Differentiating Instruction Using a Virtual Environment: A Study of Mathematical Problem Posing Among Gifted and Talented Learners

Dominic Manuel
McGill University

Viktor Freiman
Université de Moncton

Abstract

Meeting the needs of mathematically gifted and talented students is a challenge for educators. To support teachers of mathematically gifted and talented students to find appropriate solutions, several innovative projects were conducted in schools using funds provided by the New Brunswick, Canada, Department of Education. This article presents one such initiative: a collaborative project we developed with two middle school teachers to enrich the mathematical experience of their most advanced students. We worked with 40 students from both schools, involving them in creating mathematics problems using multimedia tools for the CAMI (Communauté d'apprentissages multidisciplinaires interactifs)[1] website. We analyzed the richness of the problems created by the participants (Manuel, 2010), as well as students' perceptions of their experiences, collected through semi-structured interviews. Students appreciated the experience, and recommended that the project be continued in following years. Most of the problems created by students were moderately rich, and included multiple steps, but were similar to those used in classrooms. Some students stated that they were more comfortable solving problems than creating new ones, which suggested that they found the task challenging. Our results showed that specific programs for students interested in mathematics could provide positive experiences and challenges. Our research also suggested that problem posing in mathematics classrooms needs to be investigated in more depth.

Keywords

gifted students, talented students, middle school mathematics, innovation, online problem solving, problem posing, virtual learning environment.

Introduction: Context and Issues

Educating gifted and talented students in mathematics is an unsettled educational issue internationally (Singer et al., 2016). The situation is similar within the New Brunswick, Canada, school system. The aim of the provincial government is to support all students to become

Corresponding Author:
Dominic Manuel, Ph.D Candidate, Department of Integrated Studies in Education, Faculty of Education, McGill University, 3700 McTavish Street, Room 244, Montreal, Quebec, Canada H3A 1Y2
Email: Dominic.Manuel@McGill.ca

 Citation: Manuel, Dominic & Freiman, Viktor. (2017). Differentiating instruction using a virtual environment: A study of mathematical problem posing among gifted and talented learners. *Global Education Review*, *4*(1). 78-98.

educated and productive citizens, capable of reaching their full potential (New Brunswick Department of Education and Early Childhood Development, 2011). This mission, however, is not fully realized when it comes to the education of gifted and talent students. A decade ago, Mackay's (2006) provincial report on school inclusion raised this issue. The report presented concerns about the lack of agreement on a clear definition of gifted and talented students, which could be an obstacle to accurate identification. The report also claimed that pedagogical approaches, and the curricula used in classrooms, were not suitable for educating gifted and talented students, and that schools do not provide these students with adequate opportunities to reach their full potential. In addition, Mackay argued that, in terms of inclusion, all students have specific gifts and talents that teachers need to appreciate and nurture. However, the existing resources or mechanisms that could provide gifted and talented students with opportunities to excel in their studies and to develop their specific talents were insufficient or simply missing (Mackay, 2006).

These issues, among others, motivated the New Brunswick Department of Education to develop a provincial education plan entitled *Kids Come First*. The goal of *Kids Come First* was to support innovative teaching practices that would stimulate students in language arts, mathematics, and science while meeting the specific learning needs of all students, including the gifted and talented (New Brunswick Department of Education, 2007). This plan stressed the need for creating closer collaboration between schools, local colleges and universities to help support innovative practices. A result of this plan was that teachers attempted to innovate and enrich teaching and learning approaches in their schools. Teachers received funds to purchase necessary resources, enabling the implementation of these initiatives. The project we describe in this article is one of these endeavors.

The project described in this article consists of the efforts of two teachers from two middle schools (grades 6 to 8) located in an urban area, who initiated a collaboration with the local university-based research team, CAMI, of which both authors were members, to allow their advanced students to experience more challenging mathematics activities that went beyond the regular curricula (Barbeau & Taylor, 2009). Both participating teachers were responsible for organizing school-wide activities for gifted and talented students during the school year. The CAMI team had been providing enrichment resources in mathematics using an online problem-solving environment. Although the CAMI website was not specifically designed for gifted and talented students, it had the potential to provide richer and more challenging problems than those present in mathematics textbooks (Freiman, Manuel, & Lirette-Pitre 2007; Freiman & Lirette-Pitre, 2009). We agreed with the teachers to involve their students in the process of creating new problems for the CAMI website. Besides enriching their experience in mathematics, this type of activity had the potential to enhance students' creativity, which is an important aspect that should be part of the mathematics curricula (Leikin, 2011). In this article, we focus on analyzing the problems created by the students for the CAMI website and students' overall perception about the experience collected by means of semi-structured interviews.

Meeting the Needs of Gifted and Talented Students in Mathematics

The difficulty of meeting the needs of mathematically gifted and talented students in regular classrooms is not new to researchers and teachers. Mathematically gifted and talented students lose interest in mathematics by the end of middle school because they are not stimulated intellectually by the routine tasks proposed in classrooms, which are perceived as too easy, repetitive, and are solved by applying strategies that students already know and have mastered

(Diezmann & Waters, 2004). More challenging tasks are therefore needed to nurture curiosity and to develop creativity and scientific thinking skills in the mathematically gifted and talented (Johnson, 2000; Taylor, 2008, Singer et al., 2016).

One possible method to meet the needs of gifted and talented students is to create or pose problems which are recognized as challenges that go beyond problem solving (Sheffield, 2008; Leikin, 2009). Studies also point to the importance of problem finding and investigation activities (Rosli, Capraro & Capraro, 2014) to foster, among other aspects, creativity in these students (Singer, Pelczer & Voica, 2011). Few studies, however, have dealt with online mathematical content created by gifted and talented students. We explore this issue in this article.

One of the enrichment activities we developed in this study challenged students to create mathematics problems that would be posted on the CAMI website. While most existing problems were presented as text with pictures or tables, our participants were invited to explore the multimedia tools available on the website, such as the audio and video options that allowed the addition of multimedia components to the text of the problem. These tools were not previously used, so this task was a novel contribution for the website in terms of content (new problems) and the use of multimedia tools (new affordances for the users). At the end of the project, half of the students volunteered and participated in individual semi-structured interviews (with parental consent) during which they shared their experience in the project throughout the school year. We analyzed the richness of the problems created by the students and the data about students' perceptions of their experiences from the interviews. The following questions guided our study:

1. What types of problems were created by the middle school mathematically gifted and talented students in terms of mathematical content, context and richness?
2. How did the gifted and talented students perceive their experiences in the project?

