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Responding To Mathematics Reform At The College Level

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Abstract

Ontario's elementary and secondary school mathematics curriculum was implemented in Fall 2000 having been revised according to the key principles of the social-constructivist view of mathematics education. This change in pedagogy has implications for teaching and learning mathematics, the use of technology and the emphasis in problem-solving. In the search for understanding, this paper summarizes some of the key research which provided a substantial foundation to the secondary school curriculum. The implications the revised curriculum will have on educating incoming college students are identified with respect to these pedagogical changes and some recommendations for a college response are provided.

Responding to Mathematics Reform at the College Level

Secondary school reform of Ontario's education sector was designed with sound pedagogy in mind to deliver a mathematics curriculum relevant to the future needs of society. Students are being educated to be proficient in critical thinking and problem solving, mathematical modeling and the use of technology. Teaching is supported through the application of a variety of technological tools, rich learning tasks and evaluation mechanisms. A brief overview of some of the literature in mathematics education will trace the emergence of mathematics curriculum reform, thereby setting the stage for an examination of a post-secondary response.

The background research to the mathematics curriculum reform as commissioned by the Ministry of Education and Training (MET) discusses images of mathematics, frameworks for the curriculum and the implementation of technology in the curriculum (Roulet, 1997). The paper identifies the philosophical underpinnings of the mathematics program endorsed by NCTM (1989) and submissions from provincial mathematics interest groups. According to Battista (1999), a mathematics curriculum should involve inquiry, problem-solving, structuring solutions and testing them out. An ability to "… describe patterns, construct physical and/or conceptual models of phenomena, create symbol systems to help represent, manipulate and reflect on ideas and invent procedures to solve problems" embodies the critical concepts encompassing mathematics (p. 428). KIey components to the mathematics curriculum were to include problem-solving, the social-constructivist model and the use of technology (Roulet, 1997).

The mathematics curriculum for Ontario's students is considered to be "problems-first" (Roulet, 1997, p. 3) organized by problem situations. **George Pólya** (1888-1985) (as cited in Davis, Hersch & Marchisotto, 1995) published **How to Solve It** (1945) describing his problem-solving technique. (p. 217). In the search for effective problem-solving strategies, the research conducted by Schoënfeld (1978) delineated the heuristics that college-level students apply in solving mathematics problems (as cited in Davis, et al, 1995, p. 318). Teaching mathematics includes methods to encourage students to problem-solve and create mathematical ideas (Schoënfeld, 1994, p. 59).

The social-constructivist view of mathematics education is also a key feature of the secondary school curriculum and not without support from the literature (Roulet, 1997, p. 2). The constructivist theory of learning mathematics and the basic principles of abstraction, reflection and learning are key features of the mathematics reform curriculum. The learner develops a recursive sequence of mental models at each step of the way to reinforce learning of mathematical concepts (Battista, 1999, p. 429). Work by Collins, Brown and Newman (1989) describe the cognitive apprentice and the role of constructivism in a student's learning process of mathematics. The teacher is a "master" whose role is to guide the learning process through a variety of tasks – coaching, scaffolding and fading – as the students' skills and knowledge grow. This idea comes forward in the curriculum as well. The role of the teacher is to guide classes "… through discussion and logical exploration of proposed solutions in order to construct mathematical concepts and skills" (Roulet, 1997, p. 3). Borasi (1992) is able to encapsulate these salient features under a pedagogical model entitled the "Humanistic Inquiry Approach". In this model, mathematics discovery takes place in guided environments which support a context for learning. Students are "… empowered in this model to take on greater responsibility for their own learning …" while the teacher takes on a background role as the guide in their learning as "budding" mathematicians generating mathematical knowledge for their own needs (Borasi, 1992, p. 188). Other researchers in the area of pedagogy and cognition support this perspective, such as Noddings (1990) and Honebein, Duffy and Fishman (1993) with continued work on constructivism, Glaser (1992) in the area of expert knowledge, and Schoënfeld supporting the role of teacher in this process (as cited in Collins, Brown & Newman, 1989, p. 469). Brown, Collins and Duguid (1989) also move contextual learning a step further by promoting the importance of the expert as a role model in the learning process (p. 34). Research continues in developing, testing and revising sequences of mathematical activities and associated resources (i.e. technology), gradually moving from a constructivist psychological approach which focuses on student mathematical activity and reasoning towards a strong situated perspective (Cobb, 2000, p. 45).

