PROBLEM BASED INSTRUCTION: GETTING AT THE BIG IDEAS AND DEVELOPING LEARNERS

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ABSTRACT
Written collaboratively by two former teaching partners, this paper details the journey taken by a team of teachers from a large southern Ontario school board as they completed an action research project during the 2008-2009 school year, in conjunction with ETFO and their Teachers Learning Together: A Math Journey initiative. This paper will outline the process and findings from our team.

DESCRIPTION OF TEAM
Our project team consisted of two Grade 6 teachers (team teaching at one Junior Public School) and one Grade 3 teacher (teaching at another Junior Public School). Our project focused on students who would be writing the Ministry’s EQAO Assessment test in June 2009.

Research Question: How can we as a team incorporate a problem-based instructional approach within our mathematics programming to improve students’ understanding of a problem and his/her choice when choosing an appropriate strategy to solve problems?

The action research project is described from rationale to conclusion, includes teacher reflections and is followed by data collected from EQAO results a few months after the project concluded.

Project Rationale: The two Junior Public Schools where we worked are classified as Inner City schools that are high on the Learning Opportunities Index in our large southern Ontario District School Board. As Grade 3 and 6 teachers, we proposed an action research
project that sought to improve the overall confidence, initiative and the capacity of our students to decode problems; thus impacting our students’ capability, confidence and overall achievement in mathematics.

During the 2008/2009 school year, we wanted to focus on improving our students’ success in mathematics—as reflected in class assessments/evaluations, class discussions, in report card data and on the EQAO provincial testing. We wanted to work collaboratively to plan and implement an action research project that addressed the difficulties our students were having with problem solving in mathematics, as reflected in classroom tasks and EQAO open task results. We believed our students could learn how to understand a problem better if they were introduced to a variety of problems and were able to decode the problem by breaking it down into steps (Van de Walle & Lovin, 2006). Students would also be taught how to choose an appropriate strategy from their personal toolkit, to help them when beginning a problem (Goodnow & Hoogeboom, 2007).

As teachers, we were hearing more about the research behind problem-based instruction in mathematics, but the resources at our school did not support this type of instruction—everything was still centered around textbook learning. In order to begin the process prepared and knowledgeable, each teacher received copies of A Guide to Effective Instruction in Mathematics (Ontario Ministry of Education, 2008a; 2008b) and the Van de Walle books, Teaching Student-Centered Mathematics (Van de Walle & Folk, 2003; Van de Walle & Lovin, 2006a; 2006b; 2006c). As well, we ordered some resources from our board’s professional library.

**Project Overview:** We engaged students in learning activities where they were introduced to Rich Performance Tasks through 3-part mathematics lessons, and given the opportunity to struggle and grapple with solutions to cement learning of new concepts. As teachers we introduced new problem-solving strategies (such as the KWC chart, strategy maps, diagrams, T-charts, Venn diagrams, etc.) to expand and enrich students’ toolkits. When taking up solutions, students presented their work to the class, explaining the steps they chose, while others were able to compare the problem solving techniques used. Anchor charts were co-created with students to show examples of strategies students could utilize when problem solving in mathematics. Through the gradual release of responsibility, students continued to work on tasks in small groups, then in pairs, before completing an individual task for teacher evaluation.

We also engaged in reverse learning activities where students were given EQAO exemplar work samples to discuss and assess. They were asked to determine what level they would give to each work sample and the reasons for their evaluation. This gave us insight into the students’ thinking and a way to see the extent of their consolidation of strategies taught. Students were also able to express the areas on the sample where the mathematics needed to be revised and the communication of the answer rewritten for clarity. Later, when EQAO sample questions were used in class, students were able to assess their own work through the use of exemplar comparisons. This use of exemplars for self-reflection and self-assessment was very valuable, as students made connections and critical observations...
about their own work. They also made up their own goals upon which to focus for the following math classes.

During math classes, students were introduced to various manipulatives, which were accessible for use when completing tasks. These included but were not limited to: two-sided counters, base ten rods, linking cubes, tape measures, Pattern Blocks, scales, clocks, etc. New math vocabulary was introduced during each unit and visually displayed within each classroom on a Mathematics Word Wall for students to refer to when completing written tasks and for use during discussions.

Grade 6 students utilized Math journals for reflecting on tasks and to help to explain their thinking when conferencing with the teacher about their progress. As well, they were used for setting new learning goals and any questions the student may have.

