ORIGINAL ARTICLE

Using video to teach future teachers to learn from teaching

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Abstract Video is commonly used in teacher preparation programs. Teacher educators use video for various purposes. In this study, we describe the Learning to Learn from Mathematics Teaching project. In this project, video is used to develop pre-service teachers' (PSTs) orientations, knowledge and skills for analyzing and reflecting on mathematics teaching in ways that generate knowledge for improvement. We discuss the ways we have used video in a course aimed at developing elementary PSTs' abilities to learn from teaching. In addition, we report on a study that investigated PSTs' changes in lesson analysis abilities as a result of participating in the course.

1 Introduction

Video is commonly used in teacher preparation programs. Teacher educators use video for various purposes. In this paper, we describe a project in which video is used to teach future teachers to learn from teaching. The Learning to Learn from Mathematics Teaching project aims at providing pre-service teachers (PSTs) with knowledge and skills to analyze and reflect on mathematics teaching in ways that generate knowledge for improvement. The paper is structured into three parts. We first describe the project, the framework we use to assist PSTs in the analysis of teaching, its research base, and the sub-skills necessary to implement the framework in effective ways. We then discuss the different kinds of video we have used and the criteria for their selection. Finally, we summarize a

research study that investigated PST learning from a course focused on learning to learn from teaching.

2 The Learning to Learn from Mathematics Teaching project

The Learning to Learn from Mathematics Teaching project began in 2007 at the University of California, Irvine. This project seeks to study the role of a disciplined analysis of teaching for mathematics teacher preparation. It includes the development of frameworks to guide PSTs' analyses of classroom instruction (Santagata, Zannoni, & Stigler 2007) and of activities to assist PSTs in the development of a professional vision for the work of teaching (Sherin 2007). As part of this project, two courses that make extensive use of video were developed and have been tested in the context of an elementary and secondary teacher preparation program (Santagata & van Es 2010). Here, we focus on the course targeting pre-service elementary school teachers. This was implemented for three consecutive years. The authors of this study each taught one section of the course per year during the first quarter of the credential program. This manuscript reports on a study we have conducted during the second year of implementation involving a cohort of 30 PSTs.

The Learning to Learn from Mathematics Teaching project is driven by a practical consideration. Most teacher preparation programs only begin to prepare teachers for the complex work of teaching. Much learning occurs once teacher candidates enter the teaching profession. Although most programs' curriculum includes activities that foster PSTs' abilities to reflect on their practices and learn from teaching, ways in which reflection is described is often vague (Zeichner 1994). If we think an important goal for

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teacher preparation is to equip teachers with knowledge and skills to continue to learn and improve over time, we need to consider seriously what that knowledge and skills entail (Hiebert et al. 2007). Our premise is that we need to go beyond the teaching of general reflective practices and provide future teachers with opportunities to learn to reflect on teaching in disciplined and structured ways.

Building on research by others on teacher noticing (van Es and Sherin 2002), professional vision (Sherin 2007), productive reflection on teaching (Davis 2006), and on research on lesson analysis conducted by the first author (Santagata, Zannoni, & Stigler 2007; Santagata & Angelici 2010), we consider as fundamental skills for reflecting and learning from teaching the ability: (a) to attend to important elements of instruction, (b) to reason about these elements in integrated ways, and (c) to propose alternative instructional strategies. To assist teachers in developing these skills, we have designed a framework that we use to guide their analyses of teaching.

2.1 The Lesson Analysis Framework

The Lesson Analysis Framework (Santagata, Zannoni, & Stigler 2007; Santagata & Angelici 2010) includes elements of reflection on teaching typical of Lesson Study groups (Lewis and Tsuchida 1998). It also resembles and is informed by the work conducted by Hiebert, Morris, and Glass (2003) on lessons as experiments. The framework centers the analysis of teaching on classroom lessons, which represent natural units in the process of teaching (Hiebert et al. 2007; Santagata et al. 2007). It consists of a series of questions that guide teachers through a process of lesson analysis.

The first question asks PSTs to analyze the lesson learning goals: What are the main ideas that students are supposed to understand through this lesson? PSTs then move to the analysis of student learning by attending to the following questions: Did the students make progress toward the learning goals? What evidence do we have that the students made progress? What evidence do we have that students did not make progress? What evidence are we missing? Analyzing the particulars of student learning and understanding as evidenced in the lesson lead PSTs to the next question, focused on the impact of teachers' decisions on student learning: Which instructional strategies supported students' progress toward the learning goals and which did not? This sort of reasoning on teaching and learning is typical of expert teachers (Berliner 2001; Borko & Livingston 1989). It also integrates various elements of teaching (i.e., learners and learning, subject matter knowledge, assessment, and instruction) supporting what Davis (2006) calls "productive reflection." This process also assists in teaching in ways that are responsive to

student learning as recommended by reform efforts (National Council of Teachers of Mathematics 2000; Smith 1996).

Finally, building on the analysis of the cause–effect relationship between teaching and learning, PSTs are asked: what alternative strategies could the teacher use? How do you expect these strategies to impact on students' progress toward the lesson learning goals? If any evidence of student learning was missing, how could the teacher collect such evidence? The generation of alternatives is an important element of the framework because it serves as a link between reflection on practice and action on practice (van Es & Sherin 2002). Although this phase of the framework can be challenging for novices with a limited knowledge of teaching strategies, we believe it is important for PSTs to develop the habit of considering alternatives. A study by Kersting, Givvin, Sotelo, & Stigler (2010) found that more effective teachers were better at proposing alternative strategies to those observed in video clips than teachers who were not as effective in terms of student learning.

