Probing Technology as Affordances for Negotiating Meaning in the Elementary Science Classroom ---- A Participation Perspective

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Abstract: Probing technologies are assumed to augment and speed inquiry learning. However, in practice, handheld-based classroom practice is regarded as only having scratched the surface of what is possible. The purpose of this article is to propose regarding the probe as a catalyst for negotiating meaning in inquiry learning activities rather than to perceiving the devices simply as educational computing technology. Viewed from a participation-framework perspective, we claim that probing technologies trigger the cycle of, and interplay between, reified object generation (numbers, graphs,...) and engaged participation among learners. An analysis of a probe-supported inquiry activity in a grade 5 elementary classroom is conducted. Three episodes in an inquiry classroom reveal the focusing and reified effects of probes in enhancing meaning negotiation, and in supporting student-driven exploration. The function of probes in both emergent and instantaneous aspects of learning is also discussed.

Key words: probing technology, meaning-making, participation

1. Exploring new affordances of probes

The field of probing technology in education is rapidly expanding. Probes are generally viewed as tools used in support of scientific study. Students may use probes as instrumentation to gather data (temperature or pH probes feeding data into computer ports for example), in order to visualize data for various forms of analysis, to model phenomena, and to facilitate interaction and collaboration among students. In particular, probes allow students to gather ‘accurate’ data, and, by graphing it ‘quickly,’ allow students to focus upon the interpretation of their data, rather than upon the tedious processes of recording and plotting it. Thus, probes support the long-term pedagogical goal of ‘inquiry-centered’ science classrooms, by making scientific experiments easier for students to perform and analyze (Tinker & Krajcik, 2001).

The computational power and streamlined data acquisition capabilities of probes appears to have been well established. However, the research that resulted in these findings was conducted primarily using pre-post test (Krajcik & Starr, 2001), concept mapping (Novak & Gleason, 2001), and survey (Vahey, Tatar, and Roschelle, in press), or involved establishing impressive learning gains as evidence of the benefit of probing technologies (Tinker, 2000; 2001). Of course, having students see the display change in “real time” is of great educational value, but exactly how learners are able to associate rapidly certain physical changes with changes in the representation of those phenomena remains unclear. We attempt here to reveal with empirical data the sort of meaning relationship that other methods ignore, but which might enrich their analysis through identifying the potential in these technologies for deep learning.

Research on alternative affordances and constraints of probes is promising. Vahey, et.al. (in press) propose one particular set of affordances: the ability of students to engage in, and move
seamlessly between, private interaction with their computational environment, and public interaction with face-to-face collaboration around the computational environment. Roschelle (2003) also pointed out the challenge of creating a link between the informatic world and the social world, a coupling through which these powerful probes enable and motivate social interaction. Sharples (2002) also mentioned the importance of learning conversations in externalizing the understanding of the learners. The design of mobile technology for learning must take the affordances of conversation into consideration.

Alongside this line of thinking, this study examines the affordances of meaning-making provided by the probes. We introduce the social theory of learning as an analytical framework to perceive probes as catalysts for meaning-making among students and teacher. We then present three episodes of probe use that exploit these unique affordances. In the last section, we discuss how the probe-supported activity design promotes meaning-making learning.

2. Analytical framework of probes in inquiry learning

Inquiry learning is generally considered, in school practice, to be a sound demonstration of a set of scientific process skills which include claim forming, hypotheses making, data collecting, and conclusion drawing. However, development in the sociology of science (Roth, 2001) reminds us that scientific knowledge is fundamentally a social process of negotiation. Consistent with Wenger’s communities of practice (Wenger, 1998), these issues can be explored and interpreted further within a participation paradigm using the dual concept: participation and reification. Of particular importance to our study is his argument that meaning is located in a process he termed “negotiation of meaning”, which involves the interplay of two processes: participation and reification. Participation is always based on situated negotiation and renegotiation of meaning in the world, while reification gives form to experience by producing objects that “congeal this experience into thing-ness” (p. 58).

In the case of an inquiry activity, probes can be configured as a tool for creating reified objects—digital numbers, graphs, and figures. The reification creates points of focus around which the negotiation of meaning becomes organized (Wenger, 1998, p. 58). By manipulating the probes, learners involve themselves in hands-on activities. Their discussions are focused on the generated readings from the probes. The whole aggregate of inquiry activities congeals into thing-ness. These points of focus then immediately engage group members in the process, prompting them to participate in the activities of negotiation. It is through this dynamic process that meaning is re-negotiated. These learning technologies play thus a vital role in supporting the pursuit of shared meaning construction.

