

Conceptual Development and Context: How Do They Relate?

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Abstract: This paper combines results from a larger research study that focuses on both cognitive and social aspects of learning (Otero, 2001). The theoretical perspective used is distributed cognition (Hutchins, 1995), in which students, students interacting with tools (such as laboratory apparatus and computer simulators), and students interacting with others and with tools are considered a *cognitive system* that generates learning. According to this perspective, each element of the system contributes to the cognitive product by sharing part of the *cognitive load* associated with a task. The unit of analysis of this paper is a group of three students working with tools, although results from a study where the unit of analysis was the single student are also used.

Introduction

The study was conducted in a physical science class for prospective elementary teachers. The instructor used the CPU¹ Curriculum and simulator software to teach a unit on Static Electricity. There was no textbook used for the course, students were guided in the construction of their own ideas through laboratory and computer simulator activities in an Elicitation, Development, Application format. Physics ideas were developed through the process of whole class consensus. Consensus ideas were expected to explain the student observations in laboratory and simulator experiments. The Static Electricity Unit consisted of three cycles each focusing on a particular set of concepts. The purpose of Cycle I was for students to become familiar with electrostatic phenomena such as attraction, repulsion, and distance effects. The purpose of Cycle II was for students to construct a model for charging insulators by rubbing. Cycle III focused on the development of an understanding of charge polarization within a conductor and charging by induction. All activities were named according to the cycle and their order within that cycle. For example, the third Development Activity in cycle II was labeled Activity II-D3.

Method

Over 200 hours of classroom data was video recorded, transcribed and time-stamped for the larger study. Much of class time was spent in small group discussions where groups of three students worked on computer-based activity documents using laboratory experiments and computer simulations. This analysis focused on groups' scientific behavior. Time-stamped

transcripts were analyzed and each statement or discussion was coded according to whether it had to do with laboratory prediction, observation, explanation/interpretation, predictions that had to do with the simulator, simulator observations, explanations and interpretations. Further analysis of the same data led to a coding scheme into which all comments made by students fit.

The codes of interest here are the scientific inquiry codes consisting of behaviors observed during the prediction/reasoning phase or observation/interpretation phase of both laboratory and simulator portions of activities. *Model-based reasoning*, *peer instruction*, and *unresolved issues* were the three codes that were considered to comprise *sense-making behavior*. Other codes such as *data logging*, *confirmation* and *computer/apparatus manipulation* were not considered sense-making behavior. All of the events that were coded as sense-making behavior were then used to determine the percent of time a group of students spent sense-making in a particular activity by dividing the amount of time sense making by the total amount of time spent on a particular activity.

Results

A group that was studied (MJH) consisted of three members, Mark, Heidie, and Jenny. Another group in the study (PRT) consisted of three members, Pedro, Rosa, and Tara. The sense-making profiles for each group are shown in figure 1. An interesting aspect of the graph in figure 1 is the increase in sense making that began to occur for both groups just after the simulator was introduced. This could lead one to believe that the introduction of the simulator was associated with the increase in sense-making. Other explanations include the possibility that the introduction of the sim-

¹ The Constructing Physics Understanding in a computer supported learning environment project was funded in part by NSF grant #ESI-9454341.

ulator allowed curriculum developers to include more prompts for sense-making in the activity documents.

The number of prompts for sense making in the activity documents were compared before and after the simulator was introduced. No substantial increase in sense-making prompts was found. One might then conclude that students were able to engage in more model-based discussions for longer periods of time with the assistance of the simulator. To test this hypothesis sense-making curves in figure 1 were separated into their laboratory and simulator components.

The percent of activity time spent sense making in laboratory and simulator portions of activities are represented in figures 2 and 3. The date and activity that took place on that date are plotted on the x-axis and the percent of time spent sense making in either laboratory or simulator portions of activities are plotted on the y-axis. Because the simulator was not introduced until Activity II-D3 on 10/19, the laboratory and simulator components graphs shown in figures 2 and 3 begin on Activity II-D3. Before 10/19 all activities contained the laboratory component only.