Figure 1 summarizes the main elements of the Lesson Analysis Framework.

2.2 Previous research on the use of the Lesson Analysis Framework

Previous research on the use of the Lesson Analysis Framework as a tool for developing PSTs' lesson analysis skills has provided promising results. Three studies were conducted with PSTs enrolled in a secondary teacher preparation program at an Italian university. The first two studies (Santagata, Zannoni, & Stigler 2007) included a pre-/post-test design and utilized a similar intervention. The second study replicated findings from the first. PSTs were introduced to the Lesson Analysis Framework and practiced using it with three videotaped lessons. Their ability to analyze teaching was measured prior to and on
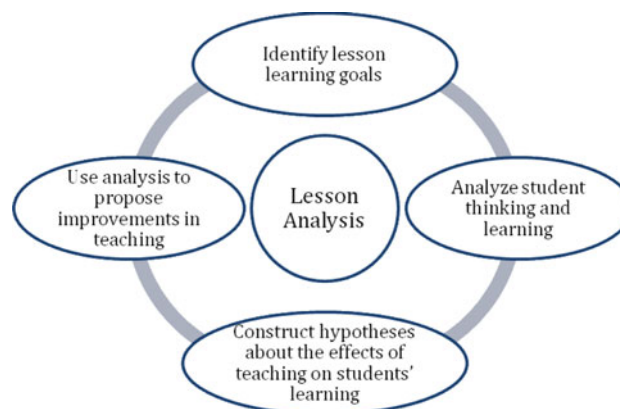

Fig. 1 Lesson Analysis Framework

completion of the intervention. PSTs were asked to watch a novel lesson (i.e., a lesson that was not included in the intervention), to choose three moments of the lesson they considered interesting, and to explain the reasons for their choices. PSTs' analysis abilities improved significantly over time on five dimensions: level of elaboration, focus on student learning, use of evidence from the video, mathematics-focused comments, and inclusion of alternative teaching strategies. A subsequent study (Santagata & Angelici 2010) included an experimental design. A group of PSTs who received an intervention based on the Lesson Analysis Framework was compared to a group of PSTs who were provided with an alternative framework: the Teaching Rating Framework. This asked them to rate separate elements of teaching on a five-point scale and to explain their ratings. The intervention utilized one videotaped lesson that both groups watched and responded to. Findings from this study included significant differences between the Lesson Analysis Framework and Teaching Rating Framework groups. Specifically, the Lesson Analysis Framework was found to assist PSTs in learning to reflect on teaching in more productive ways. Their comments became more integrated and they learned to use evidence from the video to support their evaluations of teaching. Although Lesson Analysis Framework PSTs did not have any practice evaluating instruction during the intervention, the kind of reflection in which they engaged during the intervention better prepared them to justify their evaluations of the novel lesson in the post-test. In addition, Lesson Analysis Framework participants' reflections on teaching tended to prompt them to consider more alternative instructional strategies.

The present paper summarizes a new study. This differs from the three studies described above in two fundamental ways. First, it is conducted with a sample of US PSTs, thus investigating lesson analysis skills and their improvement in a new context. Second, while in previous studies the interventions were relatively brief (i.e., 16 h in studies 1 and 2, and 4.5 h in study 3) and work with the Lesson Analysis Framework constituted the core of the interventions, in this study the intervention lasted 25 h and its structure was more complex and included various activities designed to develop necessary sub-skills for an effective implementation of the Lesson Analysis Framework. In the subsequent section, we will describe these sub-skills and the ways we have used video as a tool for teacher learning.

2.3 Lesson analysis orientations and sub-skills

Through multiple implementations of the "Learning to Learn from Mathematics Teaching" course, we have identified orientations and sub-skills necessary to effectively implement the Lesson Analysis Framework

(Santagata & van Es 2010). In this section, we describe these orientations and sub-skills and we reference other authors who have also identified them as important components of teacher dispositions and knowledge.

First, to be able to effectively implement the Lesson Analysis Framework, PSTs need to develop a set of orientations. They need to become aware of the importance and usefulness of a disciplined analysis of practice. They need to learn to appreciate the value of a teaching approach that builds on students' ideas and to come to a realization of the complexity of student thinking about mathematical ideas (Cohen 2004). Second, these orientations must be coupled with specific knowledge and analysis skills, the first of which is the ability to attend to what students are doing or saying in a lesson and to draw inferences or make hypotheses about their mathematical understanding (Carpenter, Fennema, Peterson, & Carey 1988; Ma 1999). PST must also have knowledge of strategies that assist in making students' thinking visible. This involves learning to identify and examine key routines such as effective questioning, design of open-ended mathematical problems, monitoring student work, leading a math discussion, and establishing a classroom discourse community (Chapin, O'Connor, & Anderson 2003; Hiebert & Wearne 1993; Hufferd-Ackles, Fuson, & Sherin 2004; Lampert 2001; Stein, Engle, Smith, & Hughes 2008; Stein, Smith, Henningsen, & Silver 2000). Use of the framework also requires the ability to reason about instructional strategies in terms of the extent to which they make student thinking visible and the ability to use evidence of student learning to reason about the effectiveness of teaching (Spitzer, Phelps, Beyers, Johnson, & Sieminski 2010). When reasoning about the impact of instructional decisions on student learning, PSTs need to be able to generalize the knowledge gained through the analysis of a particular teaching episode to more general hypotheses about teaching and learning that they can test again in future analyses or in their own teaching (Hiebert, Morris, Berk, & Jansen 2007).

