups' posters and for their presentations, which most of the groups followed. In addition, students reviewed a video tutorial on creating posters for professional presentations captured as part of a parallel, ethnographic study of field entomologists (Hall, 1999; Hall, Lehrer, Lucas, & Schauble, 2004; Hall, Stevens, & Torralba, 2002; Torralba, 2006).

The visitors, Mark and Jane, were graduate students studying biology at the University of California, Berkeley, who also had an interest in education. Both Jane and Mark were white, middle class, and in their late 20s at the time of the study. Jane worked in the area of human genetics, developing computer models to trace genetic contributions to human diseases, but she also worked with groups attempting to model population dynamics in a variety of other species (e.g., changes in elephant populations in Africa). At the beginning of each design review session (successive class periods), Jane described these interests and activities for students on her side of the classroom. Jane had also worked as a middle school science teacher and brought a considerable (in our judgment) capacity for understanding and interacting with eighth graders to these reviews. Jane had participated in design reviews organized by our research team during the preceding year in different classrooms with a different set of teachers. After an analysis of what we saw as successes in this first cycle of design reviews, specifically that some of the questions the visitors asked (particularly "What if?" questions) pushed students to reconsider assumptions about their models, our research team decided to organize a second cycle of design reviews that explicitly leveraged these kinds of questions (Cobb, Confrey, diSessa, Lehrer, & Schauble, 2003).

This second cycle of design reviews in Ms. Douglas's classrooms was the first in which Mark participated. Mark worked in the area of evolutionary biology, focusing on metamorphosis in different species of frogs (e.g., how their gut changes from herbivorous to carnivorous over the life span). In his introduction to the students on his side of the room, Mark described his research interests as well as his work as a teaching assistant, noting an interest in education and a constantly high "stress level" related to his research (he described this somewhat comically). In addition to the biological expertise of Mark and Jane, one of the members of our research team (Tony) drew on his graduate training in ecological biology to ask questions about students' models. The other members of the research team (Rogers and Susan), along with the teacher, also asked questions meant to push the students to discuss mathematical aspects of their attempts to model population dynamics. Again, asking "What if?" questions and pushing students about their modeling assumptions were not typical of how Ms. Douglas interacted with her students before the design reviews, and researchers played a minimal role in instructional activities leading up to the design reviews.

DATA AND ANALYSIS

Data Sources

Case materials for this article consisted primarily of video recordings of 14 design reviews from the two middle school mathematics classes taught by Ms. Douglas. The average length of a design review was 11 min, with the longest review lasting almost 16 min and the shortest ending at just over 5 min. In addition to reviewing the video recordings of the design reviews, we analyzed the posters each student group was required to create for the design reviews. We examined posters both in terms of subject matter content (e.g., the complexity and integrity of population models) and in terms of how students arranged media (symbolic labels, descriptive texts, graphs, tables and network structures) on their posters as resources for talking about their models during the design review.

Although this article focuses on conversational exchanges from the design reviews, our understandings of the reviews, in particular how they differed from the usual classroom practices, were complemented by video recordings of the daily work of three focus groups in both classrooms during the entire Guppies unit, field notes written by three members of our team, and daily debriefing conversations (also video recorded) with Ms. Douglas and members of our team. These materials are part of a larger corpus of data we collected in the Math at Work project (Hall, 1999).

Analytic Approach

Analysis of groups' models and posters. To develop an overview of all 14 of the groups' work on the extension scenarios, we conducted a content-level analysis of each of the group's models as they displayed them on their posters to document which extension scenario the group considered, what features and functions they included in their models, and how the students presented their analysis on their posters.

In analyzing the population models displayed on the posters, we described the level of integrity of the students' model or how closely the model approximated the reality of the situation to be represented. We identified models with high and medium levels of integrity; no models demonstrated what we would classify as low integrity. A model that limited population growth by including a carrying capacity[5] was rated as having a higher level of integrity than a model that did not. Groups that aimed to develop models that approximated realistic population behaviors (and indicated this in the materials displayed on their poster) but did not accomplish this were also considered to have a high level of integrity. Models rated as having a medium level of integrity were those that did not include any kind of limit on population growth but modeled what would happen in a particular scenario using appropriately selected functions from the Habitech© software. Groups whose models would have been rated as having low integrity would have demonstrated a lack of understanding of how to use the Habitech© software to implement one of the key features (i.e., a "harvest," a "predator," or "pollution") that was central to the situations suggested by the extension scenarios.

Our analysis of the material that the groups included on their posters focused on what the students chose to display on their poster (e.g., text, drawings, graphs), how much explanatory text the students included on the poster, and how informative and/or creative the materials were. We judged poster detail to be high, medium, or low. A poster that we rated as high might include printouts from the software such as graphs and tables, a typed discussion of the scenario and the group's predictions of what they thought would happen in the situation, and drawings meant to enhance the appearance of the poster. A poster rated as medium might include graphs and tables printed from the software and narratives describing the scenario and the group's predictions. A poster rated as low might include graphs or tables and a limited amount of text (if any) describing the scenario and the group's predictions. Two authors developed and agreed on the classifications of the level of conceptual integrity of the population models and the level of detail of the posters.

Analysis of interaction during design reviews. We combined insights and methods from discourse analysis and ethnography (McDermott, Gospodinoff, & Aron, 1978) to study how the questions the visiting disciplinary specialists and the classroom researchers asked during design reviews revealed (or attempted to reveal) aspects of mathematics and the modeling of biological processes to students. Our analysis attended globally to the organization of the design reviews as a type of classroom participant structure (Philips, 1972) and more locally to the partici-

[5]*Carrying capacity* is conventionally defined as the maximum number of individuals an environment can support. The teacher and the classroom researchers presented a mini-lecture to the students on the concept of carrying capacity, showed a video (a *Bill Nye the Science Guy* episode) that addressed the idea of carrying capacity, and presented the students with a formula that they could implement in the Habitech© software for incorporating a carrying capacity into their population model (e.g., reducing the birth rate when total population approached the theoretical maximum).

pant frameworks that emerged during the students' exchanges with the visitors (M. H. Goodwin, 1990; O'Connor & Michaels, 1993). We follow the distinction that O'Connor and Michaels made regarding the examination of participant structures versus participant frameworks. That is, analysis of participant structures (e.g., group work, large-group discussion) examines fairly stable arrangements that shape the roles and speaking and listening rights that students take in classrooms. This is different from an analysis of participant frameworks, which takes a more microlevel look into how alliances and participation statuses emerge out of moment-to-moment interaction.

Examination of the structure of the design reviews considered how the teacher, with the help of the classroom researchers, organized the social and physical settings of the design reviews and how these enabled and constrained the sharing and exploration of mathematical ideas. For example, we examined the recommendations the teacher provided students for how to display their guppy population models, what groups chose to include on their posters, the modeling resources available for students' on-the-spot use during the design review (e.g., a television monitor connected to a computer running the Habitech© modeling software, posters with graphical and tabular displays of population growth), and how students used these resources to share their models with the disciplinary specialists during the reviews.

Our analysis of the exchanges between the disciplinary specialists and the students began with the creation of content logs describing what happened in video recordings of the 14 design reviews (Jordan & Henderson, 1995). Drawing on our content logs and the field notes we had written while in the classes, we studied how the participants used talk, embodied actions, and physical artifacts to explore mathematical aspects of modeling population growth (Jurow, 2004). We described the participant frameworks created in these exchanges by focusing specifically on how students were positioned as respondents to the visitors' questions. What participant positions were opened up when an utterance was spoken or another type of action was taken? What types of alliances between students and ideas were proposed by visitors' questions? By describing the participant frameworks that emerged during the design reviews, we were able to study how students were able to engage in the ongoing intellectual activity and the potential they had to learn through this form of participation (M. H. Goodwin, 1990; Hall & Rubin, 1998; O'Connor & Michaels, 1993).

Re-contextualizing as a participant framework. Across all of the design reviews, we found that the questions that helped students gain access to professional views of population modeling were those that asked them to reconsider their current models in light of a change in the context to be modeled. Attending exclusively to these questions, we detailed the basic structure of all of the question sequences in which a visiting disciplinary specialist (or in some cases, one of the classroom researchers) asked students to reassess their current model. Identifying this structure involved viewing and re-viewing the videotapes and transcripts of the design reviews to describe the components of what we termed *re-contextualizing exchanges* (e.g., what the questioner asked, how the question positioned the students as respondents). Transcripts were carefully prepared to reflect speaking turn boundaries, to see evidence for agreement and disagreement among speakers. We also looked closely at how gestures were produced in coordination with talk and written or drawn representational forms, because many aspects of meaning in visitors', the teacher's, or students' utterances depended upon these details. With a working description of the components of re-contextualizing as a participant framework, we returned to the entire set of design reviews in order to identify more systematically all instances of re-contextualizing and to refine our description of the components of re-contextualizing (Chi, 1997). Two authors viewed each design review independently and, for each review, identified candidate re-contextualizing sequences that either led to new contributions or elaborated on prior contributions. These were distinguished from adult questions that sought clarification but did not attempt a change in modeling context. Independent lists of candidate re-contextualizing sequences were then compared, and disagreements were resolved by further review and discussion.