Again we see similarities in the sense-making profiles for MJH and PRT. Both profiles show an increasing trend in the laboratory components of the sense-making profiles. The simulator component on both graphs increases between Activities II-D3 and II-D5, flattens out between Activities II-D5 and III-D1

and then decreases between III-D1 and III-D2. For MJH the curve increases from III-D2 to III-D3 but decreases for PRT. It was not expected that simulator sense-making would begin to decrease because the activities became increasingly complex and different functions of the simulator became available to students over time. It is important to note that the CPU static electricity simulators use a coloring scheme to represent charge. The *coloring scheme* represents charge as red and blue lines of varied thickness instead of as various quantities of positive and negative symbols.

Attempts to explain these trends utilize data from another part of the study where each student's conceptual "model" was inferred at various points throughout the unit. Twelve models were inferred for the six students throughout the entire unit. These models are listed below from the models that are most general to models that have the greatest explanatory power: general conditions model, statically charged or not model, plus & minus condition model, plus or minus condition model, charge creation model, charge transformation model, dormant charge model, charge configuration model, charge rearrangement model, atmosphere model, two-way transfer model, and one-way transfer model (for a more detailed description of these models see http://spot.colorado.edu/~otero/NARST_2001.htm).

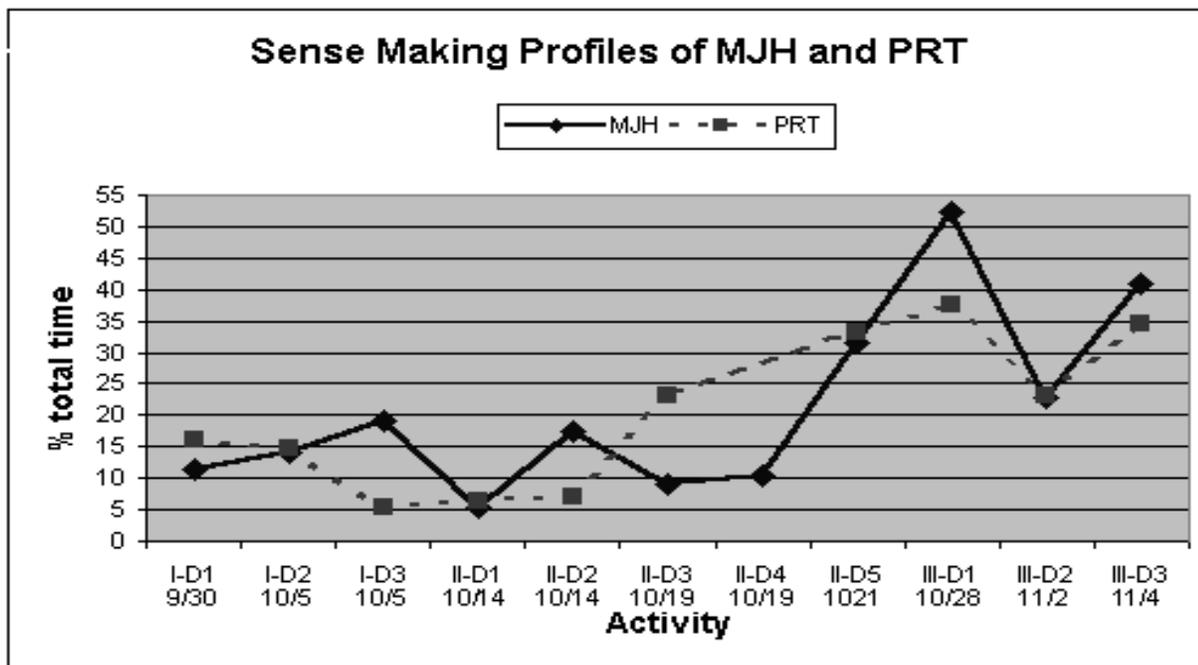


Figure 1. Sense making profiles for two groups.

