EFFECTS OF METACOGNITIVE GUIDANCE ON TEACHERS' MATHEMATICAL AND PEDAGOGICAL REASONING OF REAL-LIFE TASKS

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Standards of mathematics education pose great challenges for the preparation and continuing education of mathematics teachers (NCTM, 2000; PISA, 2003). In mathematics classrooms aligned with the standards, teachers engage students in rich, meaningful tasks as part of coherent curriculum, and mathematical discourse to guide the classroom community's exploration of important mathematical ideas.

The role tasks may have in mathematical education has specific meanings in the PISA (Program of International Assessment) context. PISA tasks are designed to encompass three broad dimensions: Processes, content and context. Processes refer to different types of skill needed for mathematics such as mathematical reasoning, using symbolic and formal language, representations, problem solving and argumentations. Such skills are organized into three "competency clusters": The first cluster-reproduction-consists of simple computations or definitions of the type most familiar in conventional assessments of mathematics; the second-connection-requires the bringing together of mathematical ideas and procedures to solve straightforward and somewhat familiar problems; and the third cluster-reflection-consists of mathematical thinking, generalization and insight, and requires students to engage in analysis, and to identify the mathematical elements in a situation. PISA organizes content in relation to phenomena and the kinds of problems for which they were created, emphasizing broad mathematical themes such as quantity, space and shape, change and relationships, and uncertainty. Such themes are called big ideas. Context is an important aspect of mathematical tasks. It refers to doing and using mathematics in a variety of situations, including personal life, school life, work and leisure, the local community, and society. PISA aims to ensure that tasks are based on "authentic" contexts which are likely to occur in a real-world setting.

To support this vision of the mathematics classroom, teacher education and professional development programs for practicing teachers are being called upon to model good mathematics teaching, to offer perspectives on students as learners of mathematics that have a sound research base, and to provide opportunities for teachers to develop their own mathematical and pedagogical reasoning as teachers of mathematics (e.g., Peressini, Borko, Romagnano, Knuth & Wills, 2004).

For more than a decade, research in the area of metacognition has looked for instructional methods that utilize metacognitive processes for enhancing mathematical reasoning. In particular, the IMPROVE metacognitive questioning method (Mevarech & Kramarski, 1997, Kramarski & Mevarech, 2003) focuses on students' understanding of the task, strategy use, constructing of connections between prior and new knowledge and reflecting on learning. Much research was made on effects of IMPROVE method on students' mathematical reasoning, problem solving with regard to providing mathematical explanations in standard and real-life tasks (e.g., Kramarski, 2004;

Kramarski, Mevarech, & Liberman, 2001; Kramarski, Mevarech, & Arami, 2002; Kramarski, & Mevarech, 2003). But little research was done on effects of metacognitive questioning on teachers' professional development with regard to mathematical and pedagogical reasoning. Studies indicate that helping teachers become more aware of how their knowledge and actions influence students' learning is critical to promote teachers' professional growth (e.g., Fennema, & Franke, 1992; Putnam, & Borko, 2000). We propose that by using metacognitive questioning teachers might notice critical aspects that promote their own mathematical and pedagogical reasoning and could motivate them to change facets of their own teaching practices.

The present study investigates effects of the use of IMPROVE metacognitive questioning on teachers' mathematical and pedagogical reasoning of solving a real-life task based on PISA conceptual framework. The purpose of this study was threefold:

(a) To investigate teachers' mathematical reasoning who were exposed either to IMPROVE metacognitive questioning (MG) or to a control group (CG) on real-life problem solving skills with regard to providing mathematical explanations;

(b) to compare teachers' pedagogical reasoning with regard to planning for understanding who were exposed to these instructional approaches; (c) to observe teachers teaching in practice of both approaches.

METHOD

Participants were 64 primary teachers who were exposed to a government sponsored professional development program in Israel. Thirty four teachers were assigned to metacognitive guidance (MG) and thirty teachers were assigned to a control group (CG). In the beginning of the study there were no significant differences between the two groups in the variables: Years of experience in teaching mathematics, and mathematical and pedagogical reasoning which were assessed by governments' test measures.

MG vs. CG instruction

Teachers in both groups were exposed during one month to four workshops. Each workshop was implemented once a week and lasted four hours, for 16 hours of total training. The training workshops were implemented on numbers and operations, and algebra ideas (e.g., patterns, mathematical representations, algebraic expressions and problem solving). A discussion was held in the whole class on the role of the task in enhancing mathematical reasoning, pedagogical ways of engaging in discourse and for providing different types of arguments for justifying mathematical reasoning.

The metacognitive guidance was based on the IMPROVE approach (Kramarski & Mevarech, 2003; Mevarech & Kramarski, 1997) that emphasizes the use of self-questioning directed to an "effective learning and teaching" model. Guidance was focused on two perspectives of self-questioning as a learner and as a teacher. Four main questions were used: Understanding questions (e.g., "What is the problem/task about?; "what is the goal of the lesson?, what is the mathematical big idea of the lesson?; what is a good mathematical argument?); connection questions (e.g., what is the similarity or the difference between the two tasks, the two explanations or two lessons?, WHY?); strategy use questions (e.g., "what, when and why should I use different representations in the solution, different techniques in the lesson?); and reflection questions (e.g., “Is the result logic?, did I achieve my goals in the lesson?). The CG teachers practiced the same tasks but they were not exposed explicitly to metacognitive guidance.

MEASUREMENTS

Three measures were used in the study:

(1) A pre/post real-life task based on PISA conceptual framework (PISA, 2003) that examined teachers’ ability to understand functional thinking in terms of relationships. Relationships were given in a variety of different representations, including symbolic, algebraic, graphical, and tabular. The tasks assessed three skills of mathematical problem solving: Reproduction, connection and reflection. In addition, the ability to explain mathematical reasoning was assessed regarding each skill.

(2) A pedagogical task that asked the teachers to plan a lesson for their students on the real-life task that they solved. Teachers were encouraged to think about the goal of the lesson, difficulties in students’ understanding, variety of ways for solution and conceptual understanding. The plan of the lesson was analyzed by three categories: Task introducing, strategy use and conceptual understanding (e.g., drawing conclusions, providing explanations).

(3) Video tape and interview of two teachers from both groups. One teacher was exposed to the MG and the other teacher was exposed to the CG. The video tapes and interviews were analyzed on the base of the same criteria of planning the lesson.

RESULTS AND CONCLUSIONS

Results indicated that the MG teachers outperformed the CG teachers on higher order skills of solving mathematical real-life task (connection and reflection), and provided significantly more logic-formal mathematical arguments. Further findings indicated that the MG teachers exhibited the CG teachers on pedagogical reasoning regarding planning a lesson for understanding on a real-life task.

The video transcripts indicated differences between the two teachers in the way they held mathematical discourse in the class. The teacher that was exposed to the metacognitive guidance (MG) actively encouraged students more to be engaged in different problem solving strategies than the CG teacher. She also used more often the metacognitive questions to guide conceptual discourse.

Data findings and teachers’ discourse in the class will be highlighted in the conference. Examples of tasks used in the study for assessment and training, and teachers’ mathematical explanations will be provided. In addition, educational and practical implications of the role of real-life tasks and metacognitive guidance in teachers’ mathematical and pedagogical reasoning development will be discussed.

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