In the next sections we present the results of our study. We begin by briefly comparing re-contextualizing to other similar classroom discourse strategies and illustrating the re-contextualizing participant framework. Then we provide an overview of all 14 of the design reviews in order to describe the conceptual and material environments in which the re-contextualizing exchanges occurred. This broad perspective on all of the design reviews is followed by two in-depth case studies from two design reviews in which re-contextualizing led to new contributions to students' understandings of population modeling.

RE-CONTEXTUALIZING TO EXPAND DISCIPLINARY UNDERSTANDING

Our identification of re-contextualizing as a participant framework emerged from the analysis of data we collected over 2 years in which Math at Work project teachers taught 8 MMAP units (with our design revisions) in their classrooms. For instance, as part of a study of another curriculum unit in a different eighth-grade classroom, Jurow (2005) suggested that design reviews provided an opportunity for students to gain access to the ways of thinking that characterized professional designers (she analyzed reviews of student work by visiting architects). And in another prior analysis (Hall & Torralba, 1997), we studied how visitors' questions highlighted alternative uses of common representational forms (e.g., in architectural drawings, calculating the ratio of "circulation" space to living/working space) or posed hypothetical situations that led to changes in students' models. We found that visitors' questions could both be engaging for students and invite them to think about their work in ways that resembled professional practice. The analysis we present here further investigates the value of design reviews in supporting students' disciplinary learning by examining aspects of moment-to-moment interaction—what we call *re-contextualizing*.

To provide background for understanding how re-contextualizing adds to the growing literature on classroom disciplinary discourse, we compare it to three closely related discourse strategies reported in other studies: reconceptualizing (Cazden, 1988), retroactive recontextualization (Lemke, 1990), and revoicing (O'Connor & Michaels, 1993). Cazden introduced the notion of *reconceptualization* to describe the process by which a teacher extends what a student has just said with the result that the student has a new way of thinking about, "categorizing, reconceptualizing, even recontextualizing" (p. 111) the object of discussion. The adult places the child's words or actions in a new light in order to create a different meaning for the original act (e.g., a child accidentally drops a ball and her mother congratulates her on a "good throw"). Furthering Cazden's discussion of how classroom discourse could be used to socialize students into a particular way of thinking, Lemke and later O'Connor and Michaels identified discursive moves that teachers use to elaborate on students' ideas and link them to disciplinary ways of talking and thinking.

In his analysis of science talk in the classroom, Lemke (1990, p. 103) described a process of *retroactive recontextualization* in which a teacher alters a student's answer so as to draw out "quite a different (or additional) meaning." For example, the teacher's retroactive recontextualization might replace the student's everyday description of how "magnets can attach to other magnets strongly" with the more scientific description "magnets can *attract* to other magnets" (this example is from Gibbons, 2006, p. 230, italics added). In using this discursive strategy, the teacher can link a student's idea to the discipline, but the move is accomplished primarily by the teacher so that he or she maintains control over what counts as knowledge in the classroom.

In a similar vein, O'Connor and Michaels (1993) described a participant framework called *revoicing*, in which the teacher amplifies, clarifies, and/or extends what a student says. But unlike retroactive recontextualization, revoicing allows for the student to accept or decline ownership of the expanded idea. By creating a conversational slot in which students have the opportunity to say whether what the teacher has revoiced is indeed what they meant, this participant framework positions students so that they have a more prominent and acknowledged role in the development of ideas through classroom discussion.

Like these earlier concepts, re-contextualizing involves the use of language by a more knowledgeable other to alter students' meanings by "contextualizing something in a new way … of creating an alternative context for a well-known action, object, or symbol" (van Oers, 1998, p. 483). Similar to retroactive recontextualization and revoicing, re-contextualizing exchanges shift the context of students' ideas to draw out a new and more sophisticated disciplinary understanding. Each of these discourse moves involves the shifting of student ideas by a person who has greater status and authority than students, which has consequences for what knowledge is valued in the classroom. However in re-contextualizing exchanges, students and disciplinary specialists (not teachers) are the participants, and this may affect how students choose to participate (or not) in the exchange and what they gain from the interaction (we return to this in the Discussion). The exchange is more collaborative than the aforementioned discourse strategies because participants think together about new problems that are based in students' work, and, though spoken language is central to how the context is shifted and investigated to highlight disciplinary aspects of a problem, the use of modeling tools and other physical representations is a key aspect of the strategy. In these ways, re-contextualizing provides students with a way to participate actively in authentic disciplinary thinking and practice that is guided by a representative of the discipline. With this background, we now detail how re-contextualizing is accomplished in interaction.

Re-contextualizing consists of the following components:

1. The disciplinary specialist asks an open-ended question that requires considering a new context in which students need to reassess their population model.
2. The exchange positions the students as respondents to a novel question, one for which there is not yet a known answer.
3. Physical modeling tools (e.g., graphs, software) along with mathematical narratives are projected as resources for responding to the question.
4. The students and the disciplinary specialist jointly imagine and assess the impact of the new context on the situation under discussion.
5. During the exchange, the disciplinary specialist highlights aspects of mathematical and biological phenomena that are salient from a professional perspective.

Based on our analysis of the design reviews, we have found that re-contextualizing exchanges can provide opportunities for students both to elaborate on their current understandings of population dynamics and to develop new understandings of the mathematical aspects of population modeling.

The following is an example of a re-contextualizing exchange in which students elaborated on what they already understood about population modeling (i.e., how to model "harvesting" using the software) in the context of a new scenario.[6] In this exchange, Jane was talking with a group of students who presented a model in which the guppy population went below zero (i.e., became extinct) after the introduction of predatory wolf-fish. Reflecting back on this extinction crisis, Jane asked the following:

1 Jane: If you were to make one change in this … Could you do anything to the model and then actually use it to convince people in Venezuela that would keep the um guppies' population above zero?
2 Lon: Uhh (4 sec)
3 Jane: Wha- why is it going below zero?
4 Lon: 'Cause there's too many wolf-fish.
5 Jane: Right.
6 Rita: (inaudible) You could take the wolf-fish out of the river.
7 Jane: What, what would be … Number one, wh- how could you do it and number two, how could you model it?

We counted this as a re-contextualizing exchange that led to an elaboration of what students already knew about population modeling. In the exchange Jane elicited a hypothetical intervention on the part of the students (i.e., taking predators out of the stream) and then pointed out that they might find a way to implement this in a revised model. Her question involved a reassessment of their model, which was posed as a novel (for these students) question that projected a future-time line of action for students as fictive biologists (i.e., acting on the stream ecology) and for the modeling tools they were using. In closing (Turn 7), Jane looked back on this group's presentation and outlined a general strategy for modeling, first thinking about an environmental event and how it affected biological processes, then proposing a change in the environment and figuring out how to represent that in a mathematical model. The students responded by identifying a change in the environment (removing wolf-fish from the river) they had already seen in the design reviews of other groups in their class.

In addition to re-contextualization exchanges that led to elaborations of students' current understandings, we also identified exchanges that led to new understandings on the part of the students. The next section presents an overview of the number of re-contextualizing exchanges that we identified across all of the design reviews and their consequences in terms of students' understandings of population dynamics.

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[6]We follow transcript conventions typical in conversation analysis (Jordan & Henderson, 1995; for other examples, see C. Goodwin, 2007; M. H. Goodwin, 1990; Hall et al., 2002), but we pay particularly close attention to turn boundaries and the coordination of talk, gesture, and action with representational forms. Our transcripts number turns for identified speakers, breaking lines at thematic boundaries and inserting index numbers for action or gestural sequences that are important for our analysis. Numbered action descriptions appear, in italics, below utterances in which they occur. Unless otherwise noted, EMPHATIC speech is shown in uppercase, stre:::tched enunciation is shown with repeated colons, brief ((*action descriptions*)) are show in italics within double parentheses, and [overlapping talk is marked with [matching square brackets across speaking turns.