Conceptual Framework

Renzulli's Three-Ring Model and Mathematical Giftedness

As mentioned in the first part of the article, meeting the needs of gifted and talented students is complex and cannot be resolved with simple educational tasks. Several types of programs and activities have been developed and are mentioned in the literature as promising options to meet the specific learning needs of these students. Among them, problem posing and problem solving seem to remain at the heart of debates, as shown in a recent review conducted by Singer et al. (2016). The authors cited joint publications of the National Council of Teachers of Mathematics, the National Association for Gifted Children, and the National Council of Supervisors of Mathematics which suggested the inclusion of an additional standard to the Common Core Curriculum[2] focusing on mathematical creativity and innovation. The standard would encourage and support all students in "taking risks, embracing challenge, solving problems in a variety of ways, posing new mathematical questions of interest to investigate, and being passionate about mathematical investigations" (Johnson & Sheffield, 2012, pp. 15-16). Recent studies showed the importance of problem posing for the development of mathematical creativity and talent (Singer, Ellerton, & Cai, 2013). In fact, many years ago, Renzulli's Three-Ring Conception of Giftedness inspired many researchers to search for winning combinations of activities to foster high-order mathematical abilities, task commitment, as well as creativity (Renzulli, 1986). Figure 1 presents his model.

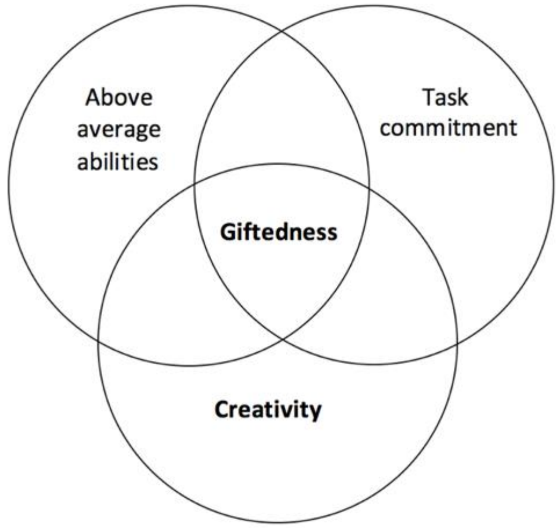

Figure *1*. Renzulli's (1986) Three-Ring Conception of Giftedness.

In later work, Renzulli and Reis (1997) proposed three independent types of enrichment to differentiate instruction in regular classrooms. Type I enrichment activities are general exploration experiences to attract students interested in a topic. Type II activities provide group training that let students practice the skills and acquire the knowledge they will need to conduct their own activities in their field of interest. Type II activities foster creative and critical thinking, help students to learn how to learn, to use advanced level reference materials, and to communicate effectively. Type III activities are individual or small group in-depth investigations of real problems based on students' interests and skills. Such activities provide opportunities for gifted and talented students to investigate different topics (not always taught in schools), and to communicate findings in various forms, such as journal articles, oral presentations, books, or plays (Renzulli & Reis, 1997).

Using this line of thought, the collaborating teachers and researchers (the authors) developed type II and type III enrichment activities and used Renzulli's framework to investigate students' creativity in terms of the richness of the problems they created, as well as their perceptions about the project, which we relate to the task commitment. Finally, the challenges reported by the students were considered as indicating possible gains in the development of their natural mathematical abilities, which is the third element of Renzulli's Three-ring model.

Creativity and Richness of Mathematical Problems

Scholars view the concept of rich problems differently. For instance, researchers from the Enriching Mathematics (NRICH) website[3] defined rich problems as problems that have multiple entry points, can have more than one solution, open the way to new territory for further exploration, and force students to think outside the box and become more creative. Stein, Grover, and Henningsen (1996) described rich tasks as those that ask for high cognitive reasoning from students. Piggot (2008) saw a rich problem as one that possesses many characteristics that altogether offer opportunities to meet the needs of learners at different moments, in an environment in which the problem is posed and is influenced by the questions asked by teachers and the expectations from students.

To investigate this variety of characteristics, Manuel (2010) conducted a review of the literature to determine features or characteristics in the text of problems that could identify them as rich. He argued that a problem is rich when it respects many of the following features found in the literature: it is open-ended (Diezmann & Watters, 2004; Takahashi, 2000); it is complex (Diezmann & Watters, 2004; Schleicher, 1999), it is ill-defined (Murphy, 2004), it is contextualized (Greenes, 1997), and it has multiple possible interpretations (Hancock, 1995).

A problem is *open-ended* if it has multiple correct answers or can be solved using various strategies (Takahashi, 2000). Though some might argue that open-ended problems automatically bring both multiple answers and strategies, Manuel (2010) saw those two criteria as distinct since some problems could lead to multiple answers, but could be solved using the same strategy.

A *complex* problem is one that respects the most of the following criteria: more than one step is needed to solve it (Schleicher, 1999); it implicitly or explicitly asks to find patterns, generalize results or make mathematical proofs; it explicitly asks to make different choices and justify them; and it explicitly asks to create other problems or questions to explore further (Diezmann & Watters, 2004; Freiman, 2006).

A problem is *ill-defined* if it is missing certain data (information) which are necessary to solve the problem, and that data can either be found by searching other sources, or it can be explicitly defined by the problem solver (Murphy, 2004). Additionally, a problem is ill-defined if it contains unnecessary data or does not present enough information for solution (Kitchner, 1983).

A problem with *multiple possible interpretations* encourages different ways of thinking (can be seen in different ways) about the problem, leading to different possible answers (Handcock, 1995). These could qualify them as open-ended. Manuel argued that some problems have multiple interpretations, but each interpretation has one correct answer.

The *contextualized* problem is one where the mathematics is presented in real life or fictional situations (Greenes, 1997).

Figure 2 illustrates all characteristics of a rich mathematical problem used as criteria to assess the richness of each problem on the CAMI website (Manuel, 2010). We use these criteria to analyze the richness of students' problems.

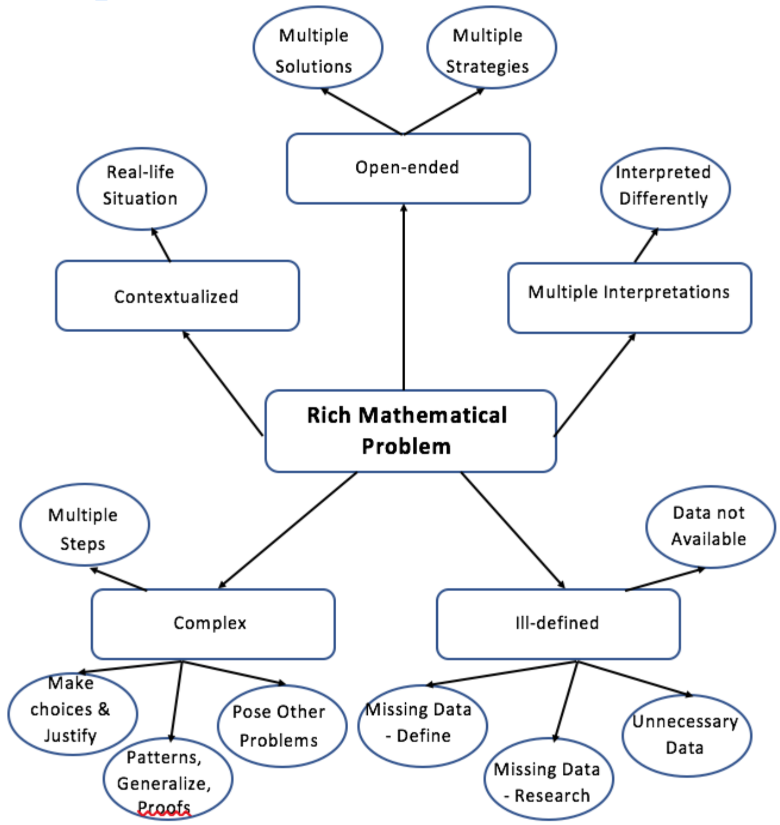

Figure 2. Model of the richness of a mathematical problem (Manuel, 2010).