Finally, planning and enactment skills are crucial to move PSTs from the analysis of the teaching of others to the analysis of their own teaching. The first skill is the ability to generate alternative strategies and justify them in terms of their potential impact on student learning. This skill can be practiced in the context of analyzing the teaching of others first and then applying to one's own teaching. This skill is at the core of the learning from teaching approach. To improve their own teaching, PSTs need to learn to think about alternative instructional decisions (Hiebert et al. 2007). The second and third skills are also necessary for PSTs to be able to apply the Lesson Analysis Framework to their own teaching: the ability to plan for teaching and to enact instructional practices, both of which make student thinking visible (Hiebert et al.

2007). Figure 2 summarizes the orientations, knowledge, and skills we hypothesize are necessary to analyze lessons effectively.

3 Using video to develop analysis skills

Video constituted the main artifact of practice we used to develop PSTs' analysis skills. Several authors have investigated the benefits of using video as a tool for PST learning. For brevity, we summarize here their main findings. Video has been found to promote elaborated reflection on teaching (Star & Strickland 2008; van Es & Sherin 2002; Wang & Hartley 2003). Videotaped lessons and interviews with students have been used effectively to focus PSTs' attention on student thinking (Franke, Carpenter, Levi, & Fennema 2001; Herrington et al. 1998; Jacobs, Lamb, & Philipp 2010; Santagata et al. 2007; Towers 1998; van Es & Sherin 2006). Finally, video cases have been used successfully to assist PSTs in learning classroom practices aligned with recent recommendations that otherwise they seldom have opportunities to observe during their fieldwork experiences (Barron & Goldman 1996; Carlson and Falk 1991; Merkley and Jacobi 1993; van Es & Sherin 2006).

3.1 Types of video

We have built on the body of literature summarized above to design video-based activities to be included in the "Learning to Learn from Mathematics Teaching" course. In this section, we will describe the different kinds of videos we used, the purposes they served (i.e., the sub-skills they were intended to support), and the types of activities in which they were incorporated.

3.1.1 Videos of interviews with individual children

At the beginning of the course, we used videos of interviews with individual students. We used two published resources: the video clips included in the book "Children's Mathematics: Cognitive Guided Instruction" by Carpenter et al. (1999) and the "Integrating Mathematics and Pedagogy" video clips by Philipp and Cabral (2005).

The main purpose of using these clips was to develop PSTs' appreciation of the complexity of students' mathematical thinking and ability, to attend to students, and to draw inferences about their mathematical understanding. Although these orientation and abilities can be developed also in the context of the analysis of a classroom lesson, interviews with individual students allow novices to focus on student thinking without too many distractions typical of more complex classroom environments. We thus used these clips at the beginning of the course and then transitioned to the analysis of students' thinking as portrayed in videos of classroom lessons.

In addition, the IMAP clips were used to introduce key mathematical ideas related to fractions before PSTs were asked to analyze the video of a fraction lesson. We thought that using clips that show children's misconceptions might be a good way to address similar conceptions in PSTs (Philipp and Cabral 2005). We, as many others involved in elementary teacher preparation, had to deal with PSTs' limited mathematical understanding (Ball 1990; Ma 1999). The first clip illustrated the role of the unit in fraction problems. We believed that for some PSTs, this would be the first time they realized that the unit of reference when working with fractions is crucial. The second IMAP clip showed how understanding of the meaning of fractions allowed a second grader to solve a fraction problem involving adding unlike fractions she had never seen

Fig. 2 Orientations and analysis, planning, and enactment abilities
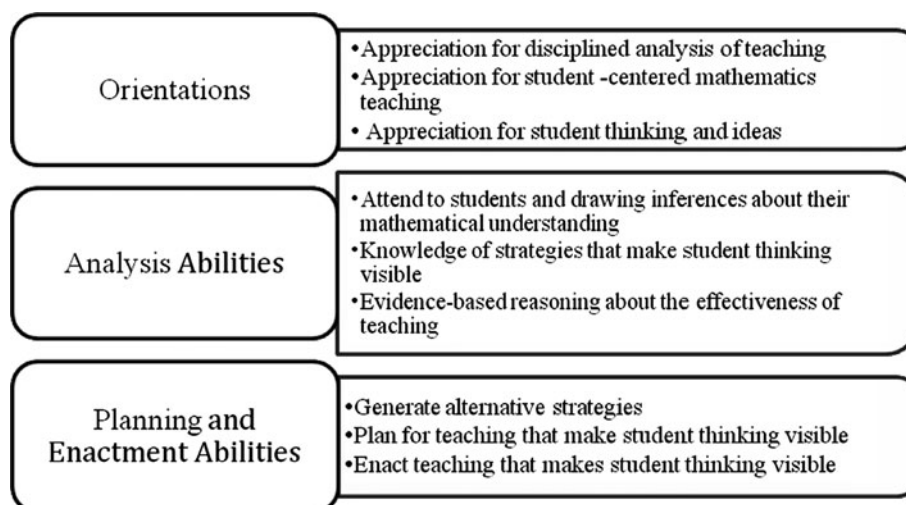
before. The third IMAP clip provided a rationale for teaching fractions for understanding: a fraction assessment and teacher interview with a student in a high-achieving school showed the student's poor understanding of the concepts of fraction.

3.1.2 Videos of classroom lessons

Videos of classroom lessons were used to provide opportunities for PSTs to apply the Lesson Analysis Framework to lessons that they could all watch together, pause, and re-watch if necessary. Videos portrayed practices that research has found to be effective for student learning (Hiebert & Grouws 2007). They provided various opportunities to observe students engaged in problem solving, explaining their thinking and sharing their solution methods, and teachers eliciting and building on students' ideas and making explicit connections between different visual representations and between concepts and procedures. Thus, lesson videos also served the purpose of modeling effective practices. Yet, lesson videos were not introduced as perfect lessons and included teaching strategies that could be improved. Cross-cultural lesson examples were also included as discussed in Table 1.