TABLE 2
Design Reviews

Group	Scenario	Integrity of Model	Poster Detail	*Re-Contextualizing Exchangse* Elaborations	New Contributions
Design reviews led by Mark					
1	Harvest	M	M	2	3
2	Predation	M	M	1	
3	Harvest	M	L	1	
4	Harvest	M	—[a]	1	
5	Harvest	H	M	1	
6	Harvest	H	H		
7	Predation	H	H	1	
8	Predation	M	L	4	2
Design reviews led by Jane					
9	Predation	H	M		
10	Harvest	H	M		1
11	Harvest	M	L		1
12	Predation	M	M		1
13	Predation	M	H		1
14	Predation	M	M		

Note: Ratings of the groups' models and posters are juxtaposed with the number of re-contextualizing exchanges that resulted in elaborations of what the students had already presented versus those that represented new contributions. The design reviews of Group 8 (Blaine, Reese, and Max) and Group 9 (Manuel, Kera, Lisa, and Ned) are analyzed in detailed case studies in this article. L = low; M = medium; H = high.

[a]In the design review for Group 4, the student responsible for putting finishing touches on the poster was absent the day Mark visited.

RE-CONTEXTUALIZING EXCHANGES ACROSS DESIGN REVIEWS, MODELS, AND REVIEWERS

We identified 23 re-contextualizing exchanges in the 14 design reviews; some (11) led to new contributions to the students' understandings of population modeling, and others (12) elaborated on what students already understood about population modeling as evidenced in their posters and talk during the design reviews. Table 2 presents an overview of the re-contextualizing exchanges and their consequences for the groups (i.e., whether the exchange resulted in an elaboration of or a new contribution to the group's understanding) organized by which visitor led the design review.[7] Our ratings of the conceptual integrity of each group's model and the

[7]The questioning during the design reviews was led by the visitors (Mark and Jane); the classroom researchers (Tony and Rogers) were asked questions much less frequently in comparison.

level of detail included on their poster are juxtaposed with the number and type of re-contextualizing exchanges that occurred in the design review in order to highlight three patterns that we identified across the data set.

First, re-contextualizing exchanges were more common in the design reviews that were led by Mark (16 re-contextualizing exchanges in 8 reviews) than in those led by Jane (7 re-contextualizing exchanges in 6 reviews). Notice, however, that the exchanges initiated by Jane resulted in more new contributions than elaborations to her groups' understandings. We suspect that this may be due to a difference in the participant frameworks for questioning and responding that Jane and Mark created. Specifically, Jane often invited all of the students in a group to share their thinking in response to her questions; we describe this as doing a "round." This contrasted with Mark's approach of taking answers from individual group members and moving on to new questions rather than asking each member of the group to contribute his or her ideas. Jane opened more possibilities for students to share their views, and, in this context where a diversity of perspectives were considered, re-contextualizing exchanges were more likely to lead to new contributions to the group's understanding.

Second, re-contextualizing exchanges (of both types) occurred in design reviews where students presented models with medium and high conceptual integrity, as well as in design reviews where students modeled harvest and predation scenarios (no groups chose to model the pollution scenario). Groups that were rated as having models with a medium level of integrity appeared to have a greater number of re-contextualizing exchanges than groups with models rated high in conceptual integrity, but the difference was not striking (17 exchanges for 9 medium groups vs. 6 exchanges for 5 high groups).

Third, most design reviews produced one or more re-contextualizing exchanges. In all, 8 of 14 design reviews led to re-contextualizing exchanges that resulted in elaborations of what groups already understood; 6 of 14 reviews produced one or more re-contextualizing exchanges that resulted in a new contribution to the groups' understandings. Only 2 of 14 design reviews did not produce any sustained re-contextualizing exchanges. Thus, although the participation structures for questioning used by Mark versus Jane seemed to lead to different types of re-contextualizing exchanges (i.e., elaborations vs. new contributions), re-contextualizing exchanges were produced in most of the design reviews and appear to be distributed uniformly across groups as an opportunity for exploring or extending models in the design reviews conducted in this classroom.

From this broad perspective on the design reviews, we next focus in on two design reviews in which re-contextualizing exchanges led to new contributions to the student groups' understandings. We are most interested in this type of re-contextualizing exchange (as opposed to the type that led to elaborations of groups' understandings) because they led to an expansion of the disciplinary expertise of the classroom. The cases focus on two student groups that differed dramatically in terms of their engagement and interest in the Guppies unit. The group described in the first case (Group 9 in Table 2) creatively pursued the task of modeling the effects of a predator on a guppy population, whereas the group described in the second case (Group 8 in Table 2) engaged the task more reluctantly. We decided to focus on how re-contextualizing functioned in these two groups in order to show that such exchanges were productive despite these differences.

CASE STUDIES OF EXPANDING DISCIPLINARY UNDERSTANDING THROUGH RE-CONTEXTUALIZING

Case 1: Re-Contextualizing a Predator/Prey Model to Follow a "Trend"

Background. In this case of re-contextualizing, Manuel, Lisa, Kera, and Ned presented their efforts to model a predator/prey relation between guppies and wolf-fish to Jane, a visiting biology graduate student (wolf-fish appear in the model as caribou; see the Appendix for a description of the predation scenario). In an earlier model, students found that wolf-fish drove guppies to extinction within 3 years of entering the closed stream, so they invented a "net wall" that could be dragged through the stream every autumn to remove 80% of the predators. This was implemented as an Emigration function for wolf-fish, which they added to the predator/prey constraint network. The net wall, as they imagined and discussed it, had mesh that was small enough to catch wolf-fish but large enough to allow guppies to pass. This was a hotly contested development in the local history of their work on this design project (for details, see Stenning et al., 2002), an innovation originally proposed by Kera, implemented by Manuel, and claimed as an idea by Lisa (earlier in this design review, turns not shown).

Design review interaction. As shown in Figure 2, these students inadvertently ran their earlier model (without the net wall, left image) on the computer display, whereas their poster displayed text and graphics from their current model, which included an Emigration function to implement the net wall. They quickly discovered that the computer was running an earlier version of their model, which led Manuel to add an Emigration function to implement (again) the net wall. The group then ran the updated model to display the graph shown on the right in Figure 2. This was a useful "mistake" as the conversation unfolded, because it foregrounded an extinction crisis as the problem they had worked to solve, as well as their current solution.

The re-contextualizing exchange started as Jane leaned into the computer display, talking and pointing at a graph of the caribou (wolf-fish) population over 3 years. At Turn 1 (see Excerpt 1.1), she started with a personal observation, inter-

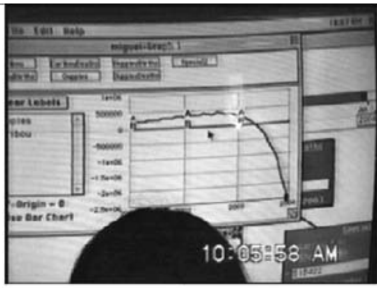
	
Students present an earlier predator/prey model in which the guppies reach an extinction crisis within 3 years. They notice this is the original problem they devised a net wall to solve.	The predator population grows over 3 years despite use of a net wall to remove predators at regular intervals. As shown on the group's poster, the guppy population also increases over this period, but more slowly in the third year.

FIGURE 2 The group creates an unintended contrast between two predator/prey models. On the left, a computer-generated graph shows the extinction of guppies just 2 years after predators are introduced into a closed stream. On the right, a graph shows the population of predators is increasing despite the installation of a net wall to remove 80% of the predators every autumn.

rupted herself, and recast what she saw as a question for the students. Manuel's response at Turn 2 provided evidence that "trend" was a novel technical term for these students, and Jane's third turn repair began a demonstration of what she meant by "trend":

Excerpt 1.1

1	Jane:	You know what I'm seeing … Do you see a trend? Going on with the- the number of caribous in the population?
2	Manuel:	What's a trend?
3	Jane:	A trend is like, (1) if it was just going up and down it wouldn't be a trend, but (2) even though it's going up and down? (1) *R point traces graph shape, up and down, in gestural stage* (2) *L point traces up and down along computer displayed graph shape*
4	Manuel:	Um hm.
5	Jane:	Is it, is it going, (1) loo- does it, if you, if you THOUGHT about what would happen out here? (2) (1) *R point traces smoothly over displayed graph shape, without up and down motion* (2) *R point opens and up and to left of entire computer screen*

6 Manuel: Um hm.
7 Jane: Would you expect the population to be GROWING even though it's going up and down, or decreasing?