Perceptions and Task Commitment

From the literature, we found multiple views about programs for the gifted and talented from students' perspectives. For example, Adams-Byers, Whitsell and Moon (2004) reported conflicted perceptions of homogeneous grouping expressed by gifted and talented students. They saw homogeneous grouping as an opportunity to be challenged, and appreciated the opportunities for deeper learning, but also felt a need to be with their peers to socialize. Yang, Gentry and Choi (2012) found that gifted and talented students had more positive perceptions of pull-out classes compared to the regular classes. Moreover, Rawlins (2004) reported that grouping gifted and talented students in an acceleration program did not harm their social development and well-being. Gross (2006) found similar results in her longitudinal study on acceleration. Doucet (2012) also obtained similar results in his study on students' perception of an acceleration program in mathematics, implemented in one school in New Brunswick.

Regarding mathematical problem posing, studies reviewed by Silver (1994) reported that such experiences increased interest in mathematics, engagement with problem solving, and that they developed a positive attitude towards mathematics in students. Another study by Silver et al. (1996, cited in Brown and Walter (2005)) indicated a cognitive commitment in the context of problem posing which is associated with a complex task setting. Sharma (2013) suggested that posing difficult problems to their friends (that they would not be able to solve) might stimulate creativity in gifted and talented students bringing them additional pleasure along with the task commitment.

Method

Participants and Project Description

During one school year, 40 francophone students from grades 6 to 8 participated in the project. The first school had 28 students: 16 boys and 12 girls. Eight were in grade 6 (4 boys, 4 girls); eight were in grade 7 (5 boys, 3 girls); and 12 were in grade 8 (6 boys, 6 girls). The second school had 12 students: 11 boys and one girl. Eight students were in grade 7 (all boys) and four in grade 8 (3 boys and 1 girl).

Students were selected by their mathematics teachers, who based their judgment on the student's academic performance in the regular curriculum in conjunction with in-class observations. The mathematics teachers made a list of students they recommended for the enrichment program. The selected students and their parents made the final decision on whether to participate. The participants were provided with individual laptops, multimedia tools, and software purchased with funds awarded by the New Brunswick Department of Education. This provided students with easy access to a variety of technological tools along with high-speed internet access during the entire project.

We worked with students by constructing and enacting enrichment activities on a weekly basis for one hour per week. During this period, students were pulled out of their regular class. We also offered students opportunities to do activities prepared by pre-service teachers enrolled in the undergraduate primary education program offered at the Université de Moncton, such as measuring the perimeter of a building, a complex task helping them seeing mathematical connections in a real-life context (Freiman et al., 2011). The undergraduate students were enrolled in mathematics education courses that we taught. Participants came to the university campus to participate in the activities. Students also participated in a provincial annual mathematics competition held on the university campus, an out-of-school activity that was shown to be fruitful in the education of gifted and talented students (Bicknell, 2012).

During the last four months of the school year, students were given the task of creating new problems for the CAMI website. At the beginning of this task, students participated in three workshops given by members of the CAMI team. The first workshop was given by the website programmer. Students learned how the site was created from both the design and programming perspectives. The second workshop focused on how solutions submitted by members to problems posted on the CAMI website were assessed, and how feedback was provided to its authors. The last workshop focused on how to create rich mathematical problems. During this workshop, the participants discussed their perceptions of characteristics that make a rich mathematical problem. We did not explicitly train them in creating rich problems, and we did not propose any criteria proposed in the literature. However, it was interesting that students came up with characteristics similar to those suggested in the literature, and also chosen for Manuel's (2010) model of the richness of a mathematical problem. These workshops consisted of group training sessions to support students in developing the skills needed for tasks, as proposed in Type II enrichment activities (Renzulli & Reis, 1997).

Following the workshops, participants began their own investigations (according to Type III of Renzulli's model) and created three sets of problems. Students worked in groups of three or four. They were free to choose the types of problem they wanted to create. Those problems were posted on the CAMI website and could be solved by the members of the virtual community. Students worked on problems with autonomy, and also had the opportunity to discuss their work with us. We prompted them with questions to help them to reflect on how to improve their problems and make them richer. The two teachers also helped with this process, and managed all the organizational aspects of the project.

Originally, three cycles of the activity were planned. The first cycle encouraged students to design their problems in a textual format, which was how problems were posted on the CAMI website. For the two other cycles, the students were supposed to add multimedia support which could support other students with the reading of the text of the problem (audio) and eventually with understanding its context (video). The use of dynamic web 2.0 tools (audio and video) enriched practices by meeting the "Net Generation's" learning style of not only being the users of the online resources but also creators of online content (Depover et al., 2008). Unfortunately, as the school year came closer to an end, it became increasingly difficult for all students to attend our weekly meetings. Some students had to remain in their regular classes for assessments and end of year activities. By the end of the project, all groups created at least one problem (in textual format), six groups succeeded in creating a second problem that included an audio file and one group created a problem that contained a video.

In total, 23 problems were created and posted on the CAMI website. Other members could solve the problems and submit their solutions electronically. Solutions came from students from all over the province, and elsewhere. This provided participants with opportunities to see how others solved their problems, to analyze the solutions, and to write feedback to the authors of the solutions. In the last part of the project, participants had an opportunity to assess solutions to their problems that were submitted by other members, and to write formative feedback to them. Because of the circumstances mentioned above, only 15 participants participated in this portion of the project.

At the end of the school year, we collected students' perceptions about the project by means of semi-structured interviews. The goal of the interviews was to get feedback on the project and determine its impact on meeting the needs of the gifted and talented. All the participants were invited to take part in individual 20 to 30 minutes semi-structured interviews at the end of the school year with one of the authors. Nine students (6 boys, 3 girls) participated with parental permission from the first school, and 11 students (10 boys, 1 girl) participated in the second school. The interviews were audio-recorded and then transcribed by a research assistant. During the interviews, participants were questioned on their motives for joining the project; their interests and abilities in mathematics; their experiences in the project in general; the experience of creating problems on the CAMI website and assessing members' solutions; their interest in continuing in the project in the following years; and their recommendations for the following years.

Data Analysis

For our first research question, we used Manuel's (2010) model to investigate the richness of each of the 23 problems created by our participants. The rubric (Table 1) shows if the problem possessed each feature and met the corresponding criteria. The shaded portions represent elements taken away after validation of the rubric. The feature "Problems with

Multiple Interpretations" and the criterion "Problem contains unnecessary data" (feature ill-defined) were taken out since the coders found it too difficult to assess this criterion. The criterion "Problem contains insufficient data, which makes it impossible to solve" was also taken out because none of the problems respected that criterion. The two criteria in Manuel's model on missing data (feature ill-defined) were combined into one because the coders could not differentiate the two (see * in Table 1).

