

USING EYE-TRACKING TECHNOLOGY TO DETERMINE THE BEST USE OF VIDEO WITH PROSPECTIVE AND PRACTICING TEACHERS

Randolph A. Philipp and Judith T. Sowder

San Diego State University

We employed eye-tracking technology and individual interviews to investigate the differences among prospective elementary school teachers, practicing teachers, and mathematics educators as they observed and analyzed a videotape of a mathematics teaching episode involving a researcher and a fifth-grade student thinking about fractions. Results indicate that, relatively speaking, mathematics educators attend more closely to the student, teachers attend more closely to the interviewer, and prospective teachers attend more to the mathematical content than do the mathematics educators and teachers. We discuss these differences in terms of an expert-novice continuum and conclude by discussing implications for video use in teacher development and enhancement.

Videotapes are widely used in the preparation of prospective elementary school teachers and in the professional development of practicing teachers because they can provide rich contexts for considering issues of learning and teaching. Although widely used, there is little research to guide mathematics educators as they determine effective ways to incorporate the use of videotapes in teacher development and enhancement. At a more basic level, we know little about that to which people attend while viewing videotapes, or how one's background and training affect the sophistication with which one interprets videotapes. The purpose of this study was to address these issues by investigating differences among three groups; prospective elementary school teachers, practicing teachers, and mathematics educators, as they viewed a mathematics teaching episode involving a researcher and a fifth-grade student. We employed a methodology whereby reactions of participants were gauged through analysis of point-of-gaze and level of attention, measured and recorded with sophisticated eye-tracking technology. Additional data was collected through interviews of the participants. The study was part of a larger project aimed at helping prospective elementary teachers better understand the depth of knowledge necessary for teaching elementary school mathematics, and was intended to inform the development of early field experiences that would meet this goal.

Early studies contrasting expert and novice reasoning (e.g., Larkin, McDermott, P. Simon, & A. Simon, 1980) have indicated that experts are more likely than novices to focus on relevant problem features that lead them to qualitatively better conclusions. Experts have access to a large body of organized knowledge that can be quickly accessed and used to guide problem interpretation and solution. In a major study of the qualities exhibited by experts, Dreyfus and Dreyfus (1986) outlined five stages of development of expertise: Novices are relatively inflexible in their reasoning, advanced beginners have experiences that allow them to build cases that complement their book knowledge; the competent performer can articulate goals and

find means to achieve them; the proficient performer recognizes similarities between different situations and are more holistic in their approach to finding solutions; and experts share this holistic approach by responding effortlessly and appropriately to the situation encountered. Livingston and Borko (1990) noted that teaching mathematics has characteristics of expertise found in other domains, that is, expert and novice mathematics teachers differ in their perceptions, information processing, knowledge structures, and decision making. Indeed, in their own comparison of review lessons of expert and novice teachers, they found that explanations of expert teachers were conceptually linked and less procedural whereas teachers spent time coming to understand the content themselves.

The eye-tracking technology used in our study was developed by Marshall (1998). The information on eye movement is coupled with documentation of effortful cognitive activity that accompanies enlargement or dilation of the pupil. A large body of research has shown that “the pupil dilates on presentation of cognitive or affective stimuli; pupil dilation occurs with effortful information processing in many areas;...(and) the degree of dilation varies by individual and task (p. 2)”.

METHOD

Four prospective elementary teachers, four experienced elementary teachers, and two mathematics educators (with doctorates) participated in the study. Each viewed a videotape of a fifth-grader being interviewed by one of our project researchers (R). While watching, each was fitted with equipment used to track point of gaze and level of cognitive activity. Each individual then was taken to another room where she viewed the video again, this time with the white dot tracking her eye movements. During this second viewing, a researcher from our project, pausing frequently, interviewed the participant regarding her reactions to the videotape.

The videotape selected for this experiment was a 22-minute interview of a fifth grade girl who was said to be of “average mathematical ability.” The girl was poised, pleasant, and cooperative, and appeared to be quite comfortable with the videotaping process. The interview was taped in a studio that allowed a double screen to be shown on the final version of the video. The top of the screen showed the interviewer on the left, the girl on the right; the bottom half of the screen, called the “work area”, allowed simultaneous viewing of all paper work and manipulative use. The interview had three distinct parts. In the first part, Terry’s fraction knowledge was assessed. She was asked to circle the larger of pairs of fractions or to place an equal sign between two fractions if they were equal. Her knowledge of fractions was very weak. In the second part of the interview, R gave an explicit, procedurally oriented lesson on changing mixed numbers to improper fractions and back again. Terry learned the procedure but could not apply it later in the interview. The third part of the interview

was a conceptually based lesson during which R used Pattern Blocks¹ to begin to develop Terry's understanding of fractions.

