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GENDER ISSUES IN VIRTUAL TRAINING FOR MATHEMATICAL KANGAROO CONTEST

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Abstract. In today's technologically enhanced world, mathematics competitions have become accessible to more boys and girls interested in challenging tasks. In previous studies, we were focused on the issue of attracting girls to mathematics generally, and math competitions specifically. We found that boys showed better results. Furthermore, across all five grades (2 – 6), the girls' performance on some tasks was better than that of the boys. Further investigation is required to ascertain the existence of a particular trend, and the possible underlying factors. In this paper we present gender-related issues pertinent to virtual training for the Israeli Mathematical Kangaroo Contest in Grades 5 and 6. We evaluated whether any differences existed in participation patterns between boys and girls, and their performance in online problem-solving programmes.

Keywords: gender; online mathematics competitions; challenge; problem-solving

Introduction

Many educators express concern about the gender gap in mathematics performance and the under-representation of women in science, technology, engineering and mathematics (STEM) careers (Hyde, Lindberg, Linn, Ellis & Williams, 2008). Gender inequity is particularly evident in data related to the number of girls that participated in the International Math Olympiad, or the number of female professors in university mathematics and engineering departments (Hyde & Mertz, 2009).

Several researchers have highlighted mathematics performance in favour of boys (Aunola, Leskinen, Lerkkanen, & Nurmi, 2004), (Githua & Mwangi, 2003), (Marsh, Martin, & Cheng, 2008), whereas others (Lindberg, Hyde, Petersen & Linn, 2010) have claimed that no significant gender gap exists in mathematics. Moreover, Robinson and Lubenski (Robinson & Lubenski, 2011), and Brown and Kanyongo (Brown & Kanyongo, 2010) showed that over the last four decades, girls have achieved slightly better grades than boys in mathematics.

As Halpern et al. (Halpern et al., 2007) pointed 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. Gherasim, Butnaru and Mairean (Gherasim, Butnaru & Mairean, 2013) also argued that there is a need for more studies on gender differences in order to fill the gaps regarding the mechanisms that are conducive to enhancing mathematical performance.

In what way do gender differences appear (if at all) in the context of mathematics competitions? Niederle and Vesterlund (Niederle & Vesterlund, 2010) found that gender differences in competitive performance are not reflective of differences in non-competitive performance. Gneezy, Niederle and Rustichini (Gneezy, Niederle & Rustichini, 2003) even revealed that the gender gap in performance under competitive conditions is three times greater than that under non-competitive conditions. Leedy, LaLonde and Runk (Leedy, LaLonde & Runk, 2003) studied the beliefs held by students participating in regional math competitions, as well as those held by their parents and teachers. They found that mathematics is still viewed as a male-dominated discipline, 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 and use them to develop strategies aimed at providing gender-equitable education. However, there is insufficient data regarding how gender-related differences are manifested in mathematics competitions and the patterns that emerge from these differences.

Applebaum, Kondratieva and Freiman (Applebaum, Kondratieva & Freiman, 2013) investigated gender issues in the context of the Virtual Mathematical Marathon by studying participation and performance. While observing students' participation during the first two years of the competition, they found that girls and boys showed similar patterns regarding the decision to remain in the competition, or to abandon it, regardless of the results in previous rounds.

In the present study, we analyse the performance of boys and girls in the first stage of the 2018 Israeli competition (as part of the International Kangaroo Contest). Students participated in online internet training over 16 weeks, during which they had to identify themselves, at home, or sometimes at their schools.

Mathematical competitions: opportunities for learning and fun

Mathematical competitions, in their current form, boast more than 100 years of history and tradition, are organised in different formats, in different venues and for different types of students. They are considered 'one of the main tools to foster mathematical creativity in the school system' (De Silva, 2014). Kahane (Kahane, 1999) claimed that large popular competitions could reveal hidden aptitudes and talents and inspire many children and young adults. Bicknell (Bicknell, 2008) found the use of competitions in mathematics programmes to have numerous advantages, such as student satisfaction, enhancement of self-directed learning skills among the students, increased sense of autonomy, and cooperative teamwork skills. The interplay between cognitive, metacognitive, affective and social factors merits particular attention by researchers, because it may give us more insight into the development of mathematical potential in young learners (Applebaum, Kondratieva, & Freiman, 2013).