We used the rubric to analyze the richness of each problem. We read the problem and then each criterion individually. If the criterion was respected in the text of the problem, we added a checkmark next to it. Finally, we counted the number of criterion checked. The sum provided a measure of the richness of the problem. A problem could vary from 0 to 8 in terms of its richness. We also looked at the relative frequencies of each criterion respected in the problems. In addition, qualitative notes were made for each problem to see themes that emerged from the student's creations, such as the concepts involved and the contexts of the problems. We used this model since the criteria align with the mathematical culture that is implicitly (or sometimes explicitly) defined in the provincial (Direction de la mesure et de l'évalution, 2010), national (Pan-Canadian Assessment Program, 2010), and International (Organisation for Economic Co-operation and Development, 2000) assessments.

Table 1
Rubric used to assess the richness of a mathematical problem

Feature	**Criterion**	**Respected (✓)**
Open-ended problem	Problem has multiple correct answers	
	Problem has multiple appropriate strategies	
Complex problem	Problem requires multiple steps to get answers	
	Problem asks to make and justify choices	
	Problem asks to find and explore other questions	
	Problem asks to find patterns and generalize results	
Ill-defined problem	Some or all necessary data or information are missing in the text of the problem*	
	Problem contains unnecessary data	
	Problem contains insufficient data, thus it is impossible to solve	
Contextualized problem	Problem presented in a real or fictive situation	
Problem with multiple interpretations	Problem can be interpreted in more than one way	
RICHNESS OF THE PROBLEM (# of criteria the problem respected)		

For our second question, we used a thematic analysis of the corpus from the interviews (Howitt & Cramer, 2011). In the following section, we present the results of both analyses.

Results

Richness of the Problems Created by the Students

The richness of the mathematical problems created by the participants varied from 2 to 6 out of a possible 8 (Mean = 3.39, Standard Deviation = 1.2). On the scale of mathematical richness, seven problems received a score of 2; 11 problems were scored as medially rich – six with a score of 3 and five with a score of 4; the remaining five problems received the highest scores of 5 (4 problems) and 6 (1 problem).

The three most respected criteria used in Manuel's (2010) model were contextualized problems (22 problems), problems that could be solved using different strategies (19 problems), and problems that needed multiple steps to find answers (19 problems). The only problem we did not consider as being contextual was one that used a reference to solving a routine exercise problem from a math textbook. All 23 problems required more than one step of calculation to find answers.

Seven of the problems created by our participants contained missing data. For instance, one group created a problem where members had to calculate the number of days in World War 1 and World War 2 combined. The start and end dates were given in the text of the problem for each war, but the information about leap years was missing, which could make the problem ill-defined. That aspect of the problem could have been difficult to detect. Thus, not only did the problem require the identification of missing data, but the solution also required the solver to find a way to obtain that data from non-specified sources. In addition, in two problems, the text asked the solver to make choices between options and to justify the selections. For instance, in one problem, the question asked for a choice of the best type of carpeting for a room in a house based on some given information. Finally, in one problem, responders were asked to find a pattern in a sequence of numbers written on a standard chessboard.

Looking at the mathematics involved in each problem, we noticed that most problems focused on arithmetic concepts. Most problems could be solved using the four basic operations. What was interesting, was that in many of the problems the participants could add some relationships between quantities, like "three less than," "twice as much as," "one more than." Only a few problems involved fractions, proportions and percentages. The problems that were not focused on arithmetic dealt mostly with measurement or space. Most of those focused on finding perimeters (or circumference), area, and time measurement. For one problem, Pythagoras' Theorem was needed to calculate the answer. One problem focused on working with patterns. There were no problems dealing explicitly with probability. In was interesting to notice that half of the problems related to measurement also involved arithmetic. The context of those problems was about finding a price for some work on a surface.

Regarding the context of the problems, we observed three main categories of problems: problems related to students' everyday lives, problems related to students' future lives or adult lives, and fictional problems. Most of the groups created contexts related to students' everyday lives and activities. In this category, a first theme that emerged was *families* (2 problems). One of them was to find the number of boys and girls in a family, while another was to find the age of each member of the family. A second theme that emerged was *sports* (4 problems). The sports involved in the problems included running, biking and hockey. A third theme that emerged was *electronics* (2 problems). One problem described a battle between two robots, and another focused on getting the correct dimensions for an electronic carpet to be placed in a playroom. The fourth theme that emerged was *hobbies* (4 problems). Shopping was a context that appeared in two problems. The articles that were being bought were things that children are interested in. Two problems focused on vacations and on popular music. The last theme that emerged was *school* (1 problem). This problem referred to the problematic situation of the prices for meals at a school cafeteria.

For problems in the categories of adult lives or future lives, we found two themes in context: *careers* (5 problems), and *finances* (2 problems). For problems related to careers, the contexts were related to building houses, comparing fields, observing the growth of a tree and a forest. The two problems dealing with finances were related to situations that students could face in their future life. One was on saving money for postsecondary studies, while the other was determining the total salary an employee would make over a period of time.

The last category of problems was fictional contexts. There were only two problems in that category. One was inspired by the movie *Twilight* while the other involved a fictional chessboard and royal family.

Figure 3 is an example of a problem created by a team of three students in grade 7. This problem received the highest score of 6 for richness. The problem is translated from French.

Since the question of the problem is ambiguous, the problem was open-ended and ill-defined. Since the popularity of music groups can be defined in multiple ways, the problem thus had multiple interpretations, and multiple solutions. Depending on the definition, multiple strategies and steps could be taken to solve the problem.

Mr. Bastarache is a journalist for a music magazine. In their next issue, he decided to write an article on the profiles of the four most known rock groups. The following table is the data he collected through research. Which group made the most profit? Which group do you think is the most popular? Justify your answers.

Name of Group	Average concert ticket Price ($)	Average number of fans at concerts	Price of a CD ($)	Number or CDs sold
A	126.00	7,759	15.50	100,056
B	107.00	50,900	9.72	3,000,000
C	89.93	1,004,361	5.97	1,098,975
D	102.12	193,384	13.04	2,009,789
E	76.06	170,488	19.04	1,000,001

Figure 3. Example of a problem that received a score of 6 for richness.

Perceptions of Students' Experiences in the Project

Three main categories of responses emerged from the interviews: cognitive aspects, social aspects and affective aspects. We found themes that emerged for each category.

Cognitive Aspects

Three main themes emerged from the data in relation to cognitive aspects. The first one was the *need for intellectual challenge*. All the students said that one of their main reasons for participating in this project was to get more challenge in mathematics. This finding is well grounded in existing literature, for example Sheffield (2008).

The second theme that emerged was *opportunity to improve their mathematical abilities*. A couple of students saw this project as an opportunity to improve their mathematical abilities and to be better prepared for what was to come in following years. The need for challenging tasks, to move faster through the curriculum, as well as having more opportunities to foster mathematical abilities is well documented in the literature on mathematically gifted and talented students (Diezmann & Watters, 2002; Johnson, 2000).