Data collected. In addition to a videotape showing point-of-gaze for each participant, the eye-tracking staff provided us with (a) gaze traces of each individual during a 2-minute interval; (b) graphs indicating the percentage of time spent by each of the three groups looking at the interviewer, at the child being interviewed, and at the work area; and (c) estimates of the cognitive activity over 30-second intervals of each individual as she watched the video. To make sense of this data, we then divided the entire video into 30 second intervals, documented what was happening in the interview during each interval, and charted the level of cognitive functioning for each individual during that 30 second interval. We of course also had the transcribed interviews from the second viewing of the video.

RESULTS OF INTERVIEWS

During interviews we asked the same set of questions of each participant and they were encouraged to say anything about the video at any time.

Initial Reactions to the Videotape. The two mathematics educators both made initial comments on the structure of the interview, on expectations, and on technological aspects of the videotape. The teachers were very aware of the conceptual problems children have with fractions. They tried to understand Terry's thinking, but sometimes found it difficult to do so. All teachers commented on Terry's confidence and poise. T2 thought it was frightening that she was so confident in her misconceptions, "She spoke like a very confident child and she's obviously had much success in her schooling. You could just tell by the way she articulated her responses to R's requests." The prospective teachers had few comments to make before reviewing the video tape.

Reactions to Assessment Section. The mathematics educators were not surprised with Terry's poor performance, but they realized that her knowledge of fractions was very weak for a fifth grader. From their own experience, they thought that their own students (preservice teachers) would find some of the questions unfair. "(My preservice teachers) often pick up on the nuances of the interviewer's questions, and say, "That was a trick question" or "She didn't understand" and "It's not the student's fault". For the most part, teachers were not surprised by Terry's responses to the assessment questions. They thought Terry should know more about fractions than she did, but thought the errors she made were typical. The prospective teachers appeared to be at least somewhat surprised at how weak Terry's knowledge of fractions was, but they were careful not to fault her. One said that "It looked like she had not learned it yet, but considering if she had not learned that, she was doing pretty good" (although she was not doing well at all).

Reactions to Procedural Lesson. ME2 thought that the interview demonstrated the chasm between what teachers think they are teaching and what is actually being learned. ME1 found value in the fact that the interview showed how easily Terry picked up on the procedures without a clue as to what they meant, and that she held on to her misconceptions. Teachers reflected on the kind of teaching Terry had probably experienced. All commented on her lack of sense-making. One said “That it’s probably the kind of teaching that she’s had, what she’s comfortable with.” The teachers realized that Terry needed something concrete to help her understand fractions as quantities. Interviews of the prospective teachers indicated that they had particular ways of doing things that made it harder for them to understand Terry’s thinking. For example, PT3 said, “I’m trying to figure out why she would choose one-half because I’m so used to, well, I was converting it to decimals, like three-tenths was point three and one-half was point five.” There was also a tendency on the part of these four to excuse Terry for her weak knowledge base.

Reactions to Conceptual Lesson. ME2 recognized that Terry’s knowledge was still very fragile at the end of the lesson, and thought Terry was beginning to feel some conflict. “In fact, she called it *I’m pretending whether I know fractions or whether I don’t*. That is how she handles the conflict. Obviously she’s recognizing that her old way failed her.” ME1 did not think this lesson helped Terry see any connection between the blocks here and the procedures from the earlier lesson. Both educators also made comments about the use of manipulatives. “When I think about using the Pattern Blocks like that, I’m also aware of the ... I’m not convinced about what she really understands about fractions in terms of relating them to a whole other than a hexagon.”

Teachers were dismayed that even after her work with pattern blocks, Terry still responded that $\frac{1}{2}$ plus $\frac{1}{2}$ was less than one. “She wasn’t convinced even though they had done all that work (with blocks). Then when prompted to push forward, to visualize the pieces, she’s got something to grab onto but that one experience wasn’t enough to undo the damage.” They could see that she was struggling to accommodate the new and contradictory information she was being exposed to. T2 said “She has all her misconceptions now and she’s really struggling because R’s really shifted her paradigm a little bit but she’s still not there yet. She’s really in disequilibrium.” The teachers picked up on small things as telling. For example, T4 noticed that Terry never used the word ‘equal’ even though R did, and even though equality was a key concept in understanding fractions.

