LESSON STUDY: THE EFFECT ON TEACHERS' PROFESSIONAL DEVELOPMENT

This study combines elements of the Japanese Lesson Study approach and teachers' professional development. An explorative research design is conducted with three upper level high school teachers in the light of educational design research, whereby design activities will be cyclically evaluated. The Lesson Study team observed and evaluated two different research lesson cycles. The first one focused on the concept of the derivative. The second one deepened teachers' pilot experiences with regard to another mathematical concept. The Lesson Study revealed students' misconceptions with regard to the tangent line. Results of teachers' professional development are used to refine the Lesson Study observation instruments.

INTRODUCTION

Lesson Study is a teaching improvement and knowledge building process that has origins in Japanese elementary education (Lewis, 2002). A salient difference with European countries is that Asian students work to develop the understanding of mathematics so that their success is not only maintained, but improved (Tall, 2008b). European governments establish guidelines for teaching and learning approaches that are controlled in more or less directive ways. As a consequence teachers are focused on preparing for the exams. Individual teachers may reflect on and improve their practice in the isolation of their own classrooms. The complexity of their daily work rarely allows them to converse with colleagues about what they discover about teaching and learning (Cerbin & Kopp, 2006).

In this study the social system in which teachers learn focuses on collaboration in a Community of Learners (CoL). This is a small research team, where participants are characterized as serious partners in the process of the development of knowledge and scientific research (Brown & Campione, 1996). The focus in a CoL is on specific subject matter based on the reality of everyday teaching. The participants share their experiences as they implement research activities and reflect on the results and the research methods. A necessary precondition is that the participants have adequate facilities in order to participate. Research reports findings that the working method explicitly prompts the participants of a CoL to mutual cooperation based on knowledge for teaching the content (Verhoef & Terlouw, 2007).

THEORETICAL FRAMEWORK

Lesson Study

The typical small, but professionally scaled process of Lesson Study generates a collaborative research framework (Matoba & Sarkar Arani, 2006). The Lesson Study

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approach involves the design of the research lesson as part of an extended sequence of lessons to teach a particular topic, the implementation of the research lesson followed by evaluation and analysis, then refining of the lesson. Observation of the research lesson by colleagues and other interested persons is an essential part of this approach (Baba, 2007; Sowder, 2007). Having several pairs of eyes looking at the classroom activity gives a more comprehensive view of different aspects.

This approach culminates in at least two tangible products: (a) a detailed, usable lesson plan, and (b) an in-depth study of the lesson. The study investigates teaching and learning interactions, explaining how the students responded to instruction, and how instruction might be further modified based on evidence (Cerbin & Kopp, 2006).

The designing process is a process of learning, because the teachers consider how they will help students achieve the goals (Wiggins & Mc Tighe, 1998). In planning a research lesson, teachers predict how students are likely to respond to specific questions, problems and exercises and then analyse what actually happens.

The primary focus of Lesson Study is not only what students learn, but *how* they learn. The framework of long-term mathematical thinking will be used to categorize aspects of students' learning processes (Tall & Mejia-Ramos, 2009). In practice, the Lesson Study approach selects of a specific course, a well-chosen topic and goals for student learning followed by a research lesson that addresses academic learning goals (e.g., understanding specific concepts and subject matter) and broad goals (e.g., development of intellectual abilities, habits of mind and personal qualities).

Long-term mathematical thinking

Skemp (1976) distinguished relational understanding in which relationships are constructed between concepts and instrumental understanding which involves learning how to perform mathematical operations. Various theories (e.g. Dubinsky & McDonald, 2001; Gray & Tall, 1994) suggest there are subtle processes occurring in learning in which operations that take place over time become thinkable concepts that exist outside of a particular time. This framework has been extended into what Tall (2008a) described as three mental worlds of mathematics:

(i) the conceptual-embodied world (based on perception of and reflection on properties of objects);

(ii) the proceptual-symbolic world that grows out of the embodied world through actions (such as counting) and symbolization into thinkable concepts such as number, developing symbols that function both as processes to do and concepts to think about (called procepts); and

(iii) the axiomatic-formal world (based on formal definitions and proof) which reverses the sequence of construction of meaning from definitions based on known concepts to formal concepts based on set-theoretic definitions.

