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GENDER-RELATED ISSUES IN MATHEMATICAL COMPETITIONS: PARTICIPATION IN THE VIRTUAL MATHEMATICAL MARATHON

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In today's technologically enhanced world mathematical competitions become available to more students who are interested in challenging tasks. In this paper we look at gender-related issues pertinent to participation in the Virtual Mathematical Marathon over two years. Our study concentrates on the following questions: what were boys' and girls' participation patterns and how successful they were in online problem-solving competition.
Key words: gender, online mathematical competitions, challenge, problem-solving

INTRODUCTION: PROBLEM STATEMENT AND CONTEXT

Our paper discusses gender-related questions regarding participation in Virtual Mathematical Marathon (VMM), an online completion open to everybody who is interested in solving challenging problems over a long period of time. It aims to contribute to the Topic Study Group 34 in many ways, but especially regarding its question 4: reporting on innovative competitions or other innovative mathematical challenges throughout the world. VMM has been established as a continuation of the virtual interactive learning community CAMI that was analysed in the ICMI-16 Study volume (Freiman et al., 2009).

Besides CAMI's regular *Problem of the week* activity that was conducted over the school year, we developed a long-term summer competition for young people who may have interest in solving more challenging tasks in a form of competition. A new section became available in summer 2008 and since that time, four summer rounds have been organized. Moreover, a support received from the Canadian Natural Sciences and Engineering Research Council (Promoscience Grant, 2009-2011) helped us to develop a bilingual version of the marathon (French and English) and introduce a winter round since 2010 thus making it a year-around competition. First results of the project based on 2008-2009 participation data were presented at the PME-36 Research Forum (Freiman & Applebaum, 2009) and a journal article (Freiman & Applebaum, 2011). This proposal extends our investigation while looking at gender-related issues that help to fill in the lack of research on gender patterns in virtual mathematical competition.

GENDER-RELATED DATA ON MATHEMATICS COMPETITIONS: IS THERE AN ISSUE?

Several educators express a concern regarding gender difference in mathematics performance and underrepresentation of women in science, technology, engineering and mathematics (STEM) careers (National Academy of Science, Beyond Bias and Barriers: Finding the potential of women in academic science and engineering., 2006 and Hyde, Lindberg, Linn, Ellis, & Williams, 2008). Gender inequity is particularly evident in data related to number of girls participated in the International Math Olympiad, or number of female professors in university mathematics and engineering departments (Hyde & Mertz, 2009). There are several ways in how this problem may be addressed.

First, psychologists are looking for gender differences in brain structure, in hormones, in the use of brain hemispheres, nuances of cognitive or behavioural development and consequent spatial and numerical abilities that may predispose males to a greater aptitude and success in mathematics (Halpern, 1997, Moir & Jessel, 1989). However, several finding reported in the literature regarding this matter are not consistent (Spelke, 2005), partly due to the fact that experience alters brain structures and functioning (Halpern, Benbow, Geary, & Gur, 2007).

Second, detailed measurements of students' achievements in mathematics are being performed by educators at different stages of schooling in an attempt to identify the moment of occurrence and further dynamics of gender gaps in mathematics. Many studies are consistent in their observation that the gender gap becomes more evident as students progress towards higher grades, especially if testing involves advanced topics in mathematics and higher cognitive level items. In contrast to earlier findings, some more current data provide no evidence of a gender difference favouring males emerging in the high school years (Hyde et al., 2008).

Yet another interesting observation is that "achievement gains are insufficient unless the self-beliefs of girls have changes correspondingly" (Lloyd, Walsh, & Yailagh, 2005, p.385). Research that views gender differences through the lenses of the attribution theory (see e.g. Bandura, 1997) suggests that girls tend to attribute their math successes to external factors and to effort and their failures to their own lack of ability (self defeating pattern), whereas boys tend to attribute the causes of their successes to internal factors and their failure to external factors (self-enhancing pattern). Since it is better for an individual to attribute success to ability, rather than to effort because ability attributions are more strongly related to motivation and skill development (Schunk & Gunn, 1986), these patterns have explained in part girl's poorer achievement (Lloyd et al., 2005).

