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Authentic science activities in the primary level classroom: Investigating the effects of a data collection and analysis interface on primary level students' scientific literacy

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Summary. — This study explores the use of technology in instruction in a primary level classroom. Though many researchers and educators advocate for the incorporation of technology into science instruction, little is known about the effects of the implementation of various types of educational technology. Here, we investigate the effects of the incorporation of a data collection and analysis interface, the Spark^{TM}, on the scientific literacy of a group of second grade students in the United States. Treatment and control group comparisons indicate that the use of this technology during a lesson designed to investigate the relationships between physical variables increases the likelihood that students will represent their ideas graphically.

PACS `01.50.-i` – Educational aids.
PACS `01.50.F-` – Audio and visual aids.

1. – Introduction

In order to meet the demand for more highly qualified secondary math and science teachers, the University of Colorado at Boulder has adopted a new model for secondary math and science teacher preparation. This model, locally called CU Teach, was conceived at the University of Texas at Austin through collaboration by the Colleges of Natural Sciences and Education. Among the central tenets of this model of teacher preparation is a focus on the use of technology in the science classroom. Because it is clear that technology is underutilized and often used inappropriately in K-12 classrooms (Songer, 2007), more research is required with respect to what functions various technologies may serve in science education.

Though it may be widely held that the incorporation of technology into K-12 science education can enhance student learning, specific goals and benefits with respect to student learning are not well defined within the teacher preparation model that CU Teach is in the process of replicating. Likewise the literature in science education is lacking in empirical evidence that could indicate the effectiveness of the implementation of various technologies in the science classroom.

Fig. 1. – The uses of an arrow as an example of discourse of the scientific community.

2. – Background

The National Research Council (2001) defines scientific literacy as including both science content knowledge (declarative facts and conceptual knowledge) and reasoning knowledge (explaining with evidence and analyzing data) Taking a *knowledge as participation* approach to scientific literacy, we characterize the NRC's aspect of *reasoning knowledge* as *practice*. That is, the ways of knowing and doing science make up the *practices* in which members of the scientific community engage. The scientific community is one example of what Lave and Wenger call a *community of practice* which they identify as "an intrinsic condition for the existence of knowledge, not least because it provides the interpretive support necessary for making sense of its heritage" (Lave and Wenger, 1991, p. 98).

Engagement in the practices of the scientific community is engagement in the *discourse* of science. According to Kelly (2007, p. 443), "Science learning can be conceptualized as students coming to know how to use specialized language, given the constraints of particular social configurations and cultural practices." Only by acquiring the specialized language of science do we become acculturated into this particular community of practice.

Here we offer examples of discourse that are very likely taken for granted by members of the scientific community but may also function as barriers to the acculturation of students into scientific practices. Figure 1 shows three different uses for the arrow symbol, which is used to indicate a vector, an electric field, and a chemical reaction. This is one example of symbolic representation that is particular to members of a community of practice.

Graphical representation is another aspect of the discourse of science. Kahn and Thornton (2009) stress the importance of representations as "a bridge between the external physical phenomenon and the internal workings of the mind." Indeed graphical representations are one very important means by which scientists both mediate and communicate abstract ideas, relationships, and phenomena.

A wide array of technologies, from internet resources to hand held data collection devices, are available in K-12 classrooms in the United States. CU Teach has acquired handheld a set of data collection and analysis tools called the Spark$^{\text{TM}}$, a Pasco product. This technology is central to this study because it allows for real-time data collection and representation in the classroom. Figure 2 is a sample display from the Spark$^{\text{TM}}$.

Given the emphasis on the use of technology in science teacher preparation and science education, it appears both important and relevant to determine what role specific technologies play in the acquisition of scientific discourse. Specifically, we pose the following research question:

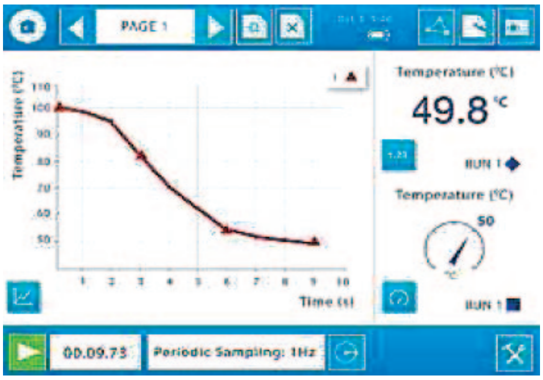

Fig. 2. – Spark$^{\mathrm{TM}}$ sample display.

Does using the Spark technology increase 2nd graders' likelihood of graphically representing their ideas?

To elaborate, we wish to know whether or not the use of the Spark can help students develop *representational competence*? And therefore encourage their participation in the discourse of science?