Derivative

Calculus in school is a blend of the world of embodiment (drawing graphs) and symbolism (manipulating formulae). The property of *local straightness* refers to the fact that, if one looks closely at a magnified portion of the curve where the function is differentiable, then the curve looks like a straight line, which, when extended gives the tangent line at this point. This conception can be encouraged by the use of technology to magnify graphs. Inglis, Mejia-Ramos & Simpson (2007) suggest that the derivative develops from embodiment to symbolism to formalism through definition and deduction. A 'sensible approach' to calculus proposes that a more natural approach to the calculus blends together the dynamic embodied visualisation of the changing slope as the eye traverses the curve and the corresponding symbolic calculation of the slope (Tall, 2010). This approach hypothesises that it is more natural to build from an operation on an *object* (looking along the graph of the function) to build a new *object* (the graph of the slope function) than to encapsulate a *process* (calculating the slope at a point) to an *object* (the symbolic derivative). Focusing on the relationship between the initial stages of the student's long-term thinking process the research question in this study is: *What is the effect of Lesson Study on teachers' professional development?*

SETTING AND METHODOLOGY

Participants

Three upper level secondary school teachers from different school organizations and five staff members of the University of Twente participated in the Lesson Study team: two educational teacher trainers, a mathematician, a researcher and a PhD-candidate. The male school teachers tagged by capitals A, B and C indicated ttheir interest in professional development. A (age 56) attained a Bachelor's degree in Mathematics and a Master's degree in Mathematics Education. He worked as a mathematics teacher for 17 years with lower level to upper level high school students. B (age 48) attained a Bachelor's degree in Mathematics and a Master's degree in Mathematics Education. He worked as a mathematics teacher from 1988 mostly with upper level high school students. C (age 48) attained a Bachelor's degree in Engineering and a Master's degree in Mathematics Education. He worked as a staff member of the University of Twente for seven years. Since 2009 he works as a mathematics teacher with mostly upper level high school students.

Application of Lesson Study in a Community of Learners

Each participant was given a research paper to study and to present the ideas to their colleagues in a seminar. Teacher A got 'Student Perspectives on Equation: The Transition from School to University' (Godfrey &Thomas, 2008). Teacher B got 'Exploring the Role of Metonymy in Mathematical Understanding and Reasoning: The Concept of Derivative as an Example' (Zandieh & Knapp, 2006). Teacher C got

'The Transition to Formal Thinking in Mathematics' (Tall, 2008a). In this first iteration of the project, teachers were encouraged to construct their own lessons based on their experience and their reading of the literature, operating as a true Community of Learning without directive guidance from research organizer.

Data gathering instruments

The data gathering instruments (in the school year 2009-2010) consisted of:

- a pretest and a posttest – and additionally a (halfway the school year) posttest at the end of the first Lesson Study cycle – with regard to subject-specific elements;
- a pretest and a posttest with regard to topic-specific elements related to each Lesson Study cycle; an exit-interview focused on students' understanding of the mathematical concept at the end of each Lesson Study cycle.

The pre- and posttest with regard to subject-specific elements consisted of priority lists on (a) goals of mathematics education, (b) the start of instruction to attain these goals. The pre- and posttest with regard to topic-specific elements consisted of aspects related to teaching the mathematical concepts.

Subject-specific pre- and posttest. The pretest was exactly the same as the posttest. Teachers were asked to prioritize statements of educational goals on a scale of 1 (high priority) to 12 (low priority). The statements represented conceptual understanding related to structures and mathematical proof e.g. 'Structures as a basis for thinking' related to problem-solving skills in contrast with a focus on procedures to solve problems e.g. 'To be able to execute correctly' (Thurston, 1990). The objectives of the teaching method *at the start* of the instruction were theoretically founded and supported (Schoenfeld, 2006). Teachers were asked to prioritize statements of teaching methods on a scale of 1 (high priority) to 8 (low priority). The statements represented a start with an abstract mathematical concept (in symbols) e.g. 'A start with definitions' or a start with situated examples e.g. 'A start with practical worked examples'. The changes in pre- and posttest results showed teachers' subject-specific professional growth.

Topic-specific pre- and posttest. The topic-specific pre- and posttest protocol focused on teachers' free associated aspects related to teaching the mathematical concept with regard to students' thinking and learning, e.g. 'Turn almost into a solution'. The changed free associated aspects in pre- and posttest results showed teachers' topic-specific professional growth.

Exit-interview. The exit-interview protocol focused on students' understanding of the derivative. Teachers' exit-interview statements about students' understanding were related to e.g. 'Students have their intuitions' or 'Students learn by doing'. The changed statements results showed teachers' growth in students' learning processes.

Procedure

Firstly teacher A, followed by teacher B, concluded by teacher C, designed, implemented and evaluated two half-year research lessons. The teachers designed observation and evaluation lists as well as criteria based on Skemp's (1976) instrumental and relational understanding and Tall's (2008a) embodied and symbolic mental worlds to analyse the data. Members of the Lesson Study team observed and evaluated each research lesson. Two independent assessors transcribed separately. In case of disagreement the assessors discussed and asked a new assessor. This resulted in a final agreement between the assessors.

Data analysis

The data with regard to teacher's professional development were analysed using Skemp's characteristics of understanding and Tall's three mental worlds of thinking.