With reference to the fraction lesson mentioned in Table 1, PSTs were first asked to solve the problem of the lesson individually and to share their solutions in a class discussion format. During this discussion, a few PSTs who solved the problem differently were asked to present their solution methods on the board. These activities mirrored those that the teacher had planned for her students in the videotaped lesson. On completion of these activities, PSTs answered a few questions about the mathematical ideas considered in the problem, the variety of solution strategies possible, and the quality of the problem that allowed for making student thinking visible. They then moved on to the analysis of the lesson, by considering both specific strategies the teacher used and specific student ideas and difficulties. To facilitate the analysis of the lesson, the viewing was segmented into eight clips, each ranging from 1 to 4 min. Together, the clips showed key parts of the lesson in chronological order. This gave PSTs a good overview of the lesson as a whole. A series of questions, summarized in Table 1, guided the viewing of the clips and the discussion.

These video-based questions were followed by the analysis of work samples the students had produced from the lesson. Each work sample included two pieces of evidence, student work on the main problem featured in the video and on a problem that was posed at the end of the lesson. Again, PSTs' analysis was guided by questions (summarized in Table 1). On conclusion of the video and student work sample analyses, PSTs were asked to discuss the effectiveness of the lesson, based on the evidence of student learning that was presented, and to consider alternative teaching strategies and their potential impact on student learning.

3.1.3 Pre-service teachers' videos

Video was also used for self-reflection and analysis. PSTs worked on two assignments that required them to videotape themselves. In the first assignment, they were asked to design in grade-level groups three or four problems around a key mathematical idea and to videotape an interview with a student who was asked to solve these problems. Once the interview was completed, PSTs transcribed it (including descriptions of the child's non-verbal behavior) and reflected on the interview process. Although transcribing the exchange was time consuming, we felt it was essential in providing PSTs with concrete evidence of student understanding. In addition, the transcribing process forced them to attend to the details of student thinking. Analysis prompts are summarized in Table 1.

With the second assignment, we pushed teaching and analysis abilities a step forward. PSTs were required to work in their grade-level groups and to plan for a half-hour problem-based lesson involving four or five students from their fieldwork placement class. Each PST then taught the lesson, transcribed the videotape, and completed a written reflection. Both the planning and reflection tasks were highly scaffolded through a series of detailed questions that asked PSTs to anticipate students' solution methods and questions they would use during each part of their lesson and to reflect on the effectiveness of their teaching by quoting evidence of students' learning from the transcript and from samples of student work (see Table 1 for a summary of these prompts).

3.1.4 Pre-service teacher selected videos

At two points during the course, PSTs were given group tasks to locate videos on the Internet that showed examples of two teaching practices discussed in the course: strategies for making student thinking visible and effective questioning. Our purpose was twofold. First, we wanted to engage PSTs in the active task of locating videos themselves. Second, we used the tasks as formative assessments to determine whether PSTs had a shared understanding of what those practices looked like.

3.2 Video selection criteria

While purpose was the main factor, we also took into account the following three criteria when choosing video for the course: (1) the mathematics portrayed, (2) teaching

Table 1 Summary of video selection, orientations, knowledge and skills supported, and guidance provided

Orientations, knowledge, and skills	Video selections	Task or guiding questions
Orientations and analysis abilities		
Appreciation for student thinking and ideas	CGI individual student clips (Carpenter et al. 1999)	*Individual reflection and small group discussion*: what did you notice? What type of problem was shown? How did the student solve the problem? Explain the student's strategy. What might have been a more or less sophisticated strategy?
Attending to students and drawing inferences about their mathematical understanding		
		Group assignment: present to the class individual CGI clips (addition/subtraction and multiplication/division) and an analysis of each clip
Knowledge of strategies that make student thinking visible	CGI classroom lesson clips (Carpenter et al. 1999)	*Individual reflection and group discussion*: what type of questions does the teacher ask?
Knowledge of strategies that make student thinking visible	IMAP clips: introduction to fractions (Philipp & Cabral 2005)	*Group discussion*: review of key mathematical ideas before analysis of classroom lesson
Appreciation for student thinking and ideas	Fraction lesson (Algebra Learning for All Projects, Santagata 2009)	*Individual student reflection and group discussion. Prior to viewing video*:
Attending to students and drawing inferences about their mathematical understanding		• Solve lesson problem
		• What are key concepts students need to understand to solve this problem? What are some different strategies that can be used to solve this problem? What elements of this problem make it a good problem for seeing student thinking?
Evidence-based reasoning about the effectiveness of teaching		
Appreciation for student centered mathematics teaching		*While viewing video* (*guiding questions posed with each selected video segment*)
		• What do you notice about the way Ms. Thompson introduces the problem? What questions does Ms. Thompson ask the students? Why do you think she chose those questions?
		• What is important about this part of the lesson? What strategies did this teacher use to make student thinking visible?
		• Describe the students' reasoning in this clip. Describe the difficulties students have with material provided by the teacher. What concepts are students struggling with? What concepts do students understand?
		After viewing the video
		• Analysis of student work samples:
		What does each student understand and/or does not understand? Does the student work completed at the beginning and at the end of the lesson show progress toward the lesson learning goals?
		• Lesson debrief:
		What evidence do you have from the video and the student work that students made progress toward the learning goals? What evidence is missing? How could this lesson be improved?
Knowledge of strategies that make student thinking visible	Pre-service teachers-selected videos	*Group assignment*: locate video examples on the Web that make student thinking visible and share with class
	Pre-service teachers-selected videos	*Group assignment*: locate video examples on the Web that include use of teacher questioning and share with class
Evidence-based reasoning about the effectiveness of teaching	US geometry lesson (Stigler, Fernandez, & Yoshida 1996)	*Individual reflection and group discussion:*
		• Identify learning goals
		• Analysis of student learning
		• Proposing alternatives
	Japan geometry lesson (Stigler, Fernandez, & Yoshida 1996)	Watch video as a group and discuss differences between Japan and US lessons