**DATA ANALYSIS AND FINDINGS**

Data analysis throughout the year involved:

- Collecting and examining student work samples to determine areas of strength and/or next steps during various tasks;
- Identifying and observing student progress with the sophistication of mathematics skills used during tasks, both language and process;
- Using checklists to track students’ use of anchor charts, manipulatives, new strategies shared/taught and visual clues posted around the classroom to assist them;
- Writing anecdotal comments to record each student’s use of new math vocabulary during discussions and written tasks; and,
- Collecting student work samples/journals in a portfolio to show examples of each student’s progress during each term.

Essential to our project was having students discuss the problems that they had solved and examine the work of others using exemplars and work samples. Using success criteria and rubrics from the Ministry of Education’s *The Ontario Curriculum Grade 1-8: Mathematics* and *A Guide to Effective Instruction in Mathematics*, released EQAO task criteria, and criteria ‘look-fors’ developed as a class, students were able to share why samples were assessed a certain way thereby helping them gain insight into their own work.

During our regular meetings, we would bring samples of completed tasks to discuss student progress through teacher moderation. By using Ministry exemplars/EQAO documents and a variety of samples, we were able to provide a measure of accuracy to our assessments and feel confident in setting next steps for teaching.

Observational analysis suggested a significant improvement in students’ ability to use math vocabulary in class, to fully explain their thoughts when writing solutions, and an increase in the sophistication of math strategy chosen for a given task. Students began to use manipulatives with confidence to assist with problem solving. There was growth in verbal
and written communication for all students. The verbal communication was more elaborate; written less so. However, across grades, there was a noted improvement in confidence in use of and familiarity with, the language of mathematics. Students needed help and continued practice with making the connection from thinking to writing. This was particularly evident with the struggling and ESL students.

Students enjoyed using exemplars and student work samples to discuss in class. They were able to identify the levels scored for each piece of work and were able to site specific examples on how to improve each answer, “This person didn’t show all their work, so they only got a Level 3, even if it’s the right answer.” The added advantage was that students were evaluating work based solely on the work—as opposed to being asked to evaluate their friend’s work which, in Grade six particularly, can become quite political!

Work samples from a student who had been absent for an extended period of time during the previous school year, showed large gaps in her knowledge. Samples from those students who achieved a Level 2 or below showed they were finding it very difficult to solve multi-step problems when basic number sense skills were not developed. The data varies with the growth of each student, but shows a great improvement over the course of the strand and term.

As a whole, students were able to better activate their schema by identifying which type of math they were completing a problem for, recall important strategies or facts and apply them when solving problems. For example, one student stated, “Perimeter is a part of measuring and goes around an object. I know some different ways to measure—and it needs units.”

When beginning a new area in math, some students struggled to select and apply a problem solving strategy immediately (as they became fixated on the new skill), but progressed significantly through the completion of the unit. They relied on anchor charts and visual prompts to assist them when self-checking their work. Some students tried several strategies when working on problems, before circling or indicating which they felt rendered the answer of best fit. Others linked new problems to previous ones they had worked on to decipher the best method to assist them. Struggling students needed prompting to do any form of self-checking as their tendency was to sacrifice accuracy for speedy task completion. However, when prompted they were often able to see errors and make corrections.

While completing the EQAO test, students said things like, “This is easy! It’s just long.” The students involved in the problem solving action research project spent a much longer amount of time completing the math section of the EQAO test, than Grade 3 students in other classes in the same school, and answered each question more thoroughly (fully showing their thinking about how they solved the problem by using pictures, numbers and words as appropriate).
The Grade 3 EQAO scores increased 12 percent, over the previous year’s results. In fact, it was the highest score ever achieved by the school’s Grade 3 students. The Grade 6 scores increased 4 percent, over the previous year’s results. This score too, was the highest achieved by the school’s Grade 6 students to date.

One of the most positive results about the Grade 3 progress was their clear understanding that a strategy was required—they didn’t always choose a successful strategy, but they knew a framework could assist them. It would be interesting to track these Grade 3 students as they progress to Grade 6 and see if this new schema has been embedded into their practice in mathematics.

**IMPACT AND IMPLICATIONS**

**Student Learning:** We noticed a significant improvement in Grade 3 and 6 students as they began to recognize new vocabulary, decode problems and select strategies they felt were appropriate for each task. They were more willing to attempt a given task and to experiment with different ways to solve the problem (trial and error/self-check). They understood the importance of showing and thoroughly explaining their work—using pictures, numbers and words as appropriate. The students enjoyed the challenge of trying to uncover the answer and working with each other to find solutions. The overall anxiety level in class was reduced, with all the students having an entry point to any word problem. Giving students the problem-solving tools has influenced their attitudes and their willingness to persevere when confronted with a problem.