Jane's demonstration created a diverse semiotic ecology of coordinated talk, gaze, gesture, and tracing over representational forms (C. Goodwin, 2007) for thinking about and seeing a trend from her stance as a biologist in this design review. In talk, she began to describe what a trend is "like" (Turn 3), then used gesture and tracing to show that "up and down" graph behavior would not be included. Her gestures started in her own gestural stage (Turn 3, Action 1), then she leaned into the computer display and traced this same motion over the graph of the caribou population (right image in Figure 2). She was, we argue, zooming into the display to select what she wanted the group members to see, in this case directing them to disregard local "up and down" behavior.

In the video, all group members but Ned (who, as was typical, retreated to the periphery and rarely spoke) attended closely to Jane, watching her motions intently and leaning in to see what she was doing at the computer display. In Turn 5, Jane struggled between starting another question and directing students' attention to what could be seen once local variation in the graph shape was ignored. At Turn 5, Action 1, she again traced over the graph shape, this time using a smooth motion that, as enacted, deleted local ups and downs. After completing this comparatively smooth gestural trace (i.e., what can be seen, selectively), Jane described a future-time context that positioned students as thinking about how the smoothed graph shape would continue "out here" (end of Turn 5).

As Jane produced this hypothetical context, she repeated the tracing gesture, but this time her trace extended to the right of the graphical frame and even off the right edge of the computer display (Turn 5, Action 2). With the students poised, hypothetically, in a moment of "THOUGHT" about events that would unfold off the edge of the display and beyond the 3-year timeline of their current model ("what would happen out here?"), Jane posed a question to students in the group. She asked (Turn 7) if they would expect the population of predators to be "GROWING," despite local variation, or "decreasing."

In subsequent turns (not shown), Jane carefully listened to the predictions of participating members of the group, encouraging each to explain "what you see" and "why do you think" the population will change. Manuel expected the predators would grow but thought they would need to find other food sources to live in a separate part of the stream (i.e., on the other side of the net wall). He pointed out "THIS simulation is thinking" the predators would grow while feeding on guppies. Lisa thought the predator population would "increase AND decrease" but go up over time. Kera thought the predator population would increase once they found an alternative source of food. As Manuel explicitly pointed out, the students intended for the net wall to separate guppies from wolf-fish, but their Emigration function assumed that the predators and prey continued to live in the same closed environment. Jane did not comment on this, and we cannot be sure that she heard the distinction.

After listening to each participating student's prediction, Jane asked if they could run the model over a longer time period. Manuel changed the time parameter in their model to 15 years and ran the model (see Excerpt 1.2). The simulation executed very quickly (Turn 6), and when Manuel opened a graph showing population values, the results surprised the students and adults alike:

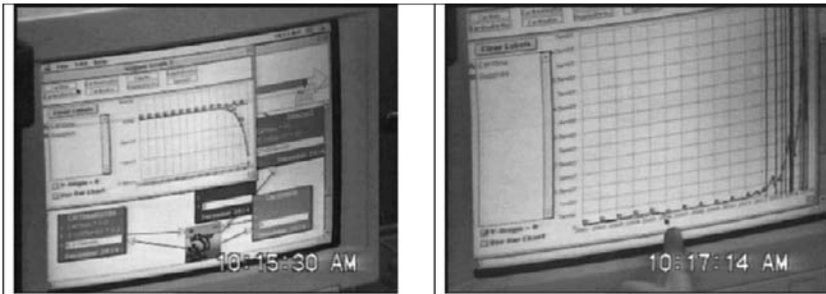
Excerpt 1.2

1	Jane:	So you think that this would, if you, if- can you RUN it for more than four years?
2	Manuel:	[Oh yeh. ((*reaches for mouse*))
3	Kera:	[Um hm.
4	Manuel:	((*scrolling*)) (6 sec) So how long do I need to run it for?
5	Jane:	How about- how about … fifteen.
6	Habitech© software:	((*simulation finishes with negative values in guppies population node*))
7	Jane:	Fast, huh? [((*laughing*))
8	Lisa:	[It DIED! ((*scoots toward screen*))
9	Habitech© software:	((*Manuel opens graph showing extinction plunge for guppies*))
10	Rogers:	[Yoh:::
11	Jane:	[What happened?

As shown on the left in Figure 3, guppies again faced an extinction crisis when the net wall model was run over a 15-year span. Lisa noticed a large negative value in the guppies population box (a node in the constraint network) and announced "It DIED!" (Turn 8). After Manuel opened a graph showing population values over time, Rogers and Jane simultaneously registered their surprise at the result (Turns 10 and 11).

Jane's request to run the net wall model over a longer time period furthered the re-contextualization that was already in progress, building on and extending the visual environment and expectations created in Excerpt 1.1. Her request projected a line of action for the model in which simulated fish behavior might provide evidence for or against students' predictions about future-time population levels. Although Jane never explicitly mentioned her expectation, the surprise that she and Rogers both expressed on seeing the results suggested that she was not asking a "known answer" question (i.e., "what would happen out here?").

As the conversation continued (turns not shown), students reflected on their earlier predictions, while Jane laughed and said to Rogers that she did not know how she guessed 15 years. In Excerpt 1.3, Rogers began a contrast between the group's 3-year and 15-year net wall models, asking "what happens to the guppies?" (Turn 3). As stu-



The Habitech© software produces a graph that surprises students and adult reviewers alike. When the net wall model is run over 15 years, guppies again reach an extinction crisis.	With negative values clipped, the graph shows the predator population rising exponentially over 15 years, while the prey population (guppies) drops to zero after about 6 years.

FIGURE 3 Two computer-generated graphs show the result of Jane's request to run the net wall model over a longer time interval (15 vs. 3 years). On the left, guppies become extinct over the longer time interval, despite the group's effort to protect them by removing 80% of the predators every autumn. On the right, with negative values concealed, guppy extinction and an explosion of predators can be seen in the same graphical frame.

dents reacted with surprise to their model's behavior, Jane's laughter increased to the point that she doubled over and was temporarily out of the conversation (Turn 10):

Excerpt 1.3

1	Rogers:	So, whereas beFORE it looked like the guppies were gonna do great. And those wolf-fish were just growin' along, [even though you're taken 'em out.
2	Jane:	[((*laughing*))
3	Rogers:	Fifteen years down the line, what happens to the guppies?
4	Lisa:	[They DIE!
5	Jane:	((*laughing*))
6	Manuel:	[(1) They start going down. But this is like, this is a LOT. This like … (1) *traces graph with mouse*
7	Kera:	((*laughing*)) That's not fair!
8	Lisa:	That's negative.
9	Rogers:	Negative. So you- (Baby) they are finished!
10	Jane:	((*laughing uproariously, doubles over*))

As the conversation continued (turns not shown), Rogers and Jane worked with the students to zoom in on selected aspects of the new simulation, clipping negative values in the graph to show a guppies extinction crisis and exponential climb for the predator population (right image in Figure 3). With these linked graph behaviors in view, students found that predators had again exterminated the guppies after about 5 years. Manuel, in an attempt to explain why this happened again, noted that they had earlier reduced the guppies' birth rate when the stream became overpopulated, and guppies' births might later rise as the size of their population fell. Rogers pointed out that the relation between population size and birth rates could be modeled as a carrying capacity, as other groups had done, and the net wall model would behave differently.

Summary. As an example of re-contextualizing, this case has several interesting features. First, in response to discovering that a "trend" is not yet hearable or visible to these students as a way of reading population graphs, Jane (Excerpt 1.1) worked to create a visual environment in which to ask what students would expect to see in the future. We think of her actions as a form of zooming into the model, selecting specific aspects and ignoring others (e.g., "up and down" local graph behavior), for the purpose of further analysis and discussion. Jane and Rogers repeatedly used zooming to shape students' visual access to model behavior as the design review proceeded. Second, while zooming in to find a trend, Jane demonstrated what is and is not to be seen, simultaneously (a) enacting a form of "professional vision" (C. Goodwin, 1994) that demonstrated how population biologists would use talk and activity with physical representations (e.g., graphs) to shape the perceptual field on which they train their attention and (b) disciplining the perception of students in ways that might lead them to adopt this form of vision (Ochs, Jacoby, & Gonzales, 1994; Stevens & Hall, 1998). Third, in producing her question about "what would happen out there" (Excerpt 1.1, Turn 5), Jane proposed a participant framework for students as future-time actors who think, make predictions, and have expectations about the behavior of an alternative run of their model. Her question projected hypothetical intellectual activities undertaken from a stance of engagement the students might take up later. If the students were to take up this stance, their activities would more closely resemble those of professional biologists (e.g., noticing and exploring a "trend") as compared with what they had done thus far during the review. In this case, we found a delicate form of interplay (Saxe, 1991) produced within and across utterances by a visiting biologist and another adult questioner. Jane zoomed into select relevant features of a model, positioned students as thinkers and askers of questions that might be realized in future turns at talk, then requested that the model be extended into this new hypothetical space in an attempt to collect evidence. Representational forms with a stable meaning and use among students (e.g., graphs showing population change over time) were extended by Jane's persistent questioning to support new functions, involving distinctions relevant to practicing population biologists (e.g., ignoring local variations to ask about long-term "trends"). The results of this interplay between different representational practices, which appeared to be genuinely surprising for students and adults, led to further discussion about the relation between predators and prey, as well as constraints on population growth within a closed environment.