The third theme that emerged from the interviews was the *opportunity to learn new mathematical content*. The participants were expecting to learn something new in the project. The project allowed students to learn new aspects of mathematics that was exciting to them. We suggest that this aspect improved their commitment to the learning tasks, even if they were more difficult. One student mentioned that (quotes are translated from French):

> Yes, this project influenced my attitude. Before I came, I thought that math was boring because I was never learning something new or something that impressed me. It was always things that I already knew or just logic. But with this project, we learn new things and I'm just like WOW! I never knew that existed. And it makes me love math more.

This finding is consistent with the existing literature (Wilkins, Wilkins & Oliver, 2006).

One of the new learning opportunities was creating problems. All students said that they liked creating problems on the CAMI website and assessing the solutions, and they were proud of the work they accomplished. All the participants mentioned that the task provided students with a real challenge that demanded creativity and imagination. One student said, "It was fun. It was a challenge because it is much harder to create a problem compared to solving it. I love difficult tasks. If there is no challenge, it's boring." In addition, most mentioned being proud of their final product because they had to think a lot about how to put challenges in the problems they created. One student mentioned feeling proud because her mathematics teacher had the rest of the class go on the website to solve her problem.

Although creating problems was a new learning experience, when the participants were asked if they preferred creating problems or solving them, opinions were divided. Those who preferred solving problems said that they wanted a fast challenge, and it took more time to create than to solve a problem. A few mentioned that they liked reading the ideas of others in the problems, and they did not feel comfortable with the task of creating quality problems. One student said, "I learn better when I am challenged by others, not when I challenge others." Some students seem to have found their problems too easy.

Students who preferred creating problems gave as reasons that it was more challenging, and that it demanded more creativity. One student added, "I love French and I love to write, create and imagine. And I could choose, if I wanted the problem to be really difficult, or if I wanted to put a trick in it or not."

These findings demonstrate the complexity of problem posing as a mathematical and a human activity, reflecting the interplay between cognitive and affective aspects of learning as mentioned by Silver (1994). Yet, the field of mathematical problem posing remains under-researched and our data pointed to the need to pay attention to its specificity in the context of gifted and talented learners.

Regarding the next steps of the project, some students said they would like to have enrichment in other subjects, such as science, and to be able to use technology more often during the project. Students also asked for special accommodations such as being able to advance faster than other students. In fact, most students would like to be able to work at their own pace and not have to wait for other students to understand the mathematical concepts being taught and practiced in the classrooms. One third of students said that they would appreciate being in a different mathematics course where they could learn new things at a faster rate. One student seemed to feel confident enough in his mathematical abilities and said that he would appreciate skipping a grade if he knew the content in the curriculum. Another student said:

> In our classes, tell our teachers that if we feel comfortable enough with the content that we could do the test before the others. And after, we could work on much harder content. I would love to learn stuff like, I will be in grade 8 next year, and I would like to learn stuff that we learn in grade 9 and higher levels. And I also love to solve enigmas.

Social Aspects

Three themes emerged from the interviews related to social aspects. The first theme was the *opportunity to be in a different learning environment*. Participants appreciated working in smaller groups. This motivated some to participate in the project. "I loved the fact that we were in small groups. We were like eight people in our group … You can learn better that way." This finding aligns with the work by Diezmann and Watters (2002).

A second theme that emerged was *interactiing with other students in the group*. Not only was the size of the group a positive aspect for our participants, but most students also appreciated collaborating with other students that have similar learning abilities in mathematics (finding confirmed by Doucet (2012)). However, the amount of time did not seem to be enough for the participants. Many recommended optional times for enrichment activities and even suggested two hours per week for the project.

A last theme that emerged was the *opportunities that some activities provided beyond the project*. Some activities had an impact that went beyond the original goal of enriching the participants' personal experiences. One student talked about sharing his experience of playing Bachet's game (see Applebaum and Freiman (2014)) with his friends:

> When we did that game with the chips, you could take away 3, 2, or 1 and all, when my friends came over, I showed them the game and then we played it and after a while, we changed the rules. We added more chips and took away like 2 to 4 instead. And we were always trying to figure it out to win.

Affective Aspects

Four themes emerged from the interviews related to affective aspects. The first theme was the student's motivation and interests towards mathematics. All participants interviewed mentioned that mathematics was one of their favorite school subjects. This was one of their reasons for participating in the project. However, almost all pointed out that the slow learning rate of regular classrooms, and the lack of challenge sometimes influenced their motivation and their interest. Most of them shared their concerns about the repetitiveness and easiness of regular classroom activities. Those same students also said that they did not like doing countless worksheets when they had mastered the concept after doing one simply because other students required more time to learn the concepts. These findings are similar to those noted by Feng (2010).

A second theme that emerged was the *excitement that the activities brought*. The participants mentioned appreciating all the activities they had done during the project. However, the activities organized outside of the school setting or with help of the members of the local community seemed to have been the most exciting for the participants. All participants found the visits to the Université de Moncton rewarding. Most found the experience with the CAMI team very interesting, especially the problem posing experience since it was new when compared to solving problems.

The third theme that emerged was *the emotions the activities evoked*. We claim that the experiences brought various and sometimes strong emotions to the students. When asked about how they felt when faced with a challenging task, most students said that they were frustrated because they did not know how to solve it immediately, but they were always motivated to solve it. Their emotions were sometimes strong, but they changed during the process, transitioning from one extreme (frustration) to another (euphoria with success). Some students mentioned feeling *stupid* for not being able to initially solve a problem. One student summarized these points by saying he felt: “frustrated, amused, and a bit mad at the end for not getting it when it wasn’t as hard as I thought it was at first”. This mainly positive feedback supported findings from previous studies, such as VanTassel-Baska et al. (2004).

The last theme, *the amount of time allowed for the project*, seemed to have been a source of disappointment for the students. While sharing their positive experiences about the project, students were unanimous in saying that not enough time was devoted to the project. They all wanted more than one hour per week, even if they found some tasks were difficult to solve. In addition, some expressed their disappointment when they had to miss a week because they had to remain in class for a test or other activity. All students asked that more time be allowed for this project. They felt that one hour per week was not adequate.

When discussing recommendations, all students mentioned that they would be sad, disappointed, and even mad if this project was not available in the next school year. One student said loudly, ”I’m starting a strike! This project is a 10.”

Overall, when reflecting on their experience, students mentioned that this learning opportunity was amusing and very challenging, and that it gave them the chance to work with other like-minded students that found mathematics easy, with whom they made new friends. A student summed it up by saying that, “It’s not every day that you learn something new and have fun at the same time.”

While students’ responses seem to reveal positive impacts related to the cognitive, social and affective aspects, it is the combination of all three that appears to be the “winning condition” for their overall satisfaction with the project.

Discussion and Concluding Remarks

Developing and implementing programs for gifted and talented students is a very complex and dynamic task that is usually well received by students. When involved in such programs, the gifted and talented report feeling more motivated, challenged, and rewarded, with higher intellectual level activities in a stimulating environment that contributes positively to their social and emotional development (Reis & Renzulli, 2010). However, gifted education is a topic that requires particular attention, even after the first decade of the 21st century (Reis & Renzulli, 2010; Singer et al. 2016). According to Koshy, Ernest and Casey (2009), such programs should stimulate the interest of students, and provide exposure to the concepts and ideas of mathematics at an appropriate level of cognitive challenge. The results of our study are aligned with the preceding points.