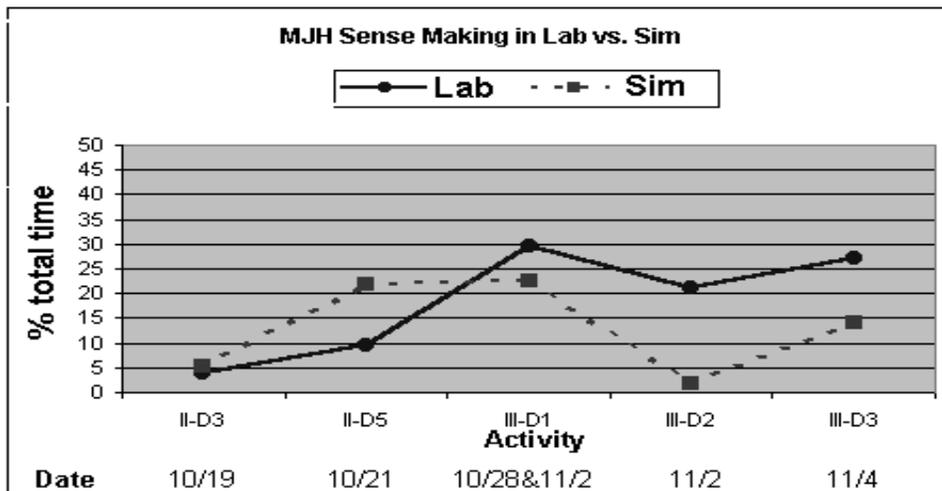


Figure 2. Laboratory & simulator components of sense-making profile—MJH.

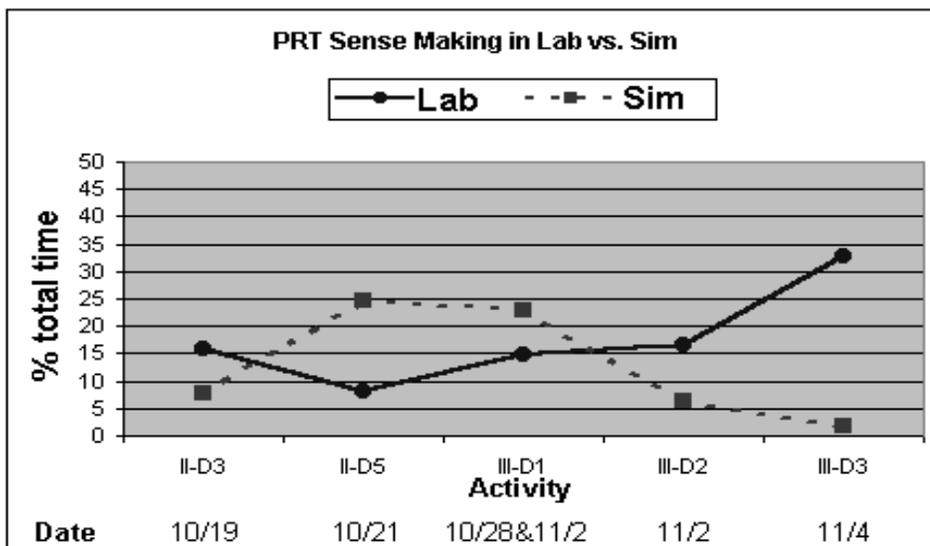


Figure 3. Laboratory and simulator components of sense making profile for PRT.

Students' model profiles for one group are represented in figure 4. The model profiles for the other group were very similar in nature. The date and the activities that took place on that date are plotted along the x-axis. The twelve models inferred for students in the study are hierarchical organized along the y-axis in terms of explanatory power and parsimony. Each of these models was empirically determined through analysis of the data. These are student-generated models and the *one-way transfer* model was the target for instruction. Notice that throughout much of the

unit, the three students in each group were *consistently* using different models from one another (models were only inferred if they appeared in several different sources of data including homework, journals, interviews, and class discussions).

Around 11/2 student models for both groups began to converge to a one-way transfer model. This data was superimposed with the sense-making data presented earlier. The results are shown in figures 5 and 6. The laboratory and simulator components of the sense-making profiles in figure 5 differ slightly

from figure 2 because in figures 5 and 6 they are plotted by date and in figures 2 and 3 they are plotted by activity. Some activities took place over two different class periods and in some cases two activities were completed in the same class period.