Case 2: Re-Contextualizing a Limited Model as the Basis for Expert Advice to Clients

Background. The re-contextualization exchange in this case took place between Mark, another visiting biology graduate student, and a group of three boys, Reese, Blaine, and Max, who also worked on the extension scenario involving predation. Using Habitech© software, the students created a model in which predatory wolf-fish drove the guppy population to extinction in less than 3 years. This group's poster was spare as compared to other groups' posters but included the basic material the teacher required (i.e., a narrative description, constraint network implementing their model, and graphs and tables showing population levels over time). One bit of personal flair, starkly visible in such a sparse display, was a provocative title, "EAT ME," for their graph of population values over time (see Figure 4). Reese, Blaine, and Max were the last students to take part in design reviews during their class period, and their review was interrupted at just over 13 min when the bell rang to dismiss class.

Reese points to a graph of predator and prey populations while explaining that the guppies (prey) have all been eaten, something that is a "pretty good" outcome for the scenario his group modeled.	Mark completes a gesture depicting the slope of the guppy population (prey) during the first year of this group's model, something an ecologist conducting only a short-term study might see.

FIGURE 4 An extinction crisis for guppies being eaten by predatory wolf-fish is described as a "pretty good" outcome of modeling by a student (Reese; left image), but the same graphical display is divided into first and second years by a visiting biologist (Mark) in order to pose a question about ecologists conducting a short-term study (right image).

This group was not one our research team followed closely during the study; however, it was notable in that Blaine, in particular, was viewed as a troublemaker in the classroom and so his actions were often highlighted by Ms. Douglas during class. Blaine was typically sarcastic and occasionally rude in his interactions with the adults, including members of our research team, and this may have been related to his struggles with the academic content of the class. An aide, Mr. Connor, who was an imposing figure, accompanied Blaine to the math class to help him with his work and to monitor his behavior in class. Because Reese and Max were not as outspoken as Blaine (Max was extremely quiet in class), we know less about their engagement with the curriculum unit.

Design review interaction. The group presentation began with Max, directed by Reese, reading a written narrative of their model displayed on their poster:

> In our scenario for the 3 years, the guppy population decreased as the wolf-fish population increased lewding [*sic*] to total extinction of the guppies in this region of the lake.

Next Reese pointed to their graph of predator and prey populations over 3 years and explained that the guppy population would die out after a year and a half while the wolf-fish population would "steadily increase" over time. Reese concluded this was "pretty good" and what they wanted to happen. Although the predation scenario (see the Appendix for a description of this scenario) framed predation in the larger context of rice farmers needing guppies to control mosquitoes, this group evidently took up the task of exterminating the guppy population.

Mark next asked (turns not shown) about the meaning of this situation for the "Venezuelan rice people," but a student in the audience interrupted to say that this was a different scenario (i.e., harvesting guppies for rice farming). Mark persisted, modifying his question to ask what if the students were ecologists considering this situation. Blaine asked what an ecologist was, providing evidence that he (at least) had not fully understood the broader framing of the curriculum unit. Mark explained that an ecologist was "someone who studies … how these fish populations are changing through time." Perhaps in an attempt to bring this group back to the intended curriculum, Ms. Douglas suggested that ecologists were similar to the "Guppy Foundation" (a fictive group from the curriculum unit), which cared about ensuring a stable guppy population.

After restating the ecologists' larger purpose and again being dismissed by Blaine (Turns 1 and 2 in Excerpt 2.1), Mark posed a question that initiated a re-contextualization exchange at Turn 3:

Excerpt 2.1

1 Mark: The "Guppy Foundation" they really care because there are lots of things that eat guppies and if the guppies go extinct lots of things go extinct. So, they want to know um if this wolf-fish population is really going to hurt the guppies or if it's fine to keep them as they are.
2 Blaine: Well they saw that they ate 'em so of course it's gonna hurt.
3 Mark: Well so, what if the study the ecologists went out and just looked for three or four months to see if there was stability in the population. What would- What would the ecologists walk away with?

Mark's question invited the students to consider another perspective on the situation they had modeled. Rather than being pleased that the guppies were eaten, Mark asked the students to take on the perspective of ecologists studying the population for "three or four months" to see if stability was possible. The proposed shift in participation for these students, if taken up, might have been significant both for their objectives in the modeling activity and for subject matter content relevant to those objectives. In response (turns not shown), Reese pointed out local variation in the graph over a year and a half time span but restated their extinction result without fully taking up the position of an "ecologist" that Mark had offered (i.e., in this re-contextualizing exchange, Reese's response elaborated information already presented). Still showing persistence, Mark began a more focused re-contextualization of their model, asking Reese to imagine drawing a slope through only the first half of their data in the graph (Excerpt 2.2):

Excerpt 2.2

1 Mark: So if, if you were to draw, say a slope, (1) slope of a line through the first half (2) of all the points that you have for the guppy population?
(1) *Reese looks from Mark to the poster, then back and forth for rest of Mark's turn*
(2) *Mark slices through air vertically with open left hand*
2 Reese: Mmhmm.
3 Mark: (1) How would it trend? What would it look like?
(1) *left hand sweeps left to right, tracing an increasing curve*
4 Reese: (1) Probably (2) straight up then (3) straight down (inaudible)=
(1) *points to origin of graph with right index finger*
(2) *traces an increasing line over first year*
(3) *traces a decreasing line over second year*
5 Mark: =Oh but so (1) just for the first half though (2) it would look=
(1) *left hand and forearm form and hold an increasing angle*
(2) *right index finger traces an increasing line up from left to right*
6 Reese: =Yeah

7 Mark: (1) like it was going up.
(1) *repeats trace of increasing line, right hand open and palm down*
8 Reese: Yeah
9 Mark: So an e(1)cologist might say a (2) population was doing great. You don't need to do a (3) longer term STUdy, (4) umm, we don't need to do anything about the wolf-fish.
(1) *hands drawn together, palms facing*
(2) *repeats same gesture*
(3) *Reese looks from Mark to poster*
(4) *Mark repeats same gesture*

Reese responded to Mark's request by tracing two different slopes over the graph of the guppy population on their poster (see Figure 4, left image), positive during the first year then negative through the extinction crisis. But Mark pushed further to focus attention on only the "first half" (Turn 5), showing with a gesture that the guppy population would look "like it was going up" (Turn 7; see Figure 4, right image). When Reese agreed, Mark shifted from a mathematical description of slope (or analyzing "trend") back to the point of view of a hypothetical ecologist, who might use an upward slope over the first year to advise his clients that the population was "doing great" with no need to further study the wolf-fish problem.

Persisting with his questions about what an ecologist might do in Excerpts 2.1 and 2.2, Mark zoomed into population behavior during the first year and re-contextualized this selection from the model as a basis for advice that the students knew was highly suspect. They had already reported the guppy population would be eaten, yet Mark's hypothetical ecologist (these students, if they took the position initially offered in Mark's re-contextualization) gave clearly misleading advice. Mark's voicing of this contradictory advice apparently provoked these students into engaging in a conversation about how their analysis *should* be interpreted.