When asked for comments on the second lesson, the prospective teachers had little to say. One said “I think the blocks helped her to visualize and really understand.” She later said that “I think it was good that you allowed her to see things first and you didn’t contradict her and tell her ‘No that was wrong’ and let her see it for herself.”

Would it be helpful to show this video to preservice teachers? Both mathematics educators thought it would be valuable for preservice teachers, but they were cautious in talking about how it could be used. ME1 said “It is long. It’s something

that might be done over two weeks. . . For me, it raises some issues. It would allow me to talk about the whole variety of issues as well as the questioning.” The four teachers also felt that the videotape should be shared with prospective elementary teachers of mathematics. From T1 we heard, “Absolutely. I think it would be a great way to help them come to believe that there is a reason to explore concepts deeply before procedures,” and from T3: “They can have an idea as to how concept development happens and why that concrete part is so important.” Interestingly, T2 would show it to prospective teachers, but not to teachers in her own district because they would simply blame the teachers Terry had had. All four thought that the most important segment to show was the teaching with manipulatives. Prospective teachers who had been exposed to the use of manipulatives in their content class for teachers thought that the video should be shown to their peers. PT4’s statement was similar to those of PT2 and PT3: “I think it is a different approach to fractions and I happen to like it. I think it’s very cool. I would show the last part definitely.

Comparing the two lessons. Both mathematics educators found value in both the procedural and the conceptually oriented lesson. ME1 found it interesting that “She doesn’t seem uncomfortable or threatened by either lesson. That was a pretty mature kid, really. It was pretty evident that she was punting, but it seemed to me that she was able to keep a presence of mind, like ‘Am I going to be able to pull this one over on him? Maybe he won’t notice.’” Teachers were well aware of the difference in the manner in which Terry responded in the two lessons. “In the second segment (the procedural lesson), she didn’t seem to connect the numbers to any conceptual knowledge. She was able to see R’s procedure and use it. But I don’t think that she connected it to anything at all. In the third segment, again, she’s a bright girl; she caught on quickly. But she would need a lot of time with the manipulatives to really cement her knowledge and to realize that some of the things she had thought before weren’t true.” When the prospective teachers were asked about the differences in the two teaching sequences, their answers showed that they saw differences, but in a very vague ways. PT3 said “(The last lesson) was more conceptual, I guess, visual. The other one was more math, as long as you knew how to do your math.” They were asked which parts should be shown to prospective teachers. “I would show the last part definitely. I think the last part took a different approach because most everyone knows how to find the improper fractions.”

WHAT WE LEARNED FROM THE EYETRACKING DATA

The point-of-gaze information we have on a selected 2 minute segment confirms that the prospective teachers spent up to 75% of their time looking at the work area where the work was being shown. All four PTs looked at the work area (and sometimes at R or Terry) during almost every 5-second interval of this time period. These prospective teachers appeared to spend a good deal of their time mentally figuring out the answers to the problems given to Terry so that they would know if she was doing them correctly. “I think during this time I was probably trying to answer the questions in my head . . . and trying to see if it would match hers” (PT3). We

conjecture that part of the reason for this focus on the work area was that these individuals needed to first work out each problem given to Terry for themselves, and that they were not always able to do this quickly. The mathematics educators, on the other hand, spent about half the time looking at the work area, and practically no time looking at R. They were most interested in Terry and what she was doing. Teachers spent about 60% of their time looking at the work area and less time looking at R than did the prospective teachers.

The three groups had significantly different levels of cognitive functioning ($F(2,43) = 106.05$), and each group was significantly different from the other two. We were surprised to find that the mathematics educators had the lowest cognitive workload, followed by the prospective teachers, with the teachers registering the highest of the three groups. Upon reflection, and after analysing interview protocols, we speculate that the mathematics educators had the lowest cognitive workload because they found very little of surprise in the interview. Both had undertaken many such interviews themselves and viewed many interviews similar to this one. The teachers, on the other hand, have little opportunity to see one-on-one interviews with children. Also, they had developed expectations built on their own experiences. Each of the teachers has a strong interest in mathematics learning, and thus found this video interview interesting, causing them to reflect on what they were seeing at the same time they were viewing the interview. The prospective teachers lacked knowledge needed to interpret what was going on in the interview. They did, however, appear to attend to the problems being given to Terry, working them out, sometimes too late, so that they could try to make sense of her responses.