Regarding the problems created, the content respected similar criteria to ones mentioned in the Manuel's (2010) model. The mean score of richness was 3.39, which is similar to the score of richness in Manuel, Freiman, and Bourque's (2012) study of 180 problems created by experts, in which the mean score for richness was 4. The criteria used most often in the problems created for this study were problems with contexts, problems with multiple strategies, and problems with multiple steps. We were not surprised with this result as students are asked to solve these types of problems in their regular classrooms. These types of problems are proposed in provincial examinations in grades 6 and 8 (Direction de la mesure et de l'évaluation, 2010). Additionally, even though students created most problems in arithmetic, measurement, and geometry, it was interesting to see that students could implement more than one mathematical concept within a problem. The diversity of the contexts used in their problems, especially when half had contexts related to their lives, was also interesting to see. However, it appears more challenging to create more open-ended and ill-defined problems that have more than one correct answer, have multiple interpretations, encourage students to find patterns and generalize results, as well as make choices and justify them.

It seemed to be more difficult to implement these types of problem, even when created by experienced adults. In fact, these criteria were less frequently respected by experts who created the problems for the CAMI website according to Manuel, Freiman and Bourque's (2012) study. This finding sheds light on the importance of increasing opportunities for students and teachers to create and pose rich mathematical problems. More research is needed as to how this can be done and how the CAMI website could better promote differentiation in its members using Renzulli's (1986) model.

Manuel's (2010) model is an alternative way to assess the richness of mathematical problems. The results of this study did confirm limitations of the model. First, the model does not consider the mathematical concepts involved in the problem. This criterion was not implemented in the model because in the CAMI website, students of any grade can choose to solve any problem of interest to them (Freiman & Lirette-Pitre, 2009). The results of our study lead to a reflection about the importance of the mathematics involved in the problem. For instance, the problem in Figure 3 received a high score in terms of richness. However, the mathematics involved in solving the problem involved only basic operations. Is the problem then rich? Second, Manuel's (2010) model was used to assess the richness of the problems by reading the texts. The model did not consider the various ways in which a problem can be presented to students in a classroom setting. Even though some problems received low scores in terms of richness, there are multiple alternatives that can be done in classrooms by *opening up* the problem, which would make it richer. For instance, one problem consisted of calculating the total price for meals at a school cafeteria if the price of one meal was $3.25. In terms of richness, this problem received a score of 2. However, students in a classroom could investigate with different prices and percentages and attempt to find patterns and generalize results, thus bring deeper mathematical concepts and processes to the task.

As for students' perceptions of their experience in the project, our results highlighted multiple aspects. First, gifted and talented students appreciated the experience of being involved in an innovative project in which they could devote part of their school time doing more complex and challenging mathematics in a different way than in their regular classroom. Namely, students felt enriched by new and challenging tasks that gave them the opportunity to discover different aspects of mathematics, to solve and create new problems by using technology, and to collaborate with people other than their teachers. These results were similar to those of Colangelo and Kelly (1983) who found that, compared to other students, the gifted and talented desire to participate in special programs for the gifted and want to spend most of the day working on activities and with other gifted and talented students rather than with general students. They also appreciated the experience of using technology. This supports Siegle's (2005) claim that the Internet is the most significant technology available to gifted and talented students.

Second, several participants found themselves in quite unusual situations when presented with tasks they could not solve after a first attempt. The experience of having difficulty, rarely experienced by gifted and talented students in their regular curriculum-based activities, made some participants confused or even angry, forcing them to persevere to solve a specific task. Ernest (1985) explained this effect on cognitive performance and abilities as a result of the interaction in the *success cycle* which includes a positive effect, including attitude and motivation towards mathematics, effort, persistence and engagement with cognitively demanding tasks, and achievement and success at mathematical tasks. Our data supports these findings.

Third, the participants reflected on the experience of posing mathematical problems and sharing them with others in an online community. This type of learning activity was viewed by researchers as important to the development of creativity in students allowing for manifestation of diverse thinking (Felmer, Pehkonen & Kilpatrick, 2016). In this respect, our data suggested a mixed reaction from the students. While being generally happy with their work and results, many felt that creating good (non-trivial) problems was a difficult task and they did not have enough experience in creating problems and making them more interesting. We also hypothesized that when facing intellectual challenges, there is a need to mobilize cognitive and socio-affective abilities not yet captured in research and practice. More studies are needed to understand this hypothesis at a deeper level.

Reflecting on the project at a more global level, we can extend our discussion by emphasizing several issues that could be studied in the future. Namely, simply stating that the gifted and talented population in public schools is underserved does not provide information regarding the services that must be provided, the form they should take, and how to make isolated opportunities more effective and sustainable.

Our questions were also directed towards the issue of homogeneous versus heterogeneous grouping for gifted and talented students. According to our participants, working in small groups and not having to wait for other students to complete tasks suited them. Some students revealed frustrations about inadequate nourishment for their minds in regular classrooms. This finding corroborates Mackay's (2006) findings. Time allocated to the project is another factor to be questioned. Namely, providing pull-out services created additional time pressure; many students receiving pull-out services said that the amount of time provided for the project was insufficient. They preferred being able to have more time to work on more challenging tasks. Moreover, that time should not conflict with other school-related activities, such as the regular tests they were still required to accomplish. This issue needs to be addressed in the future.

Also, our participants were aware of their learning needs. Some requested moving faster through the curriculum while in their classes, or if possible, in a classroom with other gifted and talented students. According to Vaughn, Feldhusen and Asher (1991), there is a small to medium positive effect on pull-out programs on academic achievement and critical and creative thinking, while there is no negative impact on the students' self-concept. A study from Rogers (2002) revealed that gifted and talented students can cover the regular curriculum in three to six months of a school year, and that acceleration is known to be the most effective strategy for those students.

The last issue is related to the benefits of self-directed learning, self-esteem, and the well-being of gifted and talented students. By participating in our project, several students mentioned their genuine interest in mathematics and appreciated challenging tasks that they could discuss with peers of similar ability who understood their ideas and thus felt able to share their discoveries and be understood. Kontoyianni et al. (2010) described gifted and talented students' self-perception with respect to the five following dimensions: learning characteristics; interest/curiosity; creativity; social-emotional characteristics; and mathematical reasoning. Their results showed that the greatest impact on students' self-perceptions were in the areas of social-emotional characteristics and mathematical reasoning. Our findings pointed in the same direction. Participants in our project appreciated taking part in the project and having the opportunity to work with others with similar ability, and to make new friends. However, few revealed their perceptions of cognitive and metacognitive aspects related to mathematical reasoning. We need to reflect on this when planning the next steps of the study.

Overall, although this project was beneficial for the participants, its continuation in today's school system requires additional financial support, which might be an issue considering budget cuts that the New Brunswick schools are facing. Doucet (2012) confirmed this reality when he interviewed school principals about their perceptions of an acceleration program that was implemented for one year. His findings revealed that, although the school administrators recognized the importance of such initiatives, that there was inadequate financial support to continue the project. Hence, more inclusive options should be considered to meet the needs of gifted and talented students (Porter & Aucoin, 2012). Teachers should implement differentiated instruction inside the regular classroom. According to Reis and Renzulli (2010), differentiating instruction inside a mixed ability classroom can help meet the needs of the gifted and talented students, while also benefiting other students.