3. – Methods

The Sample

The setting for this study was a K-5 primary school in a Western town in the United States with a population of approximately 80,000 located near a large metropolitan area. The school has a very large proportion of students eligible for free and/or reduced lunch (used as an indicator of poverty in the U.S.) and a high enrollment of students from racial and ethnic groups traditionally underrepresented in science careers. Additionally, this school has been identified as low-performing as measured by state-mandated standardized test scores. The sample is a second grade class of 13 students taught by a teacher with three years of teaching experience.

The curricular context for the study was that the class had been working on graphing for approximately one week prior to the study. Students had been introduced to bar graphs and Cartesian graphing systems and had attempted to represent relationships such as height versus age with graphs.

Lesson Design

The lesson for this study was designed to help students understand the idea of relationships between physical quantities. The lesson was delivered jointly by both the researcher, a graduate student with a background in physics and five years of experience teaching high school physics, and the students' second grade teacher. The lesson began with an introduction to the concept of a relationship between two variables as well as a review of the relationships investigated earlier in the unit.

Table I. – *Relationships between variables.*

	Treatment	Control
Measure	Speed *vs.* Ramp Height	Distance *vs.* Ramp Height
Tool	Spark$^{\mathrm{TM}}$	Meter Stick
Variations	• Speed *vs.* surface texture • Speed *vs.* cylinder diameter	• Distance *vs.* surface texture • Distance *vs.* cylinder diameter

The introduction was followed by an investigation of the relationship between several variables. Students were introduced to the Spark$^{\mathrm{TM}}$ and the equipment that they would use to investigate the relationship between the variables outlined in table I.

Students used the apparatus shown in fig. 3 to investigate the effects of changing the variables *ramp height, surface texture*, and *cylinder diameter*. Students were instructed to: (1) make predictions about the relationships between each set of variables; (2) make changes to one variable to investigate the relationship between the variables; (3) summarize the results of the investigations with respect to their predictions.

Study Design

Students were randomly selected into two groups, treatment and control, with six students in each (one student was absent that day). The treatment group used the Spark$^{\mathrm{TM}}$

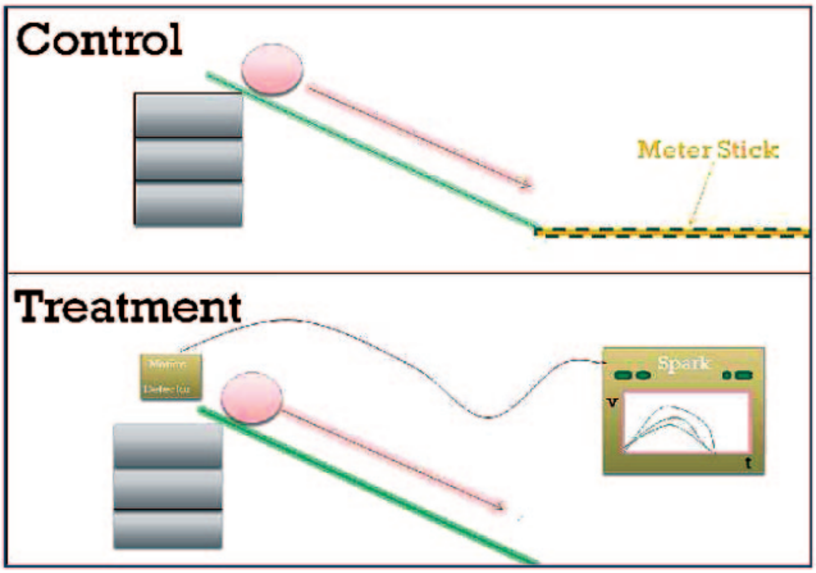

Fig. 3. – Experimental Apparatus.

technology and the control group used the meter sticks(¹). All other aspects of the investigation were identical.

Both groups were given a paper and pencil pre-assessment to gather evidence of student conceptions of the relationships between the two of the variables of interest. The pre-assessment was designed to elicit student representations of this relationship. The prompt was

> *"Show me the relationship between the height of a ramp and how fast the cylinder will go."*

After the investigation, both groups were given a paper and pencil post-assessment to gather evidence of student conceptions of the relationship between two novel variables. Novel variables were chosen in an attempt to determine the students' tendency to use a graphical representation to represent the relationship between two variables. The post-assessment prompt was

> *"Show me the relationship between how much it rains and the height of a tree."*

These variables were chosen based on the assumption that second graders would likely be familiar with the positive proportionality of this relationship regardless of social and cultural backgrounds. A commonly understood relationship would presumably reduce the probability that students' lack of knowledge of the relationship would confound any inferences drawn from the findings.