A report of the American Association of University Women *How Schools Shortchange Girls* (1992) focused on girls being discouraged from studying math and science. The report indicates that "girls receive less attention in the classroom than boys and less encouragement for their efforts. In addition, the study showed that many classrooms created the atmosphere of competition among students. Such an atmosphere played to the strength of boys, who were socialized to compete, but often intimidated girls, who were more often socialized to collaborate." (Williams, 2006, p. 301)

Third way of addressing the gender gap in mathematics is to investigate the influence of socio-cultural factors. According to Von Glaserfeld (1989), the context in which learners find themselves is important in the acquisition of knowledge. First, it was found that parents have greater expectations for sons regarding their mathematical performance that they have for daughters, and this has an influence on the students' results (Leder, 1993). It was also observed that even talented and motivated girls "are not immune to the ill effects of gender bias" (Leedy, LaLonde, & Runk, 2003, p.290). In this respect it is unfortunate that stereotypes that girls and women lack mathematical ability persist and are widely held by parents and teachers (Hyde et al., 2008). Leedy et al. (2003) studied beliefs held by students participating in regional math competitions, their parents and teachers. They found that mathematics is still viewed as a male domain by men, while girls and women fail to acknowledge the existence of the bias. They argue that the task of the school is not to ignore or deny differences in learning styles, attitudes and performance but to acknowledge them and use for developing strategies aiming at providing gender equitable education.

In conclusion, in all three perspectives in research on gender in mathematics – cognitive, instructional, and socio-cultural – care is needed in considering how the data are collected, examined and interpreted because within neither approach there is a fully consistent theory that could explain the existing gender difference observed at the higher level of mathematical tasks. As Halpern et al. (2007) point out, "there are no single or simple answers to the complex question about sex difference in mathematics", and all "early experience, biological factors, educational policy, and cultural context" need to be considered when approaching this question.

TECHNOLOGY AND GENDER: WHAT PATTERNS EMERGE IN MATHEMATICAL COMPETITIONS?

While previous section reviews research related to gender issue in mathematics education showing no conclusive findings, similar observation can be drawn from technology-related studies that we will review very briefly. For instance Fogasz (2006) reports that when talking about classroom practices that involve computers as a learning tool, mathematics teacher held gendered beliefs about their students that incorporation of technology has more positive effects on males' classroom engagement and on their affective responses, and thus technological approach benefits boys' learning to a greater extend.

At the same time Wood, Viskic, & Petocz (2003) found no gender differences in the students' use of computers or in their attitudes towards the use of computers. This agrees with ideas expressed by Willams (2006) quoted above, who reviews studies showing that girls are as confident and active as are boys in creating webpages, writing blogs, reading websites, and chatting online, among other activities.

As we mentioned in our earlier publications (Freiman, Kadijevich, Kuntz, Pozdnyakov, & Stedoy, 2009; Freiman & Applebaim, 2009), Internet can be a suitable challenging environment for organizing mathematical competitions and problem solving activities, contributing potentially to the development of mathematical ability and giftedness. The use of technology can be considered as an inclusive form of mathematical enrichment, providing a tool, an inspiration, or a potentially challenging and motivating independent learning environment for any student. For the gifted ones, it is often a means to reach the appropriate depth and breadth of curriculum, to advance at the appropriate for each learner pace, as well as to achieve better engagement and task commitment (Johnson, 2000; Jones & Simons, 2000; Renninger & Shumar, 2004; Freiman & Lirette-Pitre, 2009; Sullenger & Freiman, 2011).

Being a part of a powerful set of out-of-regular-classroom activities such as mathematical clubs, mathematical camps, mathematical competitions (Olympiads), on-line mathematical competitions play a significant role in nurturing interest and motivating young learners of mathematics, as well as in identification and fostering the most able and talented (Skvortsov, 1978; Karnes & Riley, 1996; Robertson, 2007; Bicknell, 2008). The choice of appropriate challenging tasks is also an important condition of success of mathematical competitions in developing students' learning potential. Leikin (2004, 2007) claims that such tasks must be appropriate to students' abilities, not too easy or too difficult. They should motivate students to persevere with task completion and develop mathematical curiosity and interest in the subject. As well, they must support and advance students' beliefs about the creative nature of mathematics, the constructive nature of the learning process, and the dynamic nature of mathematical problems as having different solution paths and supporting individual learning styles and knowledge construction.