The results of our research showed that the innovative project constructed by collaboration of the two local schools and the CAMI team had a positive impact on participants. The participants appreciated the opportunities that were provided. They also appreciated being in small groups with others who shared similar mathematical abilities. This project gave participants the opportunity to experience real cognitive challenges where they worked diligently to solve the proposed problems. The task of creating problems left all students proud of their efforts, although some preferred solving problems.

We believe that the impact of technology and creation of the mathematical problems should be studied in more depth, and with a variety of data (quantitative and qualitative). We also wonder how the regular classroom can be made a richer environment that meets the learning needs of gifted and talented students while supporting them socially and emotionally.

Notes

1. The name of the website is in French and stands for Interactive Multidisciplinary

Learning Community. Over the decade, the site underwent several modifications, such as adding other subject area to the original mathematics and sciences. The website was previously named CASMI, which is French for Interactive Science and Mathematics Learning Community. This explains why the publications we cite had the former name.

2. For more information about Common Core Standards, visit http://www.corestandards.org/
3. Available at: nrich.maths.org/frontpage

References

Adams-Byers, J., Whitsell, S. S., & Moon, S.M. (2004). Gifted students' perceptions of the academic and social/emotional effects of homogeneous and heterogeneous grouping. *Gifted Child Quarterly, 48*(1), 7-20.

Applebaum, M., & Freiman, V. (2014). It all starts with the Bachet's game. *Mathematics Teacher*, *241*, 22-26.

Barbeau, E., & Taylor, P. J. (Eds.). (2009). Challenging mathematics in and beyond the classroom (The 16th ICMI Study). New York: Springer.

Bicknell, B., & Riley, T. (2012). The role of competitions in a mathematics program. *APEX: The New Zealand Journal of Gifted Education*, *17* (1). Retrieved from www.giftedchildren.org.nz/apex.

Brown, S. I., & Walter, M. I. (2005). *The art of problem posing*. Mahwah, NJ: Erlbaulm.

Colongelo, N., & Kelly, K. (1983). A study of student, parent, and teacher attitudes toward gifted programs and gifted students. *Gifted Child Quarterly*, *27*(3), 107-110.

Diezmann, C. M., & Watters, J. J. (2002). Proceedings of the 25th Annual Conference of the Mathematics Education Research Group of Australasia: *Summing up the Education of Mathematically Gifted Students*. Auckland, New Zealand.

Diezmann, C. M., & Watters, J. J. (2004). Does an outcome-based curriculum provide opportunities for gifted students? Reflections on the new Queensland science curriculum. *Curriculum and Teaching*, *19*(1), 27-43.

Depover, C., Karsenti, T., & Komis, V. (2007). *Enseigner avec les technologies*. Québec, QC, Canada: Presses de l'Université du Québec.

Direction de la mesure et de l'évaluation. (2010). *Cadre d'évaluation: mathématiques 8*. Frédericton, Nouveau-Brunswick, Canada: Gouvernement du Nouveau-Brunswick.

Doucet, Y. (2012). *Accélération et enrichissement en mathématiques: perceptions d'élèves doués*. (M.A. Éd.), Université de Moncton, Moncton, NB, Canada.

Ernest, P. (1985). Special educational needs for mathematics. *CASTME Journal*. *8*(1). 22-28

Felmer, P., Pehkonen, E., & Kilpatrick, J. (Eds.). (2016). *Posing and solving mathematical problems: Advances and new perspectives*. Switzerland: Springer International Publishing.

Feng, W. Y. (2010). Students' experience of mathematics enrichment. In M. Joubert, & P. Andrews. *Proceedings of the British Congress for Mathematics Education* (pp. 81-88). Cambridge, United Kingdom: University of Cambridge.

Freiman, V. (2006). Problems to discover and to boost mathematical talent in early grades: a challenging situations approach. *The Montana Mathematics Enthusiast*, *3*(1), 51-75.

Freiman, V., Beauchamp, J., Blain, S., Lirette-Pitre, N., & Fournier, H. (2011). Problem-based scenarios with laptops: An effective combination for cross-curricular learning in mathematics, science and language. *Word Journal of Educational Technology*, *3*(3), 136-152.

Freiman, V., & Lirette-Pitre, N. (2009). Building a virtual learning community of problem solvers: Example of CASMI community. *ZDN*, *42*(1-2), 245-256.

Freiman, V., Manuel, D., & Lirette-Pitre, N. (2007). CASMI virtual learning collaborative environment for mathematical enrichment. *Understanding our Gifted*, *Summer 2007*, 20-23.

Greenes, C. (1997). Honing the abilities of the mathematically promising. *Mathematics Teacher*, *90*(7), 582-586.

Gross, M. U. M. (2006). Exceptionally gifted children: Long-term outcomes of academic acceleration and nonacceleration. *Journal for the Education of the Gifted, 29*(4), 404-429.

Hancock, C. L. (1995). Implementing the assessment standards for school mathematics: Enhancing mathematics learning with open-ended questions. *Mathematics Teacher*, *88*(6), 496-499.

Howitt, D., & Cramer, D. (2011). *Introduction to research methods in psychology*, Third Edition. Harlow, Essex: Pearson Education.

Johnsen, S., & Sheffield, L. J. (Eds.). (2012). Using the common core state standards for mathematics with gifted and advanced learners. Washington, DC: National Association for Gifted Children.

Johnson, D. T. (2000). *Teaching mathematics to gifted students in a mixed-ability classroom*. Reston, VA: ERIC Clearinghouse on Disabilities and Gifted Education.

Kitchner, K. S. (1983). Cognition, metacognition, and epistemic cognition: A three-level model of cognitive processing. *Human Development*, *26*, 222-232.

Kontoyianni, K., Kattou, M., Pitta-Pantazi, D., Christou, C., & Cleanthous, E. (2010). *Self-report questionnaire as a means to capture mathematical giftedness and* *creativity*. Retrieved from : http://www.mathgifted.org/publications/D3.6.pdf

Koshy, V., Ernest, P., & Casey, R. (2009). Mathematically gifted and talented learners: theory and practice. *International Journal of Mathematical Education in Science and Technology*, *40*(2), 213-218.

Leikin, R. (2009). Exploring mathematical creativity using multiple solution tasks. In R. Leikin, A. Berman, & B. Koichu (Eds.), *Creativity in mathematics and the education of gifted students (pp. 129–145).* Rotterdam: Sense Publishers.

Leikin, R. (2011). The education of mathematically gifted students: Some complexities and questions. *The Mathematics Enthusiast, 8(1–9)*. Retrieved from http://scholarworks.umt.edu/tme/vol8/iss1/9

Mackey, A. (2006). *Connecting care and challenge: Tapping our human potential: Report for the New Brunswick Ministry of Education*. Fredericton, NB: Government of New Brunswick.