Table 1 continued

Orientations, knowledge, and skills	Video selections	Task or guiding questions
Orientations, and planning and enactment abilities		
Generate alternative strategies	Video of interview of pre-service teachers conducted with individual student	*Individual assignment: interview a student and analyze his/her thinking*
Plan for teaching that makes student thinking visible		• *Pre-interview*: briefly describe the student. Write three or four problems you will give the student. Predict the strategies the student may use and questions you will need to ask to make the strategies explicit
Enact teaching that makes student thinking visible		• *Interview*: transcribe what is said by the teacher and student. Describe anything the student *does* to solve the problem
		• *Analysis*: explain student response and answer. Discuss things that are still unclear by making hypothesis on student thinking. Propose alternative questions you could have asked to make student's thinking more visible
	Video of lesson pre-service teachers taught to a small group of students	*Small group assignment: facilitate a small group discussion*
		• *Planning*: choose a problem, anticipate student thinking, setting up the problem, monitoring student work, launching the discussion, orchestrating the discussion, concluding the discussion
		• *Small group discussion*: videotape and transcribe the discussion. Include a description of what students *do* as they solve the problem
		• *Analysis*: analyzing setup, monitoring of student work, launching, orchestrating, and concluding the discussion

that makes student thinking visible, and (3) the background of the teacher and students portrayed.

In terms of mathematics, we structured the course around two key mathematical topics in the elementary school mathematics curriculum: number sense and operations, and fractions. While the course did not aim specifically at improving PSTs' mathematical knowledge, the mathematics was always at the forefront. Thus, we decided to focus on key content areas that we knew were emphasized in the mathematics methods course PSTs attended.

Another criterion we used, similarly to Sherin, Linsenmeier, and van Es (2009), was to find video that portrayed teaching, which made student thinking visible. We thus choose videos that included clear audio of teacher–student interactions or of interactions among students, or clear images of student work.

Finally, we purposefully chose video that portrayed teachers and students from a variety of SES and ethnic backgrounds, so the PSTs would not assume that certain kind of teaching was possible only in certain contexts.

As we used the videos in the context of the course, we faced two issues that were worth noticing. These are: (1) the necessity to couple video to live observations, and (2) the distance that PSTs may feel between their teaching ability and the ability of the teachers portrayed in the videos.

PSTs did not always find working with video a pleasant activity. Discussions of this issue with them revealed that, although video provides a window into the reality of classrooms, the distance between that reality and the observer makes those instances of teaching and learning not as believable as live observations. This was true though we carefully chose, as suggested by many (Brophy 2004; Merseth 1996), unedited and authentic video specifically to avoid the artificiality that edited or staged video may carry. Particularly for those PSTs whose fieldwork experiences did not provide opportunities to observe mathematics teaching for understanding, the videos we showed were the only occasions in which they could see images of that kind of teaching. Thus, we agreed that we needed to find ways to bring the videos to life.

We included in the course a field trip that provided PSTs with the opportunities to see for themselves (instead of through a camera lens) how teachers can make student thinking visible and how students can engage in mathematical reasoning during a mathematics lesson.

Second, engaging with the videos was for some PSTs challenging, because they felt distant from the videotaped teacher. Specifically, although they found very valuable mathematics teaching that makes student learning visible and builds on students' thinking, they reasoned that the teachers in the videos were too experienced and their practices too far from what they were able to accomplish as novices. This issue was addressed in the subsequent implementation by including in the course videos of beginning teachers, who graduated from our program.

4 The study

4.1 Study aims and participants

As mentioned in Sect. 2, we consider as important the following elements of teachers' ability to analyze teaching: (1) to attend to important elements of teaching, (2) to reason about teaching in ways that generate knowledge for improvement, and (3) to propose alternative instructional strategies (Santagata & Angelici 2010; Santagata, Zannoni, & Stigler 2007; Sherin 2007; van Es and Sherin 2002). Thus, one of the goals of the Learning to Learn from Mathematics Teaching project is to investigate empirically PSTs' acquisition of these abilities. The study summarized here focused on changes in PSTs' analysis abilities from the beginning to the completion of the course.

Participants included 30 PSTs enrolled in a fifth year, post-baccalaureate elementary teacher preparation program. The course was offered during the first quarter of the program and was taught by the second author, while the first served as the researcher. Three PSTs dropped out of the program during the first quarter; we thus have complete data for 27 PSTs.