Meaning can only be negotiated through the use of imagination. Within a community of practice, meaning is experienced through various combinations of participation and reification. The relationship between participation and reification inspires the imagination of curriculum designers. If participation and reification both require and enable each other, the relationship between the two is a duality but not one of opposites. The negotiation of participation and reification within education is a balancing act (Wenger, 1998, p. 265). Using that analytical framework, this study is intended to explore in what ways these new tools transform an established inquiry activity.

3. The emergent nature and negotiation in probe-supported inquiry learning

We worked for over a year (2003-2004) observing a grade 5 science classroom. The science teacher was our seed member in integrating technology into a science classroom research team. He struggled to introduce the use of probes (Multi-Log) to students in the time allotted. Among the challenges faced were the language barrier, as students sought to use the English interface of the probes, the fact that extra time had to be spent adopting the learning tool and dealing with the resulting tensions of meeting unified schedule of teaching progress (very common in Taiwan), and the various concerns raised by parents. However, near end of the semester, they finally shifted focus from teaching a probe-use skill-set to that of the higher order learning potentials of the tools.

The videotape analyzed in this study was the three-hour chronicle of an inquiry activity in which probes were used to measure water temperature. The teacher created six groups from the class to conduct this experiment with one probe and one tablet PC in each group (see Figure 1). Three
episodes were excerpted from the three-hour videotape to illustrate what and how students learn when studying science with the support of probes. The first one involved many-to-many interaction in which meaning is generated at the group level; while the remaining two followed a typical classroom pattern (Lemke, 1990), with teacher-interpreted meaning and teacher-centric dialog.

The central concerns in this section are: What do probe-supported activities bring to learning situations that do not exist when teaching science with the use of a traditional thermometer? How do the probes produce objects that “congeal their experience into thingness”? How do real-time readings result in greater student engagement? And, in turn, how does this engaged participation provide students with the opportunity to re-negotiate meaning in a new context?

3.1 The important concept of ‘rate of change’ was instantaneously captured

Introduction. The teacher assigned each group leader the task of fetching a cup of hot water from him. He then had each group put the temperature probe into the hot water for 500 seconds with temperature to be recorded each second. He also reminded the class not to stir the water when taking measurements. Here is a transcript of the conversation that took place in one group.

episode 1:
1  A: What is the temperature?
2  B: 69..70…
3  C: It’s going down.
4  B: Really, 63….
5  B: It’s going up again. ..66…67…
6  B: It’s going down again…64.33
7  C: It’s going down rapidly.
8  D: Is the water very hot?
9  A: What happened to the other groups? Go to check them.
10 B: Wow! It’s going down…50 something…
11 D: It’s so strange. How come it’s going down in a rush way?
12 B: Come on! Don’t stir it.
13 A: Man! Please move a little bit. I can’t see it.
14 C: Didn’t the temperature change rapidly earlier?
15 D: What the temperature is? It’s too weird!
16 A: Watch out! It’s going to be 500th second. You have to push STOP in time.
17 C: Yeh! It stops. It’s in 45 degree.

The traditional thermometer serves to measure static equilibrium, which means that the value represents a state in equilibrium. One of the traditional laboratory activities performed by students is, for example, using a thermometer to measure the temperature over time of a beaker of ice water heated by a Bunsen burner (Staudt, 2001). In this case, students have to concentrate on the tedious task of taking readings from the thermometer at specified intervals. It needs hardly to be said that the tedium of long term experiments taking place over multiple minutes, hours or days is far worse. Also significant is the fact that accurate records of events taking place within very brief periods, (within one second, or 0.01 second, etc.) are not practical.

The temperature probe, on the other hand, specializes in measuring dynamic equilibrium and changes of temperature over very short periods of time in an open system. In our study, the constantly updated digitized readings allowed students to become aware of temperature changes between fixed time intervals (one second). As the temperature probe showed on the screen one value each time, students were simultaneously led to compare values in the sequence. In line 2-6, they were very sensitive about the ups and downs with the affordable function of temperature probes. In line 7, 11, 14, and 15, the continuous readings scaffolded them to identify a very important phenomenon: the rate of change during observation. This curiosity prompted them and opened up an opportunity for exploration.

Introducing probes into the learning environment also changes the classroom’s attentional affordances (Tatar, et.al., 2003). Analyzing from a participation paradigm perspective, we conceive the probes as a tool not only for effectiveness in observing and collecting data, but as a tool for
congealing observed experience into thingness. If attention is a *sine qua non* during scientific observation, the inscriptions reified through the use of the probes can themselves generate this attention, as can conversations about the readings, and unexpected discoveries made by students during the process.