The use of technology to explore mathematical concepts and to complete the problem-solving process is advocated in the secondary school curriculum (Roulet, 1997, p. 7). Sophisticated graphing calculators and computer algebra systems make "solving" a quadratic equation redundant vis-à-vis exploring and building mathematical concepts and otherwise inaccessible problems. Kaput (1992) believes there are "educational payoffs" in integrating technology in the student's learning process. Routine or complex computations are off-loaded on machines providing an experience-enriching effect. Norman (1993) also encourages the use of technology but warns of its distracting effect when students are engaged in the experiential mode of cognition. Nonetheless, research on the importance of visualization in mathematics by Eisenberg and Dreyfus (1991) supports the continued use of graphically representing mathematical models and Clements and McMillan (1996) demonstrate research which has been successful in promoting an understanding of mathematics using manipulatives. Research continues in developing a pedagogy facilitating mathematical modeling to broaden and develop the mathematical experiences of students (English, 1999).

The emphasis on preparing the student is reinforced in the MET document **The Ontario Curriculum, Grades 11 and 12 Mathematics** (2000). Changes in the revised curriculum have encompassed a new way of thinking about mathematics (MET, 2000, p. 3). A definition of mathematics moves beyond arithmetic and calculations that can be performed by technological tools such as calculators and computers. The heart of mathematics includes working with abstraction, working with algorithms, an awareness of culture in mathematics, mathematical modeling, patterns in nature and space, and the concept of proof. The focus of the pedagogy is on understanding these concepts and not on rote memory.

In addition to the curriculum content, delivery was planned to be more engaging and dynamic for students. Students were to be educated as active problem solvers and independent learners. Mathematics is embedded in rich learning tasks that challenge the student to analyze the problem and choose the appropriate tool to solve it. The evaluation process relies less on routine manipulation and regurgitation of facts; rather, a formative and summative evaluation process is employed. Investigations integrate the student's learning into a cohesive application that has meaning and significance in the real world.

Currently there are a number of perspectives on this issue of college response. These perspectives capture the issues of pedagogy, delivery, the use of technology and assessment. It is worthwhile to explore these issues in their context, to appreciate the source of these issues, to examine these perspectives and to realize a solution.

First, if secondary school graduates have taken college level courses and have achieved the described expectations, colleges will be in a better position to prepare incoming students for their chosen careers. Colleges are "finally" going to admit students who have the skills to demonstrate success in college. Therefore, nothing should be done to change college curricula for the student coming out of secondary school reform in mathematics. If these same students do not come to college with the required knowledge and skills, then secondary school has failed to prepare the student either through the curriculum and/or teaching of the curriculum. One concern with this stance is that mathematics curriculum built on sound research in mathematics pedagogy is replacing a dated curriculum. The focus of this dated curriculum is on rote memorization of facts and algorithms and algorithms that lack contextual meaning and relevancy to society's needs and expectations. There is concern that college faculty have not themselves engaged the new pedagogy driving curriculum reform. Roulet (1997) cited the fact colleges have not been heavily involved in the debates of high school curriculum (p.4). Battista (1999) warns that North American society's perspective of mathematics and mathematics education lies in its inability to understand contemporary mathematics and in its inability to understand the current research that has gone into mathematical pedagogy. Decisions (or the lack thereof) made at the college level could be reflecting a lack of exposure to progressive mathematics teaching thereby threatening the advancement of mathematics curriculum reform in college courses.

However, curriculum adjustments to college mathematics courses and other college courses are seen as being an important challenge. But how these issues are to develop is unknown at this time. Strategies to support the adult learner in the mathematics classroom are imperative to strengthen their mathematics knowledge of their chosen career and to contribute to society's view of mathematics. Borasi (1992) emphasizes that the support of administration is necessary for the success of the social-constructivist. Commitment to the teaching and learning process becomes a shared responsibility for all stakeholders in an institution (Borasi, 1992, p. 208).

Colleges traditionally follow a behaviourist curriculum model which goes counter to the constructivist model supported in the reform curriculum. Therefore, colleges should be planning for change in their mathematics curriculum: assessment, content, delivery, use of technology and evaluation to capitalize on the student who has developed strong critical thinking skills, and an ability to manage data, think critically and select the appropriate tools to solve problems through curriculum reform.

In response to growing concern that student secondary school mathematics marks will be low, colleges may consider lowering their mathematics course requirements for applicants. Another challenge is to develop pre-technology programs and general arts and science programs to reinforce the skills students need at the college level. Offering college preparatory programs for students who require an additional semester in high school is seen as an opportunity to provide college success skills.