4.2 Methods

4.2.1 Pre- and post-measure

To measure PSTs' changes in their ability to analyze teaching, a video-based analysis task was designed that required PSTs to watch a videotaped lesson and write an analysis of it before and on completion of the course. The video portrayed a first-grade lesson on place value that was edited to include only the main parts of the lesson. The video lasted 16 min. PSTs were given the following prompt:

> Write (1) a description of the lesson, and (2) a commentary. Write your description for someone who did not have a chance to see the video and would like to know what the lesson was about and what happened. In your commentary, discuss things that you thought were interesting in terms of student learning of the content and teaching strategies. *You may watch the video multiple times.*

The prompt was designed to include the first two processes that constitute the teachers' ability to notice classroom events: (1) attending to important elements of teaching, and (2) reasoning about teaching in ways that generate knowledge for improvement (van Es & Sherin 2002). The first part of the task (i.e., the description) was intended to measure PSTs' ability to attend to the details of teacher's strategies and decisions, and of students' learning

during a classroom lesson. The second part (i.e., commentary) was designed to measure PSTs' ability to reason about teaching by reflecting on it in an integrated manner. Specifically, we were interested in capturing whether PSTs were able to reason about the effect of specific teaching strategies on student progress toward the lesson learning goal. In other words, the task was designed to measure PSTs' abilities to reflect on teaching in ways that generated knowledge for improvement. Through the analysis of strategies that assisted students in achieving the goal of the lesson, as well as strategies that were not successful and thus needed to be improved or changed, PSTs would learn something about teaching and learning that they could take with them. Such a process of analysis has been defined by Davis (2006) as "productive reflection" on teaching.

Prior to the intervention, PSTs completed the task independently at home and were allowed to watch the video multiple times. On completion of the intervention, PSTs were asked to complete the task at the university computer laboratory. Each of them had a computer available and was not given a time limit. This choice was made because the administration of this measure coincided with the end of the quarter, when many final assignments were due for other courses, and we were concerned that PSTs would not spend sufficient time on the task if a separate and protected time was not structured for them to do so.

4.2.2 Coding categories

A sub-sample of nine pre- and post-analyses was selected to identify features of the analyses that varied across individual PSTs and that distinguished pre- and post-analyses. Both a bottom-up and top-down approach were used to identify these features. Previous research on teacher noticing (van Es & Sherin 2002), as well as studies conducted by the first author with similar tasks (Santagata, Zannoni, & Stigler 2007; Santagata & Angelici 2010), guided the review of the PSTs' analyses. At the same time, the researcher made an explicit effort to keep her mind open to the identification of new features and asked researcher assistants to review the analyses and to note the features that were salient to them. Once coding categories were finalized, all analyses were de-identified so that both the PSTs who wrote the analysis and the time of completion were unknown to coders. Two research assistants independently coded all analyses for quality of description, quality of commentaries, and number of alternative instructional strategies proposed. Satisfactory inter-rater reliability ($\geq$.80) was reached for all codes. In case of disagreement, the researcher reviewed the scoring and made a final decision.

When describing the lesson, PSTs identified four main lesson parts. These included: (1) calendar activity, (2) place

value mat activity, (3) activity centers, and (4) lesson conclusion.

Some analyses broke down further the part of the video that portrayed the activity centers by describing each center independently. We built on this partitioning of the lesson to structure the coding process. For each of the seven parts of the lesson, PSTs' analyses were assigned a score that reflected the ability to describe: (1) the activity in which teacher and students were engaged, (2) the teacher's actions, and (3) the students' actions. A score of 0 was assigned when a particular element was not included in the description. A score of 1 was assigned when the element was included, but the description was rather vague, and a score of 2 was assigned when the description was detailed. The same coding process was followed for pre- and post-intervention analyses and each PST received a maximum score of 14 for the description of each element (i.e., activities, teacher's action, and students' actions) across different parts of the lesson. Sample descriptions are included in the following.

Level 1 (vague description)

To practice this skill, students were separated into different work stations. The stations were: the measurement station, inventory station, mystery number station, and race to build station. Each area practiced place values in a different way to show students how the lesson could be adapted.

Level 2 (detailed description)

The first center encourages the students to pair up and measure each other using Unifix cubes. These interlocking cubes enable the students to snap together enough cubes to measure a friend yet also allow students to separate the cubes for easier counting and grouping. After measuring, the students count and divide the bundles of "10" and individual "1's" used in measuring their partner. The value is then recorded on a sheet that asks the students amount of bundles and the amount of singles. Finally, they are asked to combine the number in the ones column and the tens column for a total measurement. The next center focuses on an inventory of buttons, beads and other small objects. Students were prompted to group the objects in bundles of 10 and "singles". Just as in the measurement exercise they recorded the number of "bundles" and "singles" and then combined them for a final answer. The third center, the "mystery number", is led by a student teacher. He places a red square around a double digit number on a chart and asks the students to illustrate the number using Base 10 Blocks and place value "mat". They are to sepa-

rate the number into tens and ones. The final center is a timed competition that challenges the children to build the longest "train" out of Unifix cubes. When the time is up, they are reminded to break their "train" into bundles of "10" and "singles".

Different parts of lessons were also considered when coding for the quality of commentaries. In this case, PSTs did not comment on each center separately, thus only four lesson parts were considered: (1) calendar activity, (2) place value mat activity, (3) activity centers, and (4) conclusions. Commentaries related to each part of the lesson were assigned a score of 0 if that part was not included in the commentary, a score of 1 if the commentary was merely descriptive, a score of 2 if it elaborated on what had been observed in the lesson, but considered different elements of teaching as distinct, and a score of 3 if it elaborated on and integrated various elements of teaching. Pre- and post-intervention analyses were coded following the same procedure, and PSTs received a maximum score of 12 for quality of commentary across different parts of the lesson. The following are sample commentaries of different quality:

Level 1 (descriptive)

She used a large piece of blue construction paper for the place value mat and then put a smaller yellow paper on the left side so the yellow side was the TENS place and the blue on the right side was the Ones place.