Reese was first to respond, and he argued (turns not shown) that the ecologist would have to explain all of the values in a graph of population change during the first year, including the number of guppy deaths, which was "steadily rising also at the same time." Blaine, who had been trying to get the floor as Reese spoke, argued (turns not shown) that the ecologists were "just unprofessional" if through laziness or lack of budget they ignored the obvious fact that wolf-fish were in the stream and were already known to eat guppies. Whereas Mark's early efforts at re-contextualization invited students to speak as ecologists, he eventually succeeded by (a) giving voice to clearly erroneous advice from a hypothetical ecologist and (b) inviting students to speak as critics of these obviously sketchy professional efforts. Perhaps in keeping with their generally skeptical stance toward the curriculum unit (e.g., the "EAT ME!" label on an otherwise spare poster) and other adults in the classroom, they were clearly engaged by the opportunity to criticize Mark's hypothetical ecologist. In doing so, they made use of both the modeling context (fish populations and ecological studies) and what they had learned about how to model fish populations. Even stronger evidence for this came in a follow-up contribution by Reese (Excerpt 2.3), in which he argued that a competent ecologist should see trouble in the contrast between guppy birth and death rates:

Excerpt 2.3

1 Reese: You wouldn't even have to look at the wolf-fish at all, all you'd (1) have to look at is their DEATH rate showing how many they come up with every THING,
(1) *right hand points to graph on poster*
because, if the death rate's (2) steadily rising in, as (3) they're rising very little as they should be,
(2) *right hand traces path of an increasing line in gestural stage, then holds*
(3) *left hand traces path of increasing line, above right hand*
as (4) many fish is in there, you'd have to notice that, it couldn't work, somethin' has to be in there so they'd have to take (5) further study into why
(4) *right hand opens, as if to offer*
(5) *right circles on "further study"*

With this, his last comment on the hypothetical ecologist, Reese constructed a detailed mathematical narrative coordinated with gesture to represent the relations between the guppies' birth and death rates (Actions 4 and 5 respectively; see Figure 5). He concluded that an ecologist would have to notice that something must be going on with the population, and this would require "further study."

Summary. Mark's questions show considerable persistence and ingenuity throughout this re-contextualizing exchange, starting with interruptions and a dismissive reception by students in the group but eventually provoking them (as we hear the exchange) into taking a critical stance toward the adequacy of advice given by a hypothetical ecologist. As with the exchange we analyzed in the first case (Jane's interaction with Manuel, Lisa, and Kera), Mark set up various efforts to re-contextualize this group's model by zooming in on selected aspects of the context and mathematical behavior of their simulated results. These created environments for further exploration and thinking on the part of students, who made a variety of valuable contributions that reflected understandings beyond what was available on their posters or in their initial presentation. Mark's initial efforts to position students as ecologists were resisted, but he then zoomed into the graph they had presented, selecting points that showed a clearly misleading "slope" or "trend" (a professional disposition to interrogate graphs similar to Jane's, we think). He finally succeeded by inviting Reese and Blaine to speak as critics of a hypothetical ecologist, whom they judged as "lazy," low on "budget," or just insufficiently at-

Because if the death rate's steadily rising in,	as they're rising very little as they should be, as many fish is in there,

you'd have to notice that it … couldn't work. It, somethin' has to be in there, so they'd have to take further study into why.

FIGURE 5 Reese explains that a responsible ecologist would have to notice the difference between how quickly the death rate is rising (upper left) and a relatively smaller rise in the guppy population (upper right). This contrast, depicted and held in Reese's gestural stage (upper far right), is offered to the visiting biologist (Mark) as evidence for why the ecologists would "have to take further study" (lower image).

tentive to detect evidence of trouble evident to them, as students, even in the restricted range of data proposed by Mark.

This re-contextualization exchange, quite different in tone from the one we analyzed in the first case, eventually provided Reese with an opportunity to deepen and then share his understanding of his group's graph, and his response to Mark's hypothetical context of model use (i.e., giving advice to Venezuelan rice farmers) went well beyond his original presentation of the population graph. Reese's final analysis of trouble, made visible in his gestures depicting different birth and death rates (see Figure 5), contributed a more sophisticated understanding of population dynamics than what was presented or displayed on this group's poster. By the end of this exchange, Reese displayed confidence in an analysis of how predator and prey populations related to one another over time, in effect (as we hear it) doing a better job than Mark's hypothetical professional. The conversational environment constructed by Mark also allowed Blaine—a student known in this class primarily for being a troublemaker—to participate thoughtfully in a discussion about the adequacy of an adult's professional advice, based on his understanding of predator–prey relations. In this way, the design review created a space in which Reese and Blaine, who under the typical classroom circumstances were treated as students who needed to be controlled, were able to explore the behavior of their model more deeply and to share their views on what counts as professional behavior.

DISCUSSION

Re-contextualizing, as detailed in this analysis, was a conversational exchange in which adults with professional expertise in population biology asked questions of students' population models that required a shift in what students were attempting to model. New contexts to be investigated included different timescales for the students' model, altered birth or death rates for the animal populations being studied, and dramatic changes in the environmental conditions in which the populations existed (e.g., a drought). When students took up such requests to reassess their models in a different context, the adults were able to help students see, consider, and investigate mathematical aspects of population modeling that were both relevant in their professional view of what is involved in modeling population dynamics and new to the students.

We argue that re-contextualizing exchanges helped expand the disciplinary expertise of the classroom because they aligned the academic task structure of the design review with forms of participation that allowed students to explore and extend their understanding of modeling population dynamics. The academic task structure of the design reviews required a sequence of turns in which students presented the work they had completed on the guppy population models, followed by another set of turns in which adults (i.e., the visiting biology graduate students, the classroom researchers) asked spontaneous questions about the students' models, which the students were then expected to answer. The questions the adults asked that initiated re-contextualizing exchanges positioned the students (a) to use tools (e.g., the Habitech© software or graphs) to predict and explain future population behaviors; (b) to consider the significance of previously unrecognized aspects of their models that were relevant to population biology (e.g., trends); and (c) to take on the concerns of ecologists who were expected to be responsible to the fictionalized Guppy Foundation (that funded their research), the Venezuelan farmers (who were trying to grow crops), and the fish populations. Re-contextualizing exchanges positioned students in the roles of population modelers, evaluators, interpreters, and ecological policy advisors.

During re-contextualizing exchanges that resulted in new contributions to the students' understanding, the academic task structure and students' participation were coordinated such that students had opportunities to try on ways of thinking and acting like population biologists. In other words, re-contextualizing exchanges opened up the *figured world* of population biology for the students. A figured world, as defined by Holland, Lachicotte, Skinner, and Cain (1998), is a simplified interpretive frame "in which particular characters and actors are recognized, significance is assigned to certain acts, and particular outcomes are valued over others" (p. 52). As Jurow (2005) and Boaler and Greeno (2000) have described, the figured worlds that emerge through classroom mathematical activities, tasks, and discourse practices can suggest a variety of identities, motivations, and concerns for students that can either facilitate or impede their engagement with mathematics. The figured world of population biology that was invoked in the curriculum unit and through successful re-contextualizing exchanges in Ms. Douglas's class helped students engage productively with mathematics.

The two groups that were the focus of our case studies approached the curricular tasks with different motivations and levels of interest in the figured world of population biology. Manuel, Kera, and Lisa engaged with the modeling task with enthusiasm and concern for the guppies' plight; they devised an innovative approach to avoid the extinction of the guppies and were persistent in their attempts to keep the population thriving. Blaine and Reese, however, completed the curricular task with much less concern for the livelihood of their guppy charges. In fact, they were eager to "kill" all of the guppies, taking the intended problem of population extinction as a resource to create a transgressive scenario ("EAT ME") that was their typical (from our field notes) stance of resistance toward classroom activities. It was the adult professionals' questions that initiated re-contextualizing exchanges during the design reviews, their genuine interest in the students' predictions, and their elaboration of hypothetical situations that required the students to act "as if" they were population biologists that opened up the figured world of population biology—with its associated technical knowledge, concerns, and values—more fully for the students. Through the active and collaborative process of re-contextualizing the groups' population models, the students were given the chance to improvise responses to novel situations and develop new understandings of mathematical aspects of population modeling. In the case of Manuel, Kera, and Lisa, Jane's and Rogers's questions and suggestions led them to see their population growth model differently. Trends in the growth of the fish populations became visible to the students, which then allowed them to make conjectures about how the population might behave at some future time. The more sophisticated practice of noticing and exploring trends was not part of this group's repertoire prior to the design review.

In addition to gaining new insights into population modeling, the re-contextualizing exchanges provided resources for the students to take on the dispositions and concerns of population biologists/ecologists. This was particularly clear in the second case we presented. Mark, the visiting biology graduate student, treated Blaine and Reese as if they were "colleagues" who were competent, invested in their projects, and willing to consider new directions that might be only tangentially related to their work; this was not how these students were typically positioned in Ms. Douglas's class. Although our study did not focus on changes in students' identities, we suspect that resources made available during the design reviews supported these students as they played with new roles in relation to mathematics and population modeling. Re-contextualizing thus not only invited these students to reconsider their model of population growth, it also created an alternative space of competence for the students in which they could refigure their roles as producers, interpreters, and users of mathematical models.