While designing our Virtual Mathematical Marathon, we aimed to provide students with an opportunity to discover their talent which they cannot normally demonstrate in regular classroom (Taylor, Gourdeau, & Kenderov, 2004) thus we considered marathon as a stimulus for improving students' informal learning. Fomin, Genkin and Itenberg (2000) described that during the marathon that they conducted on face-to-face basis, their students managed to increase the number of problems they solved, relatively to other non-competing frameworks in which the same students participated.

Regarding gender issues in virtual mathematics competition, we found a lack of data that we aim to address in our paper. In the following section we describe the Virtual Mathematical Marathon's structure that allowed us to collect data about participants, including data according to their gender. The main question we asked in our study was: *What kind of differences has been observed in boys' and girls' behaviour during their participation in VMM?* We divided our investigation in two parts addressing the following two sub-questions:

- Was there a gender difference in the initial enrolment of student-participants of VMM? How did participation evolve during the competition, according to the gender?
- What were the gender-related patterns in participants' behaviour according to the difficulty levels for each year in terms of the both, participation and success rate?

STRUCTURE OF THE VIRTUAL MATHEMATICAL MARATHON

According to our model of the VMM, one set of 4 non-routine challenging problems was posted twice a week on the CAMI website (www.umoncton.ca/cami) during 10 weeks, from June to August in 2008 and 2009. In total, 20 sets of problems were offered to the student-participants of each round. Every registered member could login, choose a problem, solve it, and submit an answer by selecting it from a multiple-choice menu. The automatic scoring system immediately evaluated students' success producing a score for the problems and adjusting a total score that affected the overall standing.

According to the level of difficulty, scores per problem were determined as follows: level 1(easiest) was scored with 3 points, level 2 with 5 points, level 3 with 7 points, and level 4 (hardest) with 10 points. To support students' participation in the marathon, unsuccessful attempts were also rewarded with 1, 2, 3, and 4 points respectively. Participants could join the marathon, solve as many problems as they wished, withdraw, and come back at any time. The tasks were developed by a team of experts in mathematics and mathematics education.

Here are examples of such tasks coming from one set:

Level 1 problem: How many numbers from 10 to 200 have the property that reversing their digits does not change the number?

A) 17   B) 18   C) 19   D) 20

Comment: students can approach this problem by simply listing all numbers with required property. These numbers are 11, 22, 33, 44, 55, 66, 77, 88, 99, 101, 111, 121, 131, 141, 151, 161, 171, 181, and 191.Thus the answer is 19.

Level 2 problem: Two dice are thrown at random. What is the probability that the two numbers shown are the digits of a two-digit perfect square?

A) 1/9   B) 5/36   C) 2/9   D) 5/18

Comment: students need to be familiar with the notion of probability, some counting techniques, and apply reasoning. They should notice that the only 2-digit perfect squares that can be constructed from digits 1,2,3,4,5,6, are 16, 25, 36, and 64. This gives 4 possible squares, with two ways for each to occur. Since there are 36 possible outcomes, the probability is 8/36=2/9.

Level 3 problem:

The volume of a cube is 64 units cubed. What is the surface area of the cube?

A) 16 units squared   B) 64 units squared   C) 96 units squared   D) 256 units squared

Comment: students need to know basic facts about cubes. They could reason as follow. If the total volume is 64, then the side length is 4 units. This means each face has area $4 \times 4 = 16$. There are 6 faces, so the surface area is $6 \times 16 = 96$ units squared.

Level 4 problem: You have 100 tiles, numbered 0 to 99. Take any set of three tiles. If the number on one of the tiles is the sum of the other two numbers, call the set “good”. Otherwise, call the set “bad”. How many good sets of three tiles are there?