Level 2 (separate elements)

Another aspect of the lesson I liked was that the teacher made the students engage in the lesson right away by using the ages of two students in their initial exploration of place value. I also liked how the teacher tested the alertness of the students by asking them if she had placed enough blocks on the place value chart when she had only placed four and she needed to have placed six. This keeps the students on their toes which I thought was an excellent way for a teacher to check on the engagement of the students.

Level 3 (integrated)

Ms. V. uses a place value chart to expand her students thinking. She asks an important question to the student to show the student's thinking to the class. She asks "why did you start counting with ten?" and she shares with the class the idea that if there is a strip in the tens column of the chart it is not necessary to start counting from one. Looking at the chart on the board, the student starts with ten and counts eleven, twelve
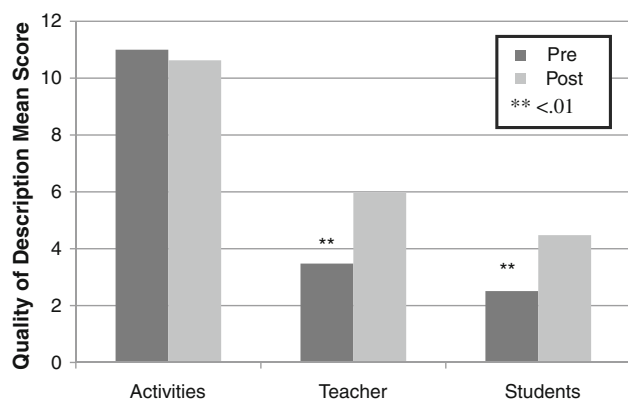
Fig. 3 Changes in quality of description from pre- to post-intervention

and thirteen. The student has clearly recognized that the long strip of paper in the tens column in equal to ten. Therefore the three remaining squares of paper in the ones column become eleven, twelve and thirteen. Her question to this student allows the rest of the class to tune in on the student thinking.

Although not explicitly prompted to consider alternative instructional strategies, some PSTs included them in their commentary. We hoped that this would happen, since we believe the consideration of alternatives to be an important process in the analysis of teaching and have included discussion of alternatives in several course activities. Commentaries were thus coded for the number of alternatives they included. For descriptive purposes only, alternatives were also categorized into types to provide information on the kinds of instructional strategies PSTs thought would be more effective than the ones used by the teacher in the videotaped lesson.

4.3 Results and discussion

4.3.1 Quality of description

PSTs' ability to describe the activities of the lesson did not change over time. Pre-intervention analyses included already quite detailed descriptions of the lesson activities (pre-intervention $M = 11.00$, SD 1.86; post-intervention $M = 10.63$, SD 1.94; $t(26) = 1.546$, $p = .134$). Activities tend to dominate what happens in the lesson and are easily identifiable. This finding is also somewhat not surprising when considering that previous studies have found that teachers tend to think about and plan lessons through activities (Shavelson & Stern 1981; Wiggins & McTighe 1998).

PSTs' ability to describe the teacher's and students' actions instead improved significantly over time. Descriptions became more detailed and specific (teachers' actions: pre-intervention, $M = 3.48$, SD 2.19; post-intervention,
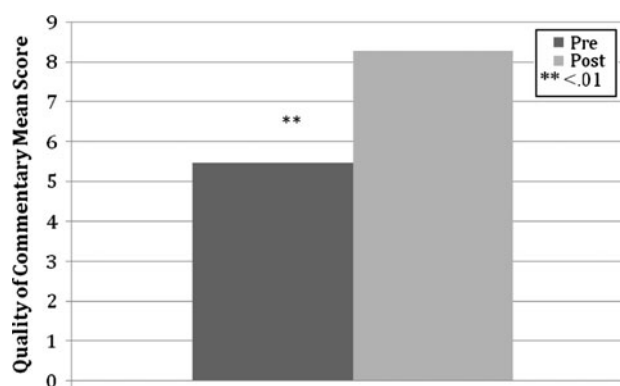

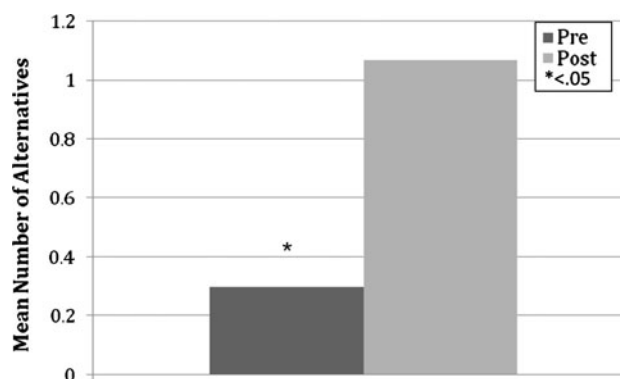**Fig. 4** Changes in quality of commentary from pre- to post-intervention

Fig. 5 Changes in number of alternative teaching strategies proposed from pre- to post-intervention

$M = 5.96$, SD 2.47; $t(26) = -5.355$, $p = .000$. Students' actions: pre-intervention, $M = 2.51$, SD 1.97; post-intervention, $M = 4.48$, SD 2.47; $t(26) = -3.31$, $p = .003$). Figure 3 summarizes this finding. As described above, various video-based course activities were targeted at developing PSTs' ability to attend to the details of student thinking and to strategies teachers can use to make student thinking visible. Thus, this finding supports the use of those activities to improve PSTs' noticing skills. This finding is also in line with research conducted by van Es and Sherin in the context of teacher video clubs. These authors found that teachers' descriptions of students' and teachers' actions became more specific as a result of participation in video-centered teacher discussions (van Es & Sherin 2008, 2010).