Figures 5 and 6 suggest that simulator sense making began to decrease around the time that students' models converged to a one-way transfer model. An explanation for this is that the simulator coloring scheme provided a *shared model* that mediated sense-

making discussions when students models were very different from one another. After students' models converged, each student knew what the other students in his group knew and he or she also knew that these students knew what he or she knew. This *intersubjectively shared* (D'Andrade, 1987) model now mediated scientific discussions and students started making sense of phenomena they observed directly from laboratory apparatus before they got to the simulator.

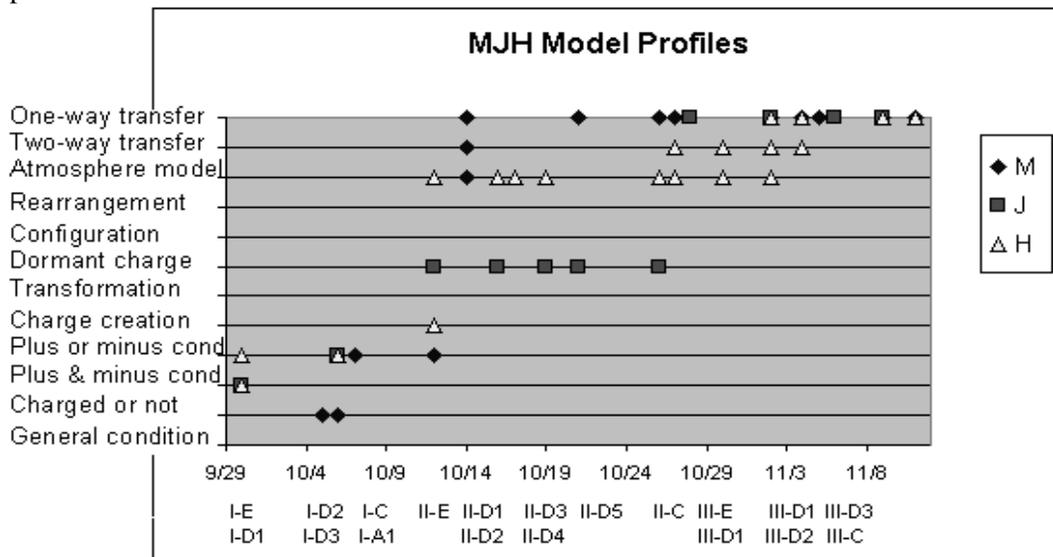


Figure 4. Model profiles for Mark, Jenny, and Heidie

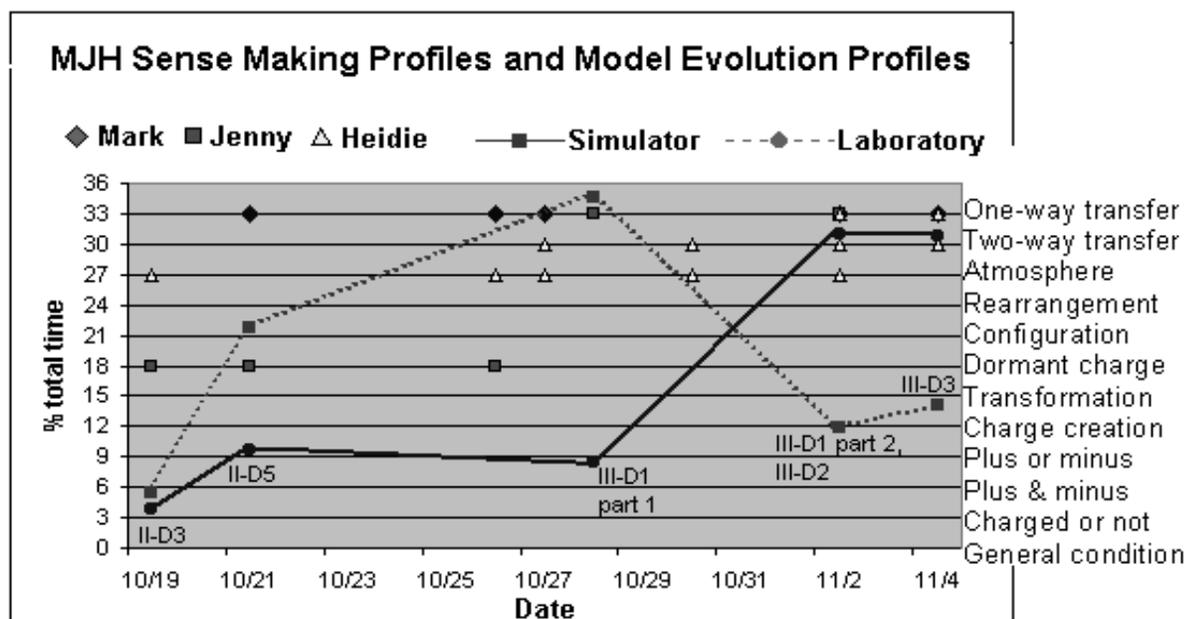


Figure 5. Superimposed model and SM for MJH

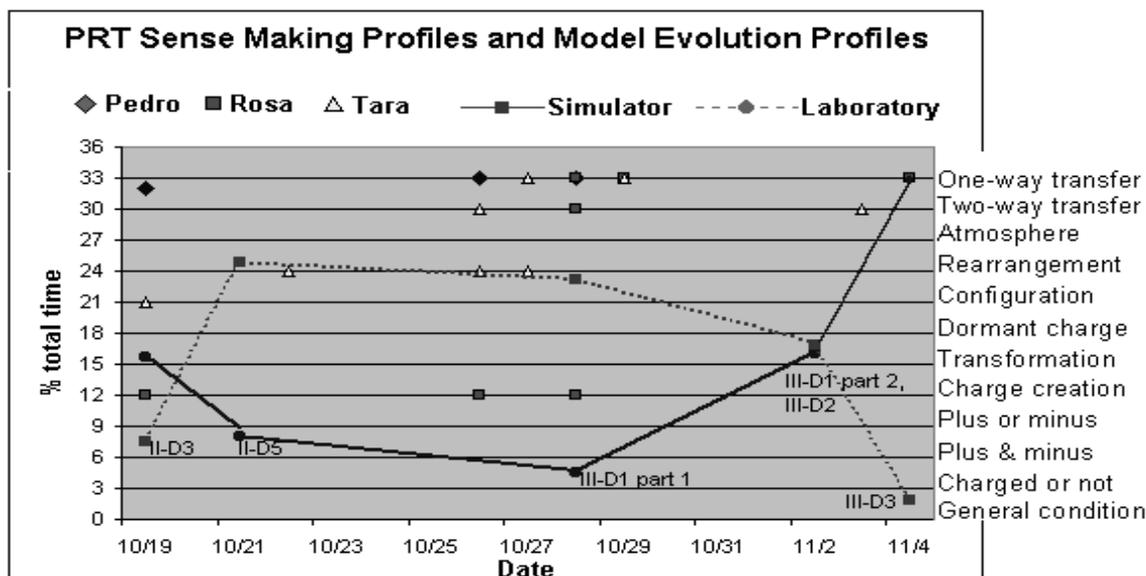


Figure 6. Superimposed model SM for PRT

The coloring scheme and computer simulator played a special role of generating and mediating model-based discussion before students understood each other's thinking. Transcripts from videotaped small group discussions confirm that discussions that centered on laboratory experiments were generally limited to confirmation and data logging before students' models converged. Discussions that centered on simulator experiments and images tended to center on model based discussions where students articulated more aspects of their thinking once they got to the simulator portion of the activity. After students' models converged, around 11/2, model-based discussions took place more frequently in the laboratory portion of activities, before students opened the computer simulator. They started to use the simulator only to confirm the theoretical model they generated and/or discussed prior to opening the simulator.