SUMMARY AND DISCUSSION

The university mathematics educators acted in ways one would expect experts to act. They responded effortlessly to the interview situation, as was evident in the cognitive workload graphs of each individual and in the composite graphs of the two individuals. Their level of cognitive functioning remained in the low range throughout. They agreed that the procedural lesson should confirm, for any viewer, the ineffectiveness of this type of instruction. Both were aware of the limitations of the Pattern Blocks as an instructional aid. Both commented on the interviewer's skill at questioning. Both were cautious about using the videotape with prospective teachers, commenting on the need to show pieces over a period of time and plan for appropriate discussion. In our discussions of this data, we realized that having the interviewer on the screen may have been an unnecessary distraction to others, who spent considerably more time looking at R.

The cognitive workload for the teachers was in the moderate to high range for the most part; higher than that of the professional mathematics educators. The teachers knew what an average fifth-grader should know about fractions, and this knowledge played out in the interviews. They recognized Terry's answers as typical of a student with poor understanding of fractions, and tried to understand the underlying

misconceptions Terry had, knowing that those misconceptions would need to be overcome for Terry to progress. But they expected the work with the Pattern Blocks to be more effective than it was, not realizing that the lesson was too brief to have lasting effects. We considered the teachers to be experts, but at a less advanced level than the professional mathematics educators. The teachers' access to their own knowledge of the mathematics involved in R's questions, their interest in Terry's responses (as compared to the greater interest of the prospective teachers in the problems posed rather than in responses), and their ability to understand and interpret the various parts of the interview were qualitatively different from those of the prospective teachers.

The prospective teachers did express some surprise at Terry's lack of understanding of fractions, but thought she had probably not learned about fractions yet. They had their own ways of solving the problems posed to Terry, and consequently found her answers hard to follow. The reactions of the prospective teachers were, in most respects, quite different from those of the teachers. They could accurately be classified as novices. As in the Livingstone and Borko study (1990), the prospective teachers had different knowledge structures and processed information differently. They spent a high percentage of the time looking at the work area, trying to understand the mathematical content of the questions rather than focusing on the verbal and nonverbal behavior of Terry.

What lessons did we learn from this study? We recognize that the teachers' reactions to the video interview were heavily influenced by their many years of experience in the classroom, working with students like Terry. They had knowledge of the mathematics appropriate for this grade level, and they had expectations that helped them evaluate Terry's mathematical knowledge. However, the data from this study led us to believe that there are experiences we can provide for prospective teachers that can help to refine their knowledge of what children know, change their expectations of what children should be able to do, and offer them new ways to observe and make sense of the children's responses to problems posed to them. This belief has guided our design of experiences that can have these effects. For example, we have prospective teachers who have just completed a highly-structured early field experience during which they, in pairs, interview individual elementary school students, then discuss, as a class, what they have learned. With another set of prospective teachers, we offered a seminar during which the prospective teachers viewed and discussed a carefully selected and sequenced set of videos of interviews with students. We believe that such experiences can change the knowledge structures of prospective teachers, the manner in which they process and interpret student answers, and make decisions about what next steps should be taken. They can move, in the words of Saber et al. (1991), from being novices to being advanced beginners, and thus will be more likely to succeed in teaching, and to take less time becoming experts. The major implication of what we learned from this study for our work with prospective elementary school teachers was that careful attention must be paid to how videos are used with prospective teachers. For them to benefit from

viewing a video in the manner intended, particular care must be given to the selection of the video and to the preparation for the viewing. But simply solving the mathematics problems beforehand may not be sufficient preparation for viewing a videotape if the children's solutions in the video do not model their thinking; prospective teachers need to anticipate the kinds of solutions children may provide. We also must pay attention to the tools used in a video, so that, for example, before showing a video of a child using a hundreds chart, it is necessary to acquaint them with the hundreds chart and even help them consider ways the chart might be used.

Observing a video twice is often helpful; the first time watching all the way through without considering any guiding questions and the second time watching with particular questions in mind. A purpose for watching videos needs to be understood, especially when if videos are assigned for homework. For example, in preparation for conducting an interview with a child, we often gave as an assignment watching a video of a child solving the same problem that they was posed to the child during the interview. In this case, we ask the prospective teachers to pay attention to particular aspects of the video such as the interviewer's prompts or wait-time or the children's use of language. Another advantage of observing video for homework is that the prospective teachers can rewatch a video as they need, which some do. Thus, the eye-tracking study has guided us in further project activities aimed at helping prospective teachers gain more expertise about children's thinking.

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