The use of technology is prevalent in most college programs. Software programs such as Excel®, Minitab®, SPSS® and AutoCad® are common. The graphing calculator is tightly integrated into the secondary school curriculum and a key question is whether this is a needed component in the college mathematics curriculum. Certainly, as mathematics problems extend beyond the powers of paper and pencil calculations, more powerful tools will be required. Also, the usefulness of the graphing calculator and its ability to perform iterative functions is invaluable. Educating mathematics faculty as to the ubiquitous use of software or adoption of graphing calculators in a mathematics classroom will also be a challenge with respect to limited college budgets and a reluctance to add costs onto the students. Faculty too will need to appreciate that the college applicant will have greater problem-solving skills and less use of rote memory. Capitalizing on the use of all these tools and student skills will be a valuable step towards productive college mathematics teaching and learning.

The majority of colleges test students in mathematics upon admission; colleges, therefore, see mathematics pre-admission assessment as a continuing component of college life. Once again there is concern that students will not be coming to college with mathematics skills needed for success. These tests are norm based and emphasize rote memorization and use of algorithms provided to the novice mathematics learner. This contrasts with the philosophy to encourage students to develop algorithms from the patterns which come out of the learning experience. However, these tests are seen as vehicles for collecting "…data concerning the high school graduation outcomes required of college bound students", but, they also may prove to be "…restrictive, as they focus largely on discrete skills in arithmetic, algebra, measurement and trigonometry" (Roulet, 1997, p. 9). As mentioned in the background research to the mathematics curriculum, "…curriculum cannot be simply a list of topics to be covered" (Roulet, 1997, p. 3). It is possible that the assessment tests are unable to weave the individual tasks needed to solve complex mathematical problems into an integrated whole with meaning and relevance to the students. These assessment tests could prove to be the initial clash for the student between a dated and an emerging curriculum.

The implications of not responding to mathematics reform are evident. Students educated as problem solvers who are tested on algorithmic, rote memory computations may perform poorly, thereby subjecting them to a remedial curriculum steeped in traditional content and delivery. The student may lose interest and involvement in the classroom, subjecting mathematics to criticism and the inevitable question, "Why am I doing this?" The value of the independent, critical thinker will be lost in a static, skills based curriculum limited in context, driven by emphasis on manipulating algorithms and finding the answers to equations in sterile learning environments.

One difficulty facing post-secondary mathematics is the paucity of mathematics departments in the colleges. Due to a focus on programs, mathematics is typically under the direction of college programs and often lacks the local leadership needed to address specific mathematics education issues. The Ontario Colleges' Mathematics Association (OCMA) has supported discussions in the college sector with the goal of understanding and responding to the issues behind mathematics curriculum reform in Ontario. Its presence on the Fields Institute Committee for Mathematics Education places it in a prime position for a proactive stance.

Second, each college is an autonomous institution endorsing its own direction for its programs. The provincial education ministry does provide standards for college programs but it is up to each college to interpret these standards and implement them. As a result, mathematics courses can differ from college to college, limiting a student's ability to transfer mathematics courses. Therefore, curriculum reform at the college level needs to be widely accepted and adopted to facilitate this process of curriculum transfer.

Discussions regarding these and other issues are valuable. However, rather than looking at reactionary responses to reform, there needs to be an initiative on developing and implementing a set of principles for college mathematics education that are supported by educational research. Colleges should be responding from their own unique perspective to curriculum reform at this post secondary level and in Ontario vis-à-vis the secondary school mathematics reform. The process should include a literature review which provides the underpinnings to the principles of college mathematics education.

College faculty should be consulted and workshops mounted to facilitate the development of college mathematics reform in response to the revised secondary school mathematics curriculum. It is imperative to include experts in the field of mathematics pedagogy, curriculum and delivery. There is danger in not applying a social-constructivist pedagogical model, not capitalizing on the strengths of the learner and/or distorting the curriculum through a dependence on written materials which have not been published in the spirit of constructivist theory. Finally, no curriculum change should go without a pre-planned measurement of the effectiveness of that change. Its relevance is achieved when the implementation cycle is completed through an evaluation process.

The focus in mathematics education in Ontario has become more relevant, context driven and focused. Students are being educated with a post-secondary education in mind to meet the challenges of a new century. It is critical that post-secondary institutions, colleges and universities, address the issue of maintaining a consistent pedagogy in mathematics education. How the colleges will respond to these changes will be worth watching.

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Through the Sustaining Quality Curriculum projected initiated by the MET, colleges were recently asked for their response to the changes made in the secondary school curriculum. The Association of Colleges of Applied Arts and Technology of Ontario (ACAATO) is currently providing a link between colleges and MET with respect to summarizing the colleges' response to the review process.

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