RESULTS AND CONCLUSIONS

Teacher A continued to highlight understanding mathematical concepts as the goal of education. He moved from a start with different examples to a start with definitions. He accentuated instrumental understanding using symbols instead of embodiment. He is aware of students' thinking and learning, e.g. 'don't understand as you think'.

Teacher B moved to structures as a basis for thinking directly followed by learning problem-solving skills as the goal of education. He began with examples and continually emphasized relational understanding using embodiment. He prefers to develop students' problem-solving skills, believing they 'learn better without ICT'.

Teacher C focused on understanding mathematical concepts rather than learning procedures as his goal of education. He switched from beginning with different examples to a focussing on a thinking model. He moved to relational understanding using embodiment. He is aware of students' thinking and learning e.g. '*seeing* before using a formula'.

All of the teachers considered general meanings of the derivative in the pretest. They considered velocity as an application of the derivative. None of them associatee the concept of the derivative in a non-mathematical context. They all concentrated on the tangent line in the posttest.

The Lesson Study team discovered – after two executions of the research lesson – in an evaluation meeting at the university, that the uncovering of students' thinking processes failed. The Lesson Study team decided to change the written question lists into short written assignments with doing activities, asked in pairs. As a consequence the teachers learned to think about students thinking and learning processes as individuals during the Lesson Study period. The teachers highlighted learning by doing to uncover students' learning processes, students' intuitions and students thinking processes as individuals. The teachers were familiar with mathematical vocabulary and possible misconceptions relating to students' interpretation of representations.

Extra remarks in the exit-interview accentuated practical tips from colleagues to improve lessons in general. The teachers indicated increased enjoyment in teaching.

DISCUSSION

The goal of the Lesson Study approach was to professionalize mathematics teachers by designing, observing, implementing and evaluating two research lessons. The lesson observations completing this study were focused on uncovering students' thinking processes as an effect of a research lesson and as an indication of a successful professional development. The refining of the Lesson Study instruments concentrated on teachers' observations by using worksheets to uncover students' thinking processes.

The teachers' professional development continued to be narrowly related to their classroom practices in spite of the recommended literature and the discussions in the Lesson Study team. As a consequence each teacher developed an individual knowledge base for teaching. For example, teacher A, with the longest time in school practice, used an applet with the intention to demonstrate local straightness as being meaningful in understanding the derivative. After his short introduction he concentrated on the ratio $\Delta y/\Delta x$ with the intention to connect the lesson to the textbook. After the Lesson Study cycles he makes consistent choices with regard to definitions, symbols and students' teaching and learning. Teacher B, decided to focus on the concept of the tangent line before introducing the derivative. Each student was given a squared graph of $y=x^2$ on squared paper and were asked to draw a tangent at a point that was not placed on a crossing of the gird line. As a consequence, the tangent lines they drew were slightly different and gave small differences in the numerical slope of the tangent. B's plenary discussion focused on the concept of the tangent, but also ended in the limit dy/dx, following the strict textbook guidelines. After the Lesson Study cycles, he focused on the learning of problems-solving skills to attain conceptual understanding relating to the standard approach. Teacher C, a former staff member of the university, kept the limit concept in mind throughout the lesson without actually naming it. The observers noted that the students were not amazed at all when their practical approach to the tangent produced different tangent lines with different slopes as compared with the graphic calculator that produced a single formula.

The teachers in this study were unable to design a research lesson based on the new theoretical framework in the first Lesson Study cycle, because of their desire to follow narrow textbook guidelines. The textbook assignments were built up step-by-step, without reflection. This approach seemed to hinder the development of 'thinkable concepts' (Tall, 2009). The experienced teachers tended to teach using familiar methods, as executed in their colleagues' groups who were teaching the course in the regular manner. External stimuli, like scientific literature, discussions in a lesson study team and reflection on classroom practices, made teachers aware of students' thinking and learning processes in addition to classroom management. This study reveals the significance of the complex reality of school practice in relation to the powerful claim of curriculum guidelines, study guides based on textbooks, and the attaining of high exam results.

The Dutch curriculum can be typified as a realistic mathematics educational (RME) approach in lower level mathematics education. The higher-level mathematics education is subdivided into a human and arts related program on the one hand and a science related program on the other hand. The latter, with a minimum of RME-characteristics, was seriously criticized because of a constant yearly growth of remedial courses at the universities. Poor mathematics results in scientific studies were attributed to the use of realistic contexts in textbooks by the scientists These realistic authentic contexts were considered to impede the development of automated mathematics operations, helpful in science studies. As a consequence the science textbooks were influenced by traditional procedural fluency with little conceptual insight. The balance between procedural fluency and conceptual insight is missing.

More research is needed into a Lesson Study approach in the context of complex school practices to focus on compression of knowledge, requiring both conceptual insight and procedural fluency, related to teachers' individual professional development. This will be the focus of the next iteration of the research project.

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