4. – Results

Types of Representations Elicited

The pre- and post-assessments elicited representations that can be grouped into three categories: *pictorial, bar-type, and Cartesian.* The pictorial representations were drawings of the relationship with no graphical representation, an example of which is shown in fig. 4. The Bar-type representation resembled a bar graph. An example of this type of representation is shown in fig. 5. Note that in fig. 5 the size of the tree increases as the size of the cloud increases

Finally, the Cartesian representation resembled a two variable relationship graphed on a Cartesian coordinate system. Figure 6 shows a students' representation of this relationship in the upper right corner.

Pre-Assessment Summary Findings

The pre-assessment prompt concerning speed and ramp height produced three key findings. The first finding was that all of the students drew the ramp. This was likely because a ramp was used to show students what one of the variables of interest, ramp height, was. The second finding was that although students' written text on the pre-assessment indicated that students likely held a correct conception of the relationship between ramp height and speed, none of the students represented this relationship graphically.

(¹) It should also be noted that at the completion of the study, the groups were switched so that the control group would have access to the technology portion of the lesson.

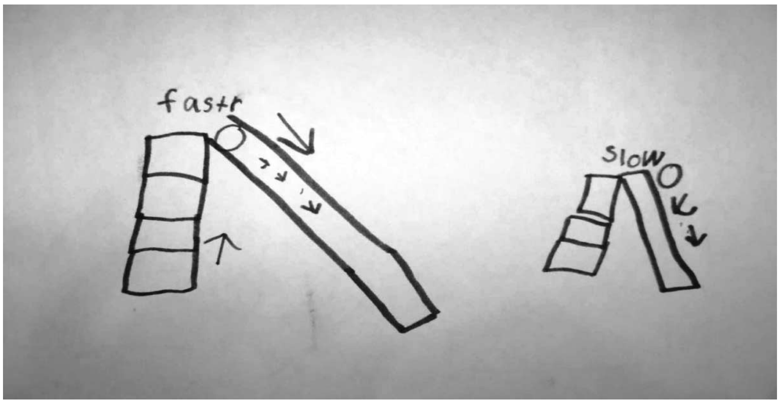

Fig. 4. – Pictorial representation.

The third finding from the pre-assessment data was that although many students' illustrations varied the ramp height, none represented the relationship between height and speed. That is, many students drew two ramps of different heights and explained that the higher ramp would result in a higher speed (as in fig. 4), but none of them represented this relationship with any type of graph.

Post-Assessment Summary Findings

Analysis of the post-assessment data indicated clear differences in the representations produced by the control and treatment groups. The control, or non-technology, group post-assessments indicated, through text written by the students, that the control group students very likely held correct conceptions of the relationship between the amount of rainfall and the height of a tree. Two of the six students in the control group also represented this relationship with a drawing categorized as bar-type.

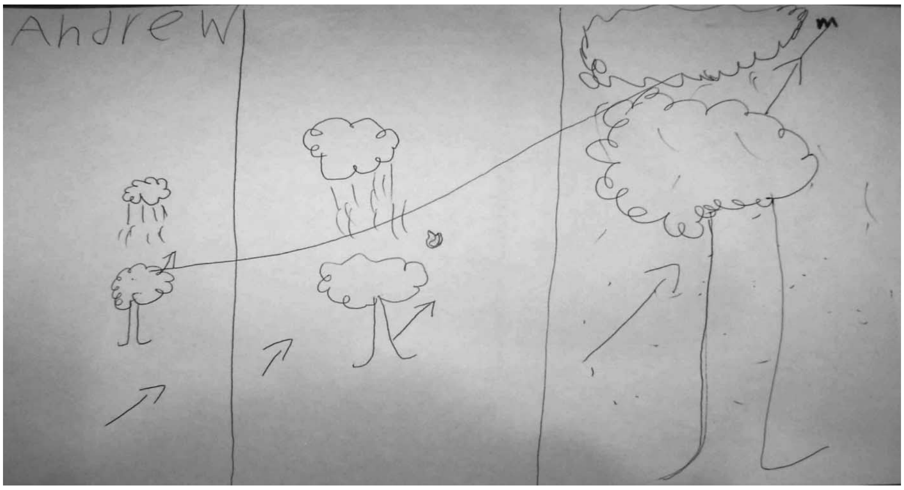

Fig. 5. – Bar-type representation.