Following this line of thinking, the perspective of “Having a tool to perform an activity changes the nature of that activity” (Wenger, 1998, p. 59) further expands our interpretation. Reifying the concept of temperature may not change its effect on our bodies, but it does change the way we experience the world by focusing our attention in a particular way and enabling new kinds of understanding. The significance of probes is not limited solely to possibly speeding-up student comprehension of this experiment; rather, the simultaneously captured concept “change of rate” provides further opportunity for exploration. “Why does it go down rapidly?” becomes a driving question for the group (and may be common throughout the class). In other words, students’ motivation was triggered by the unique affordances of temperature probes.

### 3.2. The compelling teachable moments were found

**Introduction.** This episode is taken from a whole-class discussion designed to account for the outcome of an increase followed by a decrease in temperature readings generated during the 500-second observation. Although perceived as a typical classroom pattern, we found that this discussion took place between teacher and students in a very different way. The teacher was initially intent upon getting back to the curiosity generated in many groups about “Why it goes down rapidly?” and anchored the discussion with the ‘WHY’ on the phenomenon of ‘rate of change.’ This appeared to be too difficult for grade 5 students to answer so the teacher instead asked for reasoning to explain the phenomenon of temperature “going up and then down”.

**Episode 2:**

18 Teacher: Does anyone in your group remember the beginning temperature of the water in the cup?
19 Student a: 62
20 Student b: 63
21 Teacher: OK. It doesn’t matter. The beginning temperature is around 60 degree. Let’s look at the curve. Can you see, the temperature was going up and then down, why? If anyone finds the right answer, I will give him/her a reward.
22 Student c: The digital number kept going up till a peak, then the temperature of the water in a cup began cooler, so the digital number was going down too.
23 Teacher: A little bit close.
24 Student d: The temperature probe was originally in the air, and then it was put in the hot water. These two temperatures were different, so when you put it first in the hot water, the digital number would go up from the low position.
25 Teacher: Yes, correctly! Now the number showed in your temperature probe is the same as the temperature of this classroom, which is 19 degree roughly. So the digital number would have to go up till the same as the temperature of the water.

The target of the inquiry was to provide insight into the air-water phase change, which was not easy for grade 5 learners. It was probably due to the incentive of a reward, in line 22, that one student responded quickly. Although he did not get the point, he noticed a peak in the curve, which was a key to the correct interpretation of the phenomenon behind the curve. Were traditional thermometers used, the time interval at which temperatures would be recorded could not be brief enough for observers to be sure of detecting the critical peak when dealing with dynamic balance — as was here the case.

In responding to this inquiry question the teacher posed, readings from the probes never again served as quantitative information for effective learning. Instead, the curves each group had generated became reified objects whose meaning could then be re-negotiated. In line 22, the student’s misconception about the function of the probes (i.e., they overlooked the fact that readings were a transition from measuring the air to the hot water.) was also examined and the meaning behind the peak of the curve was therefore uncovered. From a participation point of view, the interpretation of the readings was designed to rely partly on participation. That is, the emergent opportunity for learning was actually triggered by misconceptions or alternative explanations inherent in the
participatory process, and this scaffolded the negotiation of meaning. We will discuss this more in the next episode.

3.3. The negotiation of meaning-making on inscriptions followed

Introduction: Near end of the three-hour class, each group drew the curve shown on their tablet PC on the whiteboard for comparison. The teacher raised one question for whole-class discussion.

Episode 3:

26 Teacher: Attention! How come the temperature decreased differently in each group? Group 1 decreased slower than the others. Can anyone give us an explanation?

27 Student a: It was possibly that they did something to hold the temperature.

28 Group 1: No, we didn’t.

29 Student b: It’s the place that matters. It is because their group was near the door.

30 Teacher: If so, then the temperature should have been decreased quicker.

31 Student c: It’s because they sit closer to each other.

32 Teacher: Is that possible? Yes, but the chances are slim.

33 Student d: They use paper cup while we use plastic cup.

34 Teacher: Sounds interesting too.

35 Student e: Teacher, the light!

36 Teacher: It’s very simple! Right at the beginning of the experiment, the conditions among the groups were not equal. My hint is quite obvious.

37 Student f: The height of the water that you filled in each cup is different.

38 Teacher: Yeh! Maybe I put a little bit more water into group one’s cup.

39 Teacher: That’s why I remind you many times that you have to be careful about all the conditions and their relationships with the data.

Having engaged in the use of probes for observation, at end of the class many students were able to make sense out of group 1’s curve. Each student mentioned something s/he felt important to the cause of the particular shape based on his/her own interpretation (see figure 2). Although most of the answers seemed not to satisfy the teacher, it was the students who negotiated meaning with their teacher, and tried to come to a shared interpretation. The teacher, using a probing technology, created points of focus around which the negotiation of meaning became organized. The production of such a reification is crucial to the kind of negotiation that is necessary in order for them to be able to bring together the multiple perspectives, interests, and interpretations that participation entails (Wenger, 1998, p.62).