A) 160   B) 1600   C) 1225   D) 2401

Comment: students need to notice a pattern and invent some useful counting technique in order to solve this problem. For example, they may reason as follows. If 3 is the largest number, there is one good set, {1,2,3}. If 4 is the largest, there is one good set, {1,3,4}. For 5 and 6 there are 2, {1,4,5}, {2,3,5} and {1,5,6}, {2,4,6}, respectively. For 7 and 8 there are three each, for 9 and 10 there are 4 each, and so on. In this way, when we reach 97 there are 48 good sets, for 98 there are also 48, and for 99 there are 49. It remains to compute the sum 1+1+2+2+3+3+...+47+47+48+48+49=49+(1+48)+(1+48)+(2+47)+(2+47)+...+(24+25)+(24 +25)=49 × 49=2401.

GENDER-RELATED DATA SAMPLINGAND METHODS OF ANALYSIS

The participants of the marathon were all members of the CAMI community. They received an invitation by e-mail to take part in the marathon. Most of them were from New Brunswick, Canada. We also had few participants from Quebec and from France. We have no reliable data on students’ age, but the most frequent CAMI users are Grades 6-8 (ages 12-14) which is a good approximation.

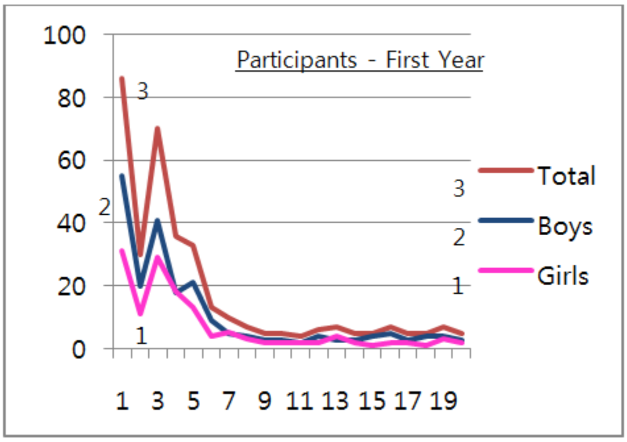
In order to investigate the first sub-question, we have collected and analysed the data about boys' and girls' participation for each of 20 sets (in both years). We collected and compared the numbers of initial enrolment and on-going visits for boys and girls separately.

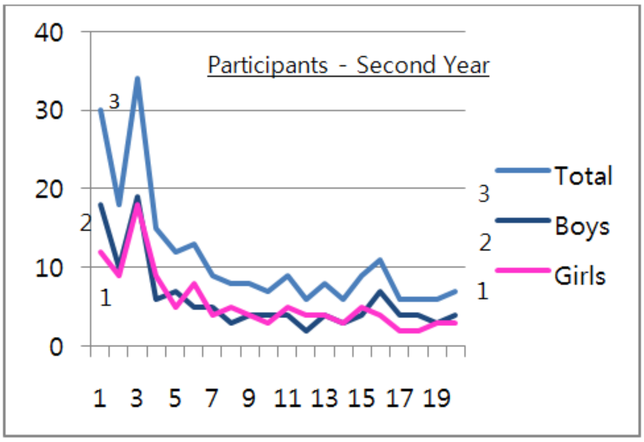
In order to address the second sub-question, we have analysed the data about boys’ and girls’ attempts to solve either all or some particular problems from each set. For example, some students could attempt only easier questions (levels 1-2). We were interested if the student was trying to stay in a ‘safer’ zone, or to take some greater ‘risks’ solving more challenging problems (levels 3-4). In this respect, we were curious whether a virtual problem solving environment had allowed girls to exhibit risk-taking behaviour at a rate comparable to the one of boys. Moreover, we draw on our data from previous analyses that emphasized particular behaviour of students who were the most active and successful (the winners of each 20-round game), the group we called the ‘most persistent’ (Freiman & Applebaum, 2011). We have compared the number of girls and boys among this group. The next section presents our findings.

PRELIMINARY RESULTS AND DISCUSSION

There were 298 students (194 in the first year and 104 in the second year) participated in at least one round (of the total of twenty rounds each year) of the marathon. In the first year, there were more boys (110, or 56.7%) than girls (84, or 43.3%). In the second year the number of girls was slightly higher than number of boys (56, or 53.8% against 48, or 46.2%). Over two years, our data do not indicate any significant difference in participation according to the gender: girls seem to be as active as boys.