In choosing re-contextualizing exchanges to present in this article, we purposefully selected two groups that were quite different in terms of the students' attitudes toward the population-modeling tasks presented to them and the level of conceptual integrity of their population models. Manuel, Kera, and Lisa (with the exception of Ned, who typically did not participate actively in the group) welcomed the opportunity to share their innovative approach to the modeling task, whereas Blaine, Reese, and Max initially resisted presenting anything more than what was required. Recall as well that Manuel, Kera, Lisa, and Ned's model had high conceptual integrity, whereas we rated Blaine, Reese, and Max's model as having medium integrity. Despite these differences, the re-contextualizing exchanges productively invited students in both groups to consider the effects of changes to the situations they modeled in terms of their impact on the fish populations. The number and productivity of re-contextualizing exchanges in design reviews, regardless of whether student models were rated as having high or medium conceptual integrity, was corroborated by our analysis of all 14 of the design reviews. What did seem to make a difference for the type of re-contextualizing that was enacted in a design review was who led the review: Jane's questioning style (doing a round) more consistently led to new contributions to groups' understandings than Mark's (focusing on individual student's ideas). In other words, the social arrangements for participation enacted during the design reviews—the speaking and listening behaviors and participant roles that were expected of students in the visitors' questions—affected what could be learned through the academic task structure of the design reviews (i.e., an elaboration of what was already known vs. a new contribution to the group's understanding). Our analysis of cases and the entire corpus of design reviews suggests that re-contextualizing has the potential to expand students' understandings. To better understand the potential of re-contextualizing exchanges, further studies might examine how to invite participation by all students in a group being reviewed (e.g., Jane's use of a round) or how to create explicit comparisons with the work of students in other groups, who participated as an audience for in-progress design reviews in our study but rarely made spoken contributions.

Designing for Productive Design Reviews

We hope our analysis of the interactions between visiting disciplinary specialists and middle school mathematics students during design reviews provides some insight into how experts might infuse disciplinary expertise into classrooms and make productive use of these specialists' participation in project-based instruction. Based on our efforts over 2 years to use design reviews in multiple classrooms, we found ways to improve the interactions between the visitors and students that may be helpful to others who would like to arrange similar activities in their classrooms. We present these as three design principles for creating hybrid interactional practices in which students can see and begin to participate in aspects of professional practice beyond what is carried in the curriculum, specifically through participation in re-contextualizing exchanges.

Principle 1: Provide authentic tasks, tools, and methods of displaying thinking. Students should work on problems that are genuine in relation to a given professional practice if they are going to try to think in ways that are centrally relevant in that field. Ideally, the problems should allow the students to take on some of the concerns and dispositions relevant to the target profession in addition to developing appropriate cognitive skills. Related to this, students need to use some of the central representational tools and physical artifacts that the adult professionals in a particular field use in order to gain an understanding of some of the constraints and dilemmas that might emerge while solving such problems. When an adult professional interacts with students who have attempted to solve problems and use tools that are part of the adult's work practices, it is more likely that the visitor will understand the accomplishments and problems of the students' work and, at the same time, that students will appreciate the disciplinary expert's perspective and advice. In this sense, tasks, tools, and representational displays provide a liminal or hybrid space between conventionalized classroom practices and those familiar to visiting specialists. The interactive context created in design reviews provides students with opportunities to experience and participate directly in aspects of professional practice that, at least in the classrooms we studied, were difficult to simulate in other ways.

Another aspect of the design reviews we held that seemed to be useful in stimulating conversations that explored disciplinary ideas was that the students displayed their work on posters, a format that was familiar to the adult professionals. Ms. Douglas, with help from the research team, showed students how practicing biologists create posters for research meetings, drawing explicitly from a case study of professional practices in an entomology research group studying the population ecology of forest insects (Hall et al., 2002; Torralba, 2006). The students were also advised on how to present information on their poster and what to expect in terms of questions from the adult visitors. This activity system for presenting their work (i.e., a "poster session") may have contributed to the adult visitors treating the students "as if" they were the population biologists figured by the curriculum unit, rather than relatively passive subjects of evaluation.

Principle 2: Share student work in a way that facilitates thinking on your feet. To encourage professional visitors to ask questions that might invite students to try out different ways of thinking and seeing, teachers need to arrange the classroom environment needs in a way that facilitates on-the-spot thinking and reanalysis. Toward this end, teachers should create events where students share works-in-progress, rather than polished products, so that students are more open to receiving criticism and suggestions for improving their work. The products that students share should demonstrate careful thinking and attention to all aspects of the problem, but students should be aware that the goal of the conversation is to push their thinking as opposed to evaluating what they know. Creating a public forum as we did in Ms. Douglas's class for sharing student work makes it easier for both the visiting professionals and other students in the class to see the model under discussion as unfinished work, and this makes it easier to understand one another's thinking and suggestions as movement toward more adequate or useful models. Furthermore, the actual modeling tools that students used to develop their products should be at hand so that when visitors ask them to think on their feet, they can do so with relative ease. In the design reviews documented in this article, we not only made the Habitech© software accessible, but we also connected the computers the students used to respond to the adults' questions to a larger screen (a television, but other display technologies are possible), and this made modeling entities (quantities, functional relations, graphs) visible to the adult professionals and to the students in the audience. This attention to the visibility of models for conversation was a change from how we organized design reviews in prior years and seemed to be a useful modification.

Principle 3: Prepare disciplinary experts to think with students. In our experience leading design reviews in multiple classrooms, we have found that the most productive conversations occur when the disciplinary representatives engage in thinking *with* the students rather than telling the students information or evaluating the students' work against an external standard (similar to the "partner" participation structure described by Tabak and Baumgartner, 2004; see also Moje, Tucker-Raymond, Varelas, & Pappas, 2007). Getting the adults to participate in this type of exploratory talk may require a shift in how they think about the role of assessment in learning. As described in this article, we were fortunate to work with Jane and Mark, who not only were knowledgeable about modeling population dynamics but were also interested in education (e.g., as evident in the case of Jane, who encouraged wider participation by students and apparently elicited more new contributions). However, we have also worked with disciplinary representatives who approached the design reviews as an opportunity to lecture students on various aspects of schooling or their work. Based on these experiences, we recommend helping the adult visitors to see the value in assisting students' performance, as a way to help students learn about things they could not generate on their own. When inviting the adult professionals into the classroom, for example, teachers might emphasize the unique value of the adults' professional knowledge and suggest that the adults build on what the students know by asking questions that could lead students to attempt—with the adults' expert guidance—to solve problems using the concepts and tools that are central to the target field. We prepared visitors by showing them examples of student work they might see in the reviews (from prior years), giving them the "challenge tasks" students were working on, encouraging them to push on students' assumptions in relation to model behavior, and encouraging them to ask "What would happen if …" questions. Of course, as we show in this article, not every question (no matter how good) leads to a productive conversation—students may be resistant to thinking more about their work, or they may not understand what is being asked of them. A word of advice to the adult questioners is to be persistent and creative in going about asking questions. Teachers who are part of these conversations can help the professionals decide when to keep or stop pushing students' thinking.

These three principles provide some guidance for creating the tasks, participant structures, and resources that could lead to generative re-contextualization exchanges. Yet it is also important to keep in mind that adult attempts at re-contextualizing students' ideas might also lead to interactions that are less successful in terms of creating opportunities for young people to learn (E. Moje, personal communication, April 9, 2006). Re-contextualizing, at its most basic level, involves a shift in the context in which an idea is presented in order to highlight a new meaning; issues of power and social status therefore will have an effect on the process and the consequences of any re-contextualization exchange. *Whose* context needs to be shifted? In classrooms such as the one we described in this article, where teachers or adult professionals re-contextualize student ideas in order to draw out meaning that is more closely aligned with disciplinary knowledge, power and social status are in play. As these exchanges are used to align students with disciplinary practice, they are generally viewed, by teachers and students alike, as beneficial for student learning. But if adults want to silence student voice (e.g., Kirshner & Geil's, 2006, study of youth sharing their marginalized opinions with a school board), they can as easily shift the context of students' ideas so as to censure them. Re-contextualizing students' ideas in these ways, in the classroom as well as in other settings, can send the message that youth are deficient and that their ideas are illegitimate. With this in mind, an important issue that future researchers might consider is how power and social position are enacted in re-contextualizing exchanges and how this influences what might be learned (Wortham, 2005). Attention to this issue should help clarify the contexts in which re-contextualizing will provide expansive learning opportunities for students.