Sense making behavior appears to have increased after the simulator and coloring scheme was introduced for two main reasons: (1) The simulator and coloring scheme provided assistance that mediated model-based discussions within groups since the simulator images were based on a simplified model, (2) experience using model-based reasoning based on simulator images scaffolded the process of scientific behavior. This led to an overall increase in sense-making about observable phenomena near the end of the unit.

A smoothed, averaged sense-making curve is shown in figure 7. The curve represents three different segments of the unit: before the coloring scheme was introduced, after the coloring scheme was introduced but before students' models converged, and after students' models converged. From this curve it is clear that the pattern of sense-making behavior, and the tools associated with it changed as students' conceptions changed.

Discussion

Results discussed in this paper suggest that student conceptual development influences the classroom context or cognitive system. When a group of students, a computer, activity documents, laboratory apparatus etc. are viewed as a *cognitive system* we can see that interactions within any part of the system effects the overall structure and processes of the system. Understanding student conceptions is only part of understanding the process of learning within a student-centered classroom. The roles of various tools in the environment may change as a result of conceptual changes of the students. In the earlier part of the unit, the simulator played a mediating or role, or acted as a form of assistance for students' scientific discussions. In the latter part of the unit, students no longer needed this assistance. Learning environments should be structured in such a way that flexibility in the role of such tools allows for conceptual development of individuals and for resulting changes in their use of tools.

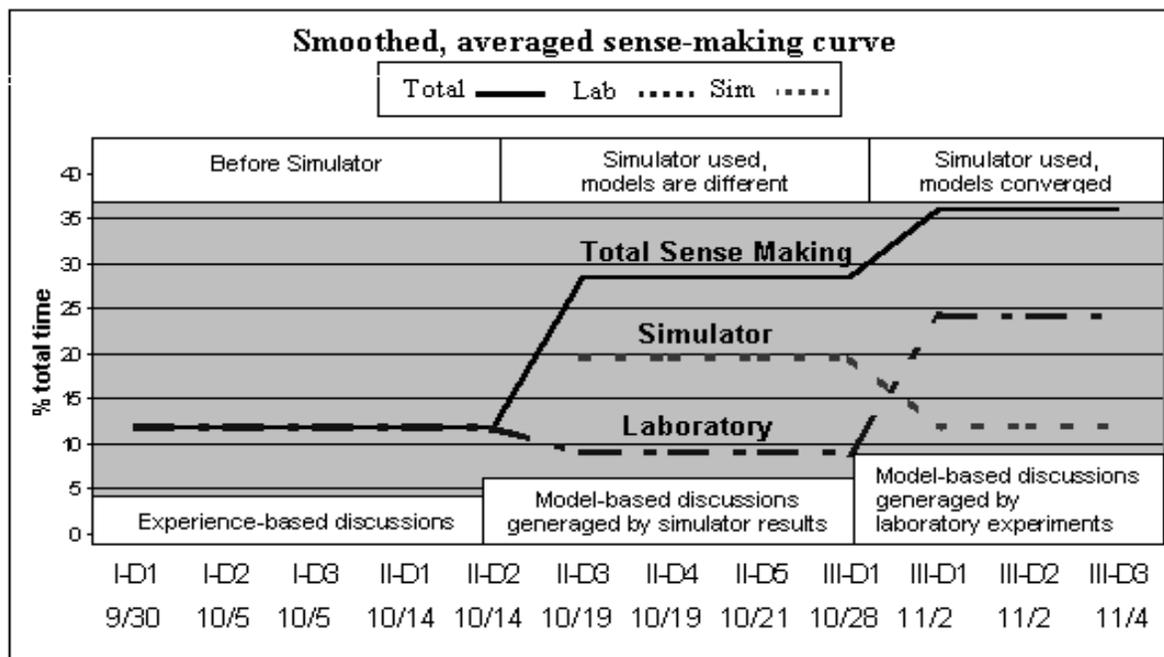


Figure 7. Smoothed, averaged curve.

References:

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Hutchins, E. (1995). *Cognition in the Wild*, Cambridge MA: MIT press.

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