Further, the Figures 1 and 2 below show how the number was changing over each competition. From the Figure 1, we learn that in the first 3 sets of the Year 1, the number of boys was higher than number of girls, but starting set 7, the numbers are nearly the same in each of remaining sets. We can see therefore that girls who decided to continue participation were as persistent as boys. A similar trend can be observed in Year 2 data (Figure 2); while the number of participants is much lower than in the first year, there were still more boys than girls in the first set but starting from the set 7, the number of girls and boys was nearly the same until the end of the competition. It is remarkable that among the winners of the two 20-round games there were 6 boys and 5 girls, so nearly the same number of each gender.





Figures 1 and 2. Dynamic of the total number of students (3), boys (2), and girls (1).

X - Set number; Y - Participant amount

The repartition of the number of attempts by gender, according to the Table 1 (Year 1 and 2) shows that there was no significant difference in the number of attempts related to the difficulty levels between girls and boys. Usually, the participants who tried the problem of the level 1 (easiest) were attempting to solve the problem of the other levels; some difference is only between the levels one and two for both genders. This observation is particularly valuable in view of the fact that in a regular classroom setting “teachers perceived that girls … produced fewer exceptional, risk-taking [learners] than did boys.” (Williams, 2006).

The dynamic of success rates is similar between the girls and the boys in the first year; also, both genders were more successful on easier levels (1 and 2) and less in more difficult levels (3 and 4). In the Year 2, however, the boys have clearly outperformed girls at all levels; with the same trends between levels 1-2 (easier – better solved) and 3-4 (harder – less success).

<table>
<tr><th></th><th></th><th></th><th>Level 1</th><th>Level 2</th><th>Level 3</th><th>Level 4</th><th>Total</th></tr>
<tr><td rowspan="4">First year</td><td rowspan="2">Boys</td><td>Number of successful solutions / Number of attempts</td><td>124/211</td><td>115/202</td><td>89/201</td><td>72/200</td><td>400/814</td></tr>
<tr><td>Per cents</td><td>58.77%</td><td>56.93%</td><td>44.28%</td><td>36%</td><td>49.14%</td></tr>
<tr><td rowspan="2">Girls</td><td>Number of successful solutions / Number of attempts</td><td>81/137</td><td>70/121</td><td>60/122</td><td>39/122</td><td>250/502</td></tr>
<tr><td>Per cents</td><td>59.12%</td><td>57.85%</td><td>49.18%</td><td>31.97%</td><td>49.80%</td></tr>
<tr><td rowspan="4">Second year</td><td rowspan="2">Boys</td><td>Number of successful solutions / Number of attempts</td><td>78/119</td><td>65/108</td><td>51/105</td><td>50/104</td><td>244/436</td></tr>
<tr><td>Per cents</td><td>65.55%</td><td>60.19%</td><td>48.57%</td><td>48.08%</td><td>55.96%</td></tr>
<tr><td rowspan="2">Girls</td><td>Number of successful solutions / Number of attempts</td><td>52/106</td><td>45/94</td><td>29/98</td><td>34/100</td><td>160/398</td></tr>
<tr><td>Per cents</td><td>49.06%</td><td>47.87%</td><td>29.59%</td><td>34%</td><td>40.20%</td></tr>
</table>

Table 1. The success rate of boys and girls at each difficulty level

CONCLUSIONS:

Our preliminary data analysis has several limitations, the major being that we did not see students' solutions and did not asked them directly about their satisfaction with the game. Nevertheless, we found that in both years there was an introductory period (first few weeks) of participants' self-selection after which we observe similar participation rate, risk taking behaviour and persistence for both genders. This gender similarity is consistent with other researchers' finding (Lloyd et al., 2005; Williams, 2006) indicating non-significant gender difference at the junior high level mathematics as well as equal abilities and interest of both boys and girls to participate in on-line activities. Our future work will use more data and look at more detailed data analysis including students' interviews that could reveal the reasons of students' behaviour and insightful comments about their thoughts and attitudes during this on-line problem solving activity.

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