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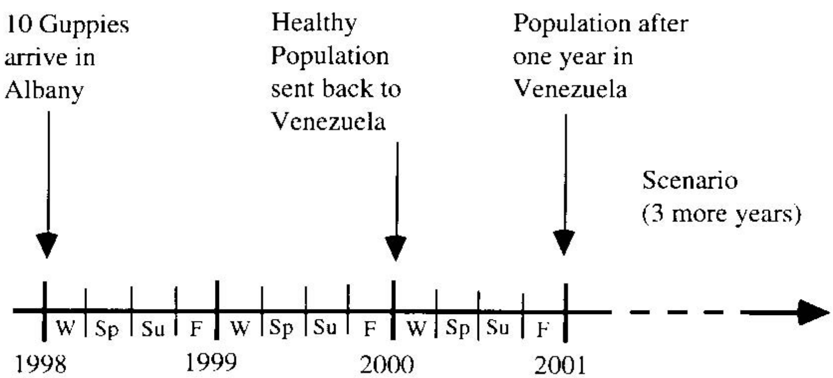
APPENDIX
EXTENSION SCENARIOS

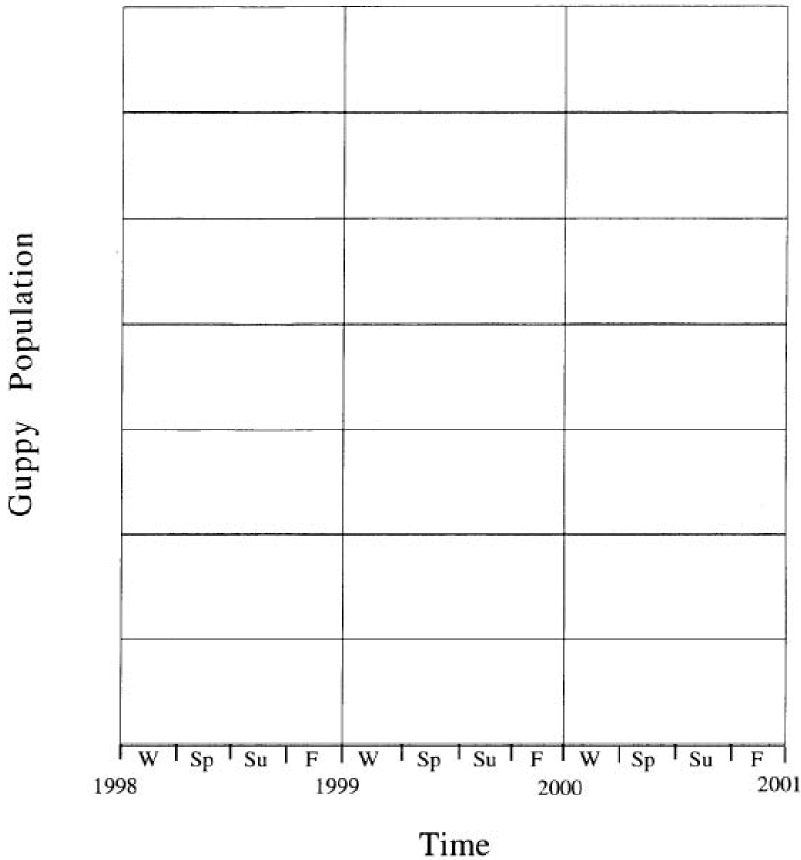
Back in Venezuela ...

Let's say your group's healthy guppy population was sent back to Venezuela and they've been there for one year. From the time the ten guppies came under your care, it has been a total of three years. They arrived in (your city) during Winter of 1998 and stayed until the start of Winter 2000 (8 seasons). Their first year in Venezuela will end at the start of Winter 2001 (4 more seasons).



1. Run your model for the three year period (1998 to 2001). Using the graph and table in the software, draw a graph of the guppy population by hand (use the coordinate grid in the handout). On your graph, indicate the number of guppies that were sent back to Venezuela at the end of two years (according to your model) and

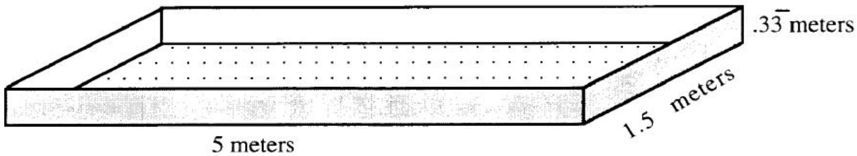
the number of guppies there were at the end of 2001. Write both these numbers below and write about the growth that occurred during the third year.



2. The stream habitat where your guppies were returned can be visualized as a rectangular solid, that is, having a length, width, and height (or in this case, depth). Water enters from upstream and flows out downstream, but guppies stay inside this part of the stream.

Using the measurements given in the illustration below, determine the volume of the habitat and the top surface area. What is the maximum number of guppies that this habitat could support? (Please show all your work)

3. After checking up on our guppies back in Venezuela, you know how many guppies will be in the stream by the year 2001. Now, something is going to happen over the next three years (from 2001 to 2003). Your group gets to choose which of



the following three scenarios you want to work on. Read over these scenarios tonight then your group will choose one scenario tomorrow.

Rice Farming, *Anopheles* mosquitoes, Malaria, and Guppies

Although most of us see guppies as "Pets," there are places where guppies play a very important role in preventing epidemics (large numbers of people get sick from a particular illness). Some of these places are in tropical climates, like Venezuela. You see, guppies eat mosquito larva and so prevent the population of mosquitoes from reaching dangerous levels. *Anopheles* mosquitoes can transmit malaria, a human illness in which red blood cells are destroyed, by carrying a parasite called *Plasmodium* (one-celled organisms, very small!). When a mosquito bites a person, these parasites enter the human blood stream. There are about 300 million people infected with malaria every year in the world, so you can see that controlling the population of these mosquitoes is important.

In Venezuela, rice farmers are required to have guppies in their fields, which are covered by water and so make a perfect breeding ground for mosquitoes. One of these farmers has rice fields nearby the stream where your guppies were placed. Every Spring, he takes 99% of the population of guppies from the stream and places them in his rice fields. *Your task is to figure out*:

(a) How will the population in the stream change because of harvesting over three years?

(b) How could you use Habitech© to model the result of harvesting in the stream? Is the farmer taking too many guppies?

(c) If you were a Venezuelan biologist in charge of making sure that guppy populations are not over-harvested, at what level and how often would you recommend that farmers harvest guppies from this stream?

Rice Farming, Weeds, Pesticides, and Another Pollution Event

Unfortunately, we have more bad news from Venezuela. The stream where we sent the guppies has again been polluted. Apparently several containers (100,000 units) of a weed pesticide were accidentally dumped into the stream. This type of chemical is fairly toxic to animals, but we don't know exactly how it will affect the population of guppies in the steam. For example, we expect the pesticide will affect birth and death rates, but we don't know HOW. We also know that these chemicals will be flushed out of the stream over a few years.

The local rice farmers are pretty upset, since they depend on guppies to control mosquitoes in their rice fields. Yet, they also use this weed pesticide to increase their rice crop. So they want to hire some biologists to tell them what the effects of the pollutant will be on the guppy population. Your task as a biologist is to figure out:

(a) How will this new pollutant affect the population of guppies we put in the stream over the next three years (2001 to 2003)?

(b) As you know, models help you predict what will happen to a population over time. Please, try to model the effects of the pollutant on the Guppy population using Habitech©.

(c) If you were a Venezuelan biologist studying the effects of pollution on Guppy populations, what would your study results be from this case? Try to be as specific as you can, so next time this type of accident occurs, we will have a better understanding of what to expect.

Guppies are Disappearing in a Venezuelan Stream!!!

Rice Farmers in Venezuela are required to place guppies in their fields to combat *Anopheles* mosquitoes that cause malaria. Staring in 2001, however, they notice that the number of guppies they can harvest from the stream has been getting lower and lower. They know guppies pretty well but can't figure out why their numbers are going down lately.

It turns out that people who live upstream have released some exotic wolf-fish from Thailand, and a small number of these have reached the pond area where our guppies are living. Wolf-fish are very aggressive and bigger than guppies. Apparently, they are very effective predators of guppies, and their population in this part of the stream is growing. The farmers are very mad and worried that the guppies they rely upon will be killed by this new fish. Your task as a consulting biologist is to figure out:

(a) How will wolf-fish affect the population of guppies living in this stream over a three year period (2001 to 2003)?

(b) Using Habitech©, how to build a model that can help you and the farmers understand the effects of these new predators. How could you use this model to explain your predictions to the farmers?

(c) Is it possible that guppy and wolf-fish populations could both live in this part of the stream for a longer period of time?