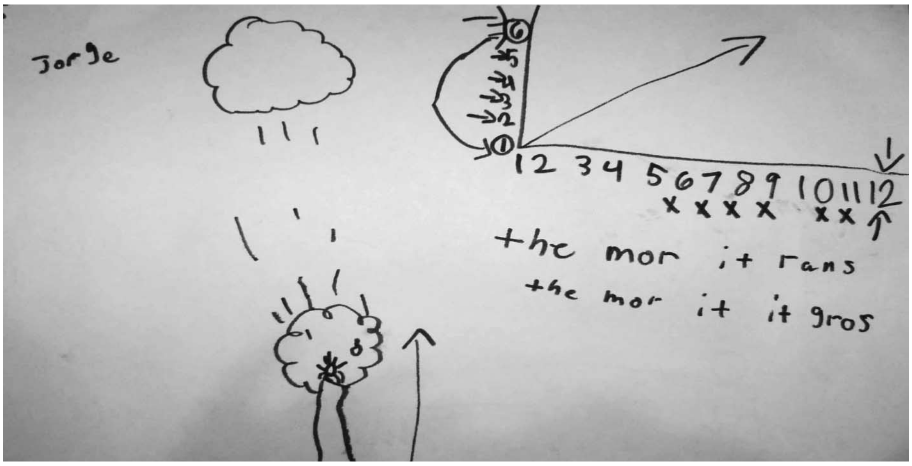

Fig. 6. – Cartesian representation.

The treatment, or Spark$^{\mathrm{TM}}$ technology, group post-assessments contained several key findings. Two of the six Spark$^{\mathrm{TM}}$ group students produced bar-type representations. Three of the six Spark$^{\mathrm{TM}}$ group students produced Cartesian representations. It is also probable that at least some of the Cartesian representations were reproductions of what the students saw on the Spark$^{\mathrm{TM}}$ display during the investigation, as in fig. 6.

These findings are summarized in fig. 7. Note that some of the students produced more than one type of representation on both the pre- and post-assessments, accounting for the fact that the total number of representation exceed the sample size ($N = 12$) for the study.

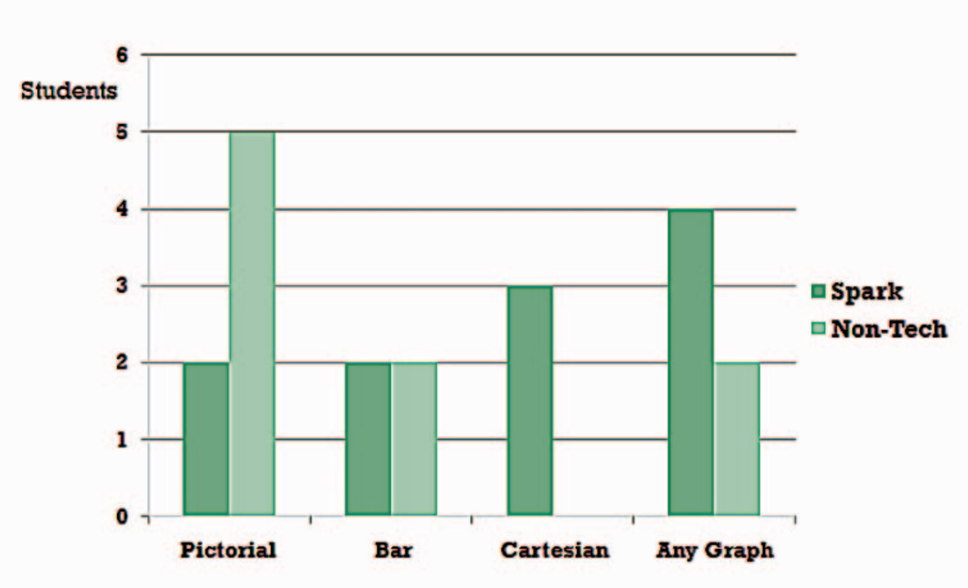

Fig. 7. – Summary of post-assessment findings.

5. – Conclusions

From the findings above, we conclude that the group using the Spark^{TM} technology was more likely to graphically represent their ideas on the post-assessment. Our results also indicate that the Spark^{TM} appeared to mediate students' representation in scientific discourse through graphical representation. In other words, the implementation of this educational technology appeared to enable students to communicate their ideas graphically, a key practice in the greater scientific community.

Another question that this study has addressed is whether or not second grade students are developmentally ready to participate in technology-based science learning. Our finding is that these students, who on average performed well below average on state-mandated standardized tests were eager and able to use the technology to perform this investigation. And though, as expected, there were varying levels of comfort with the technology, many students showed competence in navigation of the software interface beyond the expectations of the researchers.

Limitations of this quasi-experiment include the small sample size and the short duration of the study. The researchers also have questions about how much the teacher may have influenced performance on the administered assessments, however, we found that the teacher was enthusiastic about the incorporation of technology into her science curriculum.

Considerations for future research in this area include the consideration of a more sustained interaction with students and a preliminary phase in which students are familiarized with technology first (Kahn & Thornton, 2009). Consideration should be given to larger sample sizes that may include multiple grade levels. Other types of representation can be explored as well as research that focuses on teacher impact, particularly for those teachers who do not identify themselves as competent in science or science instruction.

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