4.3.2 Quality of commentary

PSTs' ability to comment and reason about teaching improved significantly over time. Commentaries became more elaborate and more integrated (pre-intervention, $M = 5.48$, SD 1.95; post-intervention, $M = 8.30$, SD 2.49; $t(26) = -3.923$, $p = .000$). The course video-based activities supported PST learning in that in the post-

analyses, they more often reasoned about teaching by considering the impact of teacher's decisions on student mathematics learning. Figure 4 summarizes this finding.

4.3.3 Alternative teaching strategies

PSTs' ability to propose alternative instructional activities, as measured by the number of alternatives they proposed, improved significantly over time (pre-intervention, $M = .30$, SD .61; post-intervention, $M = 1.07$, SD 1.57; $t(26) = -2.487$, $p = .020$). Figure 5 summarizes this finding. Not all participants included alternatives in their commentary: 6 out of 27 PSTs proposed alternatives in their initial analyses and 14 did after the intervention. Thus, approximately 50% of participants thought about different ways to teach the lesson after the intervention, while the other 50% did not.

To be able to propose alternatives, PSTs first need to identify a problem with student learning as portrayed in the video. They then need to access their knowledge of teaching strategies to make the case that a strategy different from the one the teacher used in the video would be more effective. Although the course included several video-based activities that prompted PSTs to discuss alternatives (and, as we mentioned above, we think it is important for novice teachers to begin to think about them), the limited teaching experience most likely restricted access to these alternative strategies. In addition, because PSTs were not explicitly asked to provide alternatives, it is also possible that they did not think it was appropriate to include them in their analyses.

On the other hand, a categorization of the alternatives into types revealed that the course had an impact on the ways that PSTs thought about effective strategies. Specifically, PSTs proposed that the teacher elicit more explanations of student thinking (an alternative proposed once in the pre- and 6 times in the post-intervention analyses), improve her formative assessment of student understanding (3 times in the pre- and 11 times in the post-intervention), and make more explicit connections to underlying concepts (3 times in the pre- and 11 times in the post-intervention). These were all strategies discussed in the course and portrayed in the course videos. An additional alternative proposed was for the teacher to address a student's error more directly, but this was proposed only twice in the pre- and once in the post-intervention.

5 Conclusions

In this study, we have discussed the types of videos and video-based activities used in a teacher preparation course that aimed at developing PSTs' abilities to analyze and learn from mathematics teaching. This work builds on previous research conducted with Italian secondary PSTs and extends it to elementary PSTs in the USA. Analyses of PSTs' changes in analysis abilities, from the beginning to the completion of the course, overall replicated findings from the previous Italian studies (Santagata, Zannoni, & Stigler 2007; Santagata & Angelici 2010).

Video-based activities were found to support PSTs' learning to attend to the details of student thinking and of teachers' instructional moves that make student thinking visible. Video-based activities also supported PSTs' learning to reason about teaching in an integrated way by considering the impact of the teacher's decisions on student learning. Finally, although this finding was restricted to half of the participants, video-based activities also improved PSTs' ability to spontaneously propose alternatives to what they had observed in the video.

These findings are limited, as with any pre-/post-test research design, in that other experiences in the preparation program may have contributed to PSTs' learning. Yet, this study constitutes only a first phase in our program of research.

We conclude by pointing the reader's attention to two important ideas related to the use of video representations of teaching in this project: (1) purpose and (2) guidance. First, we chose videos with a purpose in mind. As explained above, we had a very specific teacher learning goal: developing PSTs' abilities to analyze teaching. We used a particular framework for looking at teaching (i.e., the Lesson Analysis Framework), and we chose specific videos to develop the orientation and skills necessary to apply the framework effectively. This led us to the use of videos of both interviews with children and classroom lessons. It also led us to the use of videos of lessons that PSTs taught and of videos they searched for as representing the teaching strategies we discussed in the course. Because purpose was at the forefront, we used different kinds of videos at different moments during the course to address particular teacher learning needs.

Our specific purpose also led us to consider particular criteria when choosing the video: (1) the mathematics portrayed, (2) teaching that makes student thinking visible, and (3) the background of the teacher and the students portrayed. Two issues emerged as we worked on the project: (1) the necessity to couple video to live observations, and (2) the distance that PSTs may feel between their teaching ability and the ability of the teachers portrayed in the videos. These issues highlight the complexity of using video as a representation of practice. Although many choose video exactly because of its closeness to the complex reality of the classroom, teachers' past experiences and beliefs about what is possible and not possible in teaching may turn even video into an artificial representation of

teaching that teachers can easily dismiss. In addition, it might be the case that for optimal learning, the practices portrayed in the videos need to be within the zone of proximal development of the viewer. This hypothesis needs to be further investigated.

Second, we took a specific stance toward video as a representation of teaching. We did not let the videos speak for themselves. Instead, we highly scaffolded PSTs' viewing and analysis experiences. We have developed this approach to the use of video as a tool for teacher learning through experiences in teacher professional development contexts (Santagata 2009; Santagata, Kersting, Givvin, & Stigler 2010). In part, because of the lack of a common language for describing features of teaching practice (Hiebert, Gallimore, & Stigler 2002), also reflected in different labels researchers use in teaching observation rubrics (Grossman & McDonald 2008), we feel the need to guide teachers by pointing their attention to specific aspects portrayed in the videos. In addition, because of our focus on developing a disciplined approach to reflection on teaching, the prompts we use to guide teachers' viewing model the kinds of analysis we hope teachers will perform later on their own.

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