We believe that these skills were reflected in the students beyond the mathematics classroom. Students became more independent when solving problems in other subjects, often by choosing a framework for solving whatever task was in front of them. As well, students were encouraged to use some of their new skills when dealing with student conflicts. As teachers we repeatedly told the children that problem solving models are not just for math but a way that strategies can help them in their “real lives.” As the year continued, they progressed more quickly through the gradual release of responsibility, and were eager to receive new challenges.

When working in pairs/groups earlier in the year, some students assumed other students were smarter in math, and would take their suggestions about how to solve a problem as correct (e.g., Grade 3 student: “Okay, you must be right, because you’re smarter than me.”). By end of the school year, students were more likely to share their opinions in small groups, challenge each other’s ideas, look at classroom anchor charts for assistance and brainstorm possible solutions before deciding on a strategy to solve the problem together. Probably the most significant impact to student learning has been the improved overall mathematical confidence and each student’s belief that they can tackle any problem. The development of perseverance in class is clearly evident as we saw/heard them attack problems, communicate with each other, and analyse their work to self-edit/correct.
**Teachers as Professionals:** Although we always believed in the power of problem solving as a teaching tool, completing this project provided us with concrete evidence to support our opinions and the research we had read about. It has completely changed the conscious way we plan our mathematics program, the resources we use in class, how we assess/evaluate student work, how we communicate student achievement with parents, and how we scaffold units for struggling and ESL students.

As a team, we have increased our frequency of utilizing work samples and math exemplars when discussing and modeling problem solving. We found it essential to introduce new vocabulary for each unit and continue to post words on a Mathematics Word Wall for student reference, as needed. Possibly most importantly, we continue to meet with more frequency to continue moderated marking, discussing student progress and brainstorming strategies for our struggling students.

We were inspired to share these findings with new and experienced teachers, through hosting faculty students and presenting problem solving workshops at various math conferences in southern Ontario.

While conducting this action research project we learned the importance of providing regular problem solving opportunities for students. We believe problem-based instruction should be utilized as often as possible. We see more clearly the need for students to have real-life applications for the skills they are acquiring. Our students were beginning to understand how their newly acquired mathematics skills could assist them in other subject areas and how math is a life-skill used every day in the world around them. We have become more passionate about problem-based mathematics instruction because we (not just the students) were more engaged.

It was less threatening for students to have single question to answer in math class rather than the overwhelming “drill and kill” of math classes they were used to. As teachers we need to be there pushing the students to take time with the single question, try different strategies, find solutions/different ways of approach, and even, sometimes, be wrong. We feel our students became more willing to discuss their difficulties and struggles as they saw it was okay to not be sure and to try something even if it had an unsuccessful outcome.

The traditional approach where problem solving is completed at the end of a unit, is contrary to the real-life use of mathematics. Students need to construct their knowledge in order to apply it effectively in an often confusing world. We are also helping our students become more math literate if they can decode what is being asked of them, what they have to figure out, what they need to know in order to figure it out, and how to go about it. The explicit integrated and ongoing teaching of problem-solving skills is both essential to illuminate the BIG IDEAS in math and to instill confidence in our students.

In February 2010, we presented a workshop to share our action research project findings with colleagues; we received a lot of positive feedback. It can be difficult to share this approach with colleagues because some are receptive and others are not open to 'new'
ideas. Perhaps resistance on the part of some teachers exists because in order to make the switch (to a different way for teaching mathematics), one must acknowledge that s/he may not be teaching in a way that is best for student learning, and/or s/he may not be comfortable with the mathematics involved. This relates to what we perceive as the need for more reflective practice, team planning, and classroom transparency amongst teachers.

REFERENCES


BIографICAL NOTE:

Laura Inglis is a teaching coach with the Toronto District School Board, where she works with students and teachers from several inner city middle schools. Laura is qualified across all four teaching panels and has participated collaboratively in action research projects at the Primary, Junior and Intermediate levels. Laura and Nicole were team teachers for five years and have worked together collaboratively on many projects.

Nicole Miller is a Vice Principal at an inner city model middle senior public school in the Toronto District School Board. Her background includes a Master’s degree in Education with a focus on collective bargaining and school culture from Nipissing University, and additional qualifications in mathematics and guidance. Nicole and Laura were team teachers for five years and have worked together collaboratively on many projects.