Manuel, D. (2010). *Étude de la créativité mathématique dans les solutions aux problèmes proposés dans la communauté virtuelle CASMI*. (Maitrise-ès Arts en éducation (mention enseignement)), Université de Moncton, Moncton, NB, Canada.

Manuel, D., Freiman, V., & Bourque, J. (2012). Richesse des problèmes posés et créativité des solutions soumises dans la Communauté d'apprentissages scientifiques et mathématiques interactifs (CASMI). *Éducation francophone en milieu minoritaire, 7*(1), 1-18.

Murphy, E. (2004). Identifying and measuring ill-structured problem formulation and resolution in online asynchronous discussions. *Canadian Journal of Learning and Technology*, *30*(1), 5-20.

New Brunswick Department of Education. (2007). *Kids come first*. Fredericton, NB: Government of New Brunswick.

New Brunswick Department of Education and Early Childhood Development. (2011). *Mathematics*. Fredericton, NB: Government of New Brunswick.

Organisation for Economic Co-operation and Development. (2000). Measuring Student Knowledge and Skills : A New Framework for assessment. Retrieved from http://www.pisa.oecd.org/dataoecd/45/32/33693997.pdf

Pan-Canadian Assessment Program. (2010). *Report on the Pan-Canadian assessment of mathematics, science, and reading*. Toronto, ON, Canada: Council of Ministers of Education of Canada.

Piggott, J. (2008). *Rich tasks and contexts*. Retrieved from http://nrich.maths.org/public/viewer.php?obj_id=5662.

Porter, G. L., & AuCoin, A. (2012). *Consolider l'inclusion pour consolider nos écoles: rapport du processus de revision de l'inclusion scolaire des écoles du Nouveau-Brunswick*. Fredericton, NB, Canada: Gouvernement du Nouveau-Brunswick.

Rawlins, P. (2004). Students' perceptions of their experiences from within acceleration programs in mathematics. *Australian Senior Mathematics Journal*, *18*(1), 42-51.

Reis, S. M., & Renzulli, J. S. (2010). Is there still a need for gifted education? An examination of current research. *Learning and Individual Differences, 20*(6), 308-317.

Renzulli, J. S. (1986). The three-ring conception of giftedness: A developmental model for creative productivity. In R. J. Sternberg & J. E. Davidson (Eds.), Conceptions of giftedness (pp. 53–92). Cambridge, UK: Cambridge UP.

Renzulli, J. S., & Reis, S. M. (1997). The schoolwide enrichment model (2nd ed). Mansfield, UK: Creative Learning Press.

Rogers, K. B. (2002). *Re-forming gifted education: Matching the program to the child*. Scottsdale, AZ: Great Potential Press.

Rosli, R., Capraro, M. M., & Capraro, R. M. (2014). The effects of problem posing on student mathematical learning: A meta analysis. International Education Studies, *7*(13), 227-241.

Schleicher, A. (1999). *Measuring Student Knowledge and Skills: A New Framework for Assessment*. Paris: Organization for Economic Co-operation and Development.

Sharma, Y. (2013). Mathematical giftedness: A creative scenario. *Australian Mathematics Teacher*, *69*(1), 15-24.

Sheffield, L. (2008). *Promoting creativity for all students in mathematics education: An overview*. Paper presented at the 11th International Congress on Mathematical Education: Discussion group 9, Monterrey, Mexico.

Siegle, D. (2005). Six uses of the Internet to develop students' gifts and talents. *Gifted Child Today*, *28*(2), 30-37.

Silver, E. A. (1994). On mathematical problem posing. *For the Learning of Mathematics, 14*(1), 19-28.

Singer, F. M., Ellerton, N., & Cai, J. (2013). Problem-posing research in mathematics education: New questions and directions. *Educational Studies in Mathematics*, *83*(1), 1–7.

Singer, F. M., Pelczer, I., & Voica, C. (2011). In M. Pytlak, T. Rowland, & E. Swoboda (Eds). Proceedings of the seventh congress of the European society for research in mathematics education (pp. 1133-1142):.*Problem posing and modification as a criterion of mathematical creativity*. Rzeszow, Poland: University of Poland.

Singer, F. M., Sheffield, L. J., Freiman, V., & Brandl, M. (2016). *Research on and activities for mathematically gifted students*. Springer Open.

Stein, M. K., Grover, B., & Henningsen, M. (1996). Building student capacity for mathematical thinking and reasoning: An analysis of mathematical tasks used in reform classrooms. *American educational research journal, 33*(2), 455-488.

Takahashi, A. (2000). NCTM annual meeting*: Open-ended problem solving enriched by the Internet*. Retrieved from http://www.mste.uiuc.edu/users/aki/open_ended/

Taylor, C. (2008). *Promoting mathematical understanding through open-ended tasks: Experiences of an eighth-grade gifted geometry class*. (Unpublished doctoral disseratin). Georgia State University. Atlanta, GA.

VanTassel-Baska, J., Feng, A. X., Quek, C., & Struck, J. (2004). A study of educators' and students' perceptions of academic success for underrepresented populations identified for gifted programs. *Psychology Science*, *46*(3), 363-378.

Vaughn, V., Feldhusen, F., & Asher, W. (1991). Meta-analyses and reviews of research on pull-out programs in gifted education. *Gifted Child Quarterly*, 35(2), 92-98.

Wilkins, M. M., Wilkins, J. L. M., Oliver, T. (2006). Differentiating the curriculum for elementary gifted mathematics students. *Teaching Children Mathematics, August 2006,* 6-13.

Yang, Y., Gentry, M., & Choi, Y. O. (2012). Gifted students' perceptions of the regular class and pull-out programs in South Korea. *Journal of Advanced Academics*, *23*(3), 270-287.

About the Author(s)

Dominic Manuel is a Ph.D. Candidate, course lecturer, and research assistant in mathematics education in the Department of Integrated Studies in Education, Faculty of Education, at McGill University. His current research focuses on studying teaching practices and the co-construction of knowledge between teachers and students with inquiry-based learning instruction (including problem solving) in mathematics. His other areas of interest include: meeting the learning needs of mathematically gifted and talented students; developing mathematical creativity in students; implementing challenging rich tasks in mathematics classrooms; and using information and communication technologies (ICT) in classrooms. Since the beginning of his masters in 2007 at the Université de Moncton, he participated in multiple research projects, wrote and co-wrote articles and book chapters, and presented at local, provincial, national, and international conferences in all his areas of interest and other areas. He also worked in local schools where he offered enrichment activities and created an acceleration program for the gifted and talented students, and supported teachers with meeting the learning needs of students who needed extra challenges in mathematics.

Viktor Freiman, Full Professor at the Faculty of Educational Sciences, Université de Moncton, New Brunswick, Canada, Ph. D. in computer science teaching. His research is focused on innovations in mathematics education, use of digital technology, problem solving, giftedness and creativity, from inter- and trans-disciplinary perspective. Since 2003 he has been running several online projects on mathematical problem solving. He has several articles and book chapters published on this topic. His recent partnership development project, funded by the Canadian Social Sciences and Humanities Research Council, looks into the development of digital competencies as a lifelong continuum. He is a co-editor for the book Series Mathematics Education in the Digital Era by Springer, since 2014.