Within the frames of Wenger's (1998) social theory of learning, such sharing processes are not merely translations (p.68); they are indeed transformations — the production of a new context of both participation and reification, in which the relationships between the tacit and the explicit are renegotiated. The inscriptions (reification) were meaningful to them because, through participation, they experienced the process of generating the curve and came to know exactly how the readings configured this curve. The inscriptions were also new to them because, through participation, they gained new understanding. In other words, they re-negotiated their meaning.
These three episodes emphasize the unique attributes probing technologies afford in the science classroom. Indeed, with the focusing and reified effects of the probes, students instantaneously noticed some important concepts beyond the simple act of observation. In this case a teacher-centered dialogue transformed into a student-driven exploration. The more the students negotiate, the more meaningful learning they appropriate.

4. Lessons learned

This study proposes a participation framework to uncover the catalytic affordances of probing technologies in support of inquiry learning. We now turn to some implications of this work.

4.1. From computational to catalytic affordances

From the designers or manufacturers’ viewpoint, the affordances of the probing technologies are perceived mainly from a technological perspective. Probing technologies are regarded as real-time data acquisition collectors, the major purpose of which, in an inquiry-based learning context, is to enhance and accelerate the learning process. However, in elementary school, some practitioners argue that paying too much attention to the accuracy and real-time functions of the data does not inspire children very much (Chen & Jiang, 2004). Rather, they believe that science education in elementary school should be focused primarily upon the ontological aspect of scientific phenomena. For example, they think “What does humidity mean?” is a higher priority than determining ‘Is place A more humid than place B?’ It seems that these practitioners have their own perspectives on how a classroom is made effective and how that efficacy can be promoted with the support of technology.

In our study, we described how the computational power of probes is transformed. The computational power of the probe did play its role in successfully measuring the temperature of dynamic balance in an open system but, more importantly, the process of data-taking with short intervals (i.e., per second) provided students with higher data resolution with which they were able to make sense of the readings on a deeper level. The three episodes are not excerpted to represent a probe-centered, but rather a probe-supported activity. In other words, it is not our intent to demonstrate how powerful a tool the probe proved to be each episode; instead, we depict the probes as triggers for developing and sustaining a meaningful inquiry activity in the elementary classroom.

4.2. The interplay between the readings and the learners

Research on mobile technology (e.g., Roschelle, 2003; Sharple, 2002) is beginning to pay attention to coupling issues. Indeed, the existing enabling technology does not yet couple well with desirable social practices. Also in practice, wireless or internet discussion is not specific enough to describe what sorts of informatic coupling are desirable in mobile learning. It therefore seems that we need more empirical research on the separation of the roles of technology-based communication and non-technology-based interpersonal communication.

Based on our findings, it appears that the learning that occurred did not result directly from being mediated by technology. From a participation perspective (Lave & Wenger, 1991), classifying things can only captures surface features of the learning, not its fundamental processes. The duality of participation and reification is not just a distinction between people and things for what it means to be a person and what it means to be a thing both involves an interplay between the two. Through the negotiation of meaning, it is the interplay of participation and reification that makes people and things what they are (Wenger, 1998, p.70). In our study, students engaged in a probe-supported activity and generated readings from the probes. The reified readings have no meaning without a learner’s interpretation. On the other hand, in the process of re-negotiation, learners gained new understanding while the reified readings themselves remained unchanged. The readings and the learners cannot be transformed into each other, yet they transform each other. Therefore, designs for a probe-supported classroom practice must always be distributed between participation and reification – and its practical realization depends on how these two sides fit together. The three episodes in our study demonstrate how teacher and students make meaning of measurements as the result of coupling well between the enabling technology and desirable social practices.
5. Conclusions

The purpose of this study is to bridge the gap between the technological affordances perceived by the designers, and the educational affordances perceived by the practitioners. Starting with the concept of Wenger’s duality fundamental to the negotiation of meaning, which involved the interaction of two constituent processes, participation and reification; we illuminate the potentials of probes as catalysts for meaning making in inquiry learning. By proposing this pair of constituent processes for purposes of conceptualization and as an analytical framework for orchestrating classroom activities, we pinpoint a new understanding of the educational affordances of probing technologies in inquiry activities.

We are not discounting the contribution of computing and the simultaneous data-taking power of probes to student learning, but rather we are reacting to the failure of traditional perspectives to account for the inscriptions and reified objects and the individual interpretation through which engaged and meaning-making participation emerges.

References


Acknowledgements

This work was supported, in part, by National Science Counsel Grants NSC 94-2520-S-008-005 and NSC 94-2524-S-008-003.