Among the various competitions, the Kangaroo Contest stands out because of its main objective: the popularisation of mathematics with the special purpose of showing young participants that mathematics can be interesting, beneficial and even fun. The target population of the Kangaroo Contest is not limited to the most mathematically talented students; it aims to attract as many students as possible. Although it has been generally accepted that the vast majority of people find mathematics difficult and very abstract, the number of competitors in the contest proves that this need not be the case. As it attracts a substantial number of competitors, the contest helps to eradicate such prejudice towards mathematics.

Choosing appropriately challenging tasks is an important condition for the successful contribution of mathematical competitions to developing the learning potential of students (Bicknell, 2008). In contrast to other more challenging competitions, the mathematical problems in the Kangaroo Contest are more appropriate and based on the challenging task concept suggested by Leikin (Leikin, 2004). Such tasks should be neither too easy nor too difficult, to motivate students and develop their mathematical curiosity and interest in the subject.

Regarding the tasks and learning opportunities, Brinkmann (Brinkmann, 2009) mentioned that when students of Grades 7 and 8 were asked about the most interesting mathematical problems, they selected puzzles, while commenting that the problems should not be too difficult. For example, more than half of the students cited one of the 2003 Kangaroo Contest problems as 'a fascinating math problem', which targeted spatial abilities in the context of paper folding (Brinkmann, 2009). Moreover, Applebaum's (Applebaum, 2017) recent study confirmed earlier research showing that spatial thinking and mathematics are inter-related, especially in the early grades, thus indicating that early intervention is crucial for closing the achievement gaps in math.

Gender-related data on mathematics competitions: is there an issue?

Several educators express concern regarding gender differences in mathematics performance and the under-representation of women in STEM careers (National Academy of Science, 2006); (Hyde et al., 2008). Gender inequity is particularly evident in data related to the number of girls participating in the International Math Olympiad, or the number of female professors in the mathematics and engineering departments of universities (Hyde & Mertz, 2009). This problem can be addressed in several ways.

First, some psychologists look for gender differences in brain structure, hormones, the use of the brain's hemispheres, nuances of cognitive or behavioural development, and consequent spatial and numerical abilities that may predispose males to a greater aptitude for, and success in mathematics (Halpern, 1997; Jessel & Moir, 1989). However, several relevant findings in the literature are inconsistent (Spelke, 2005), partly due to the fact that experience alters brain structures and functioning (Halpern et al., 2007).

Second, detailed measurements of students' achievements in mathematics are being recorded by educators at different stages of schooling, in an attempt to identify when the gender gaps in mathematics first occur, as well as further dynamics of the gap. 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, more current data provide no evidence of a gender difference favouring males in the high school years (Hyde & al., 2008).

Yet another interesting observation is that '… as a practical matter, achievement gains are insufficient unless the self-beliefs of girls have changed correspondingly'(Lloyd, Walsh & Yailagh, 2005, p.385). Research that views gender differences through the lens of the attribution theory (e.g. Bandura,1997) suggests that girls tend to attribute their math successes to external factors and efforts, and their failures to their own lack of ability (self-defeating pattern); whereas boys tend to attribute their successes to internal factors, and their failures to external factors (self-enhancing pattern). It is better for an individual to attribute success to ability, rather than effort, because ability attributions are more strongly related to motivation and skill development (Schunk & Gunn, 1986). These patterns partially explain the poorer achievement of girls (Lloydet & al., 2005).

According to Asante (Asante, 2012), the attitudes of secondary students towards mathematics are influenced by a set of factors including the' school environment, teachers' attitudes and beliefs, teaching styles and behaviour and parental attitudes towards mathematics'. That study was focused on girls being discouraged from studying math, and strongly argued that girls receive less encouragement and support in the classroom than boys. Williams (Williams, 2006) showed that many classrooms create an atmosphere of competition among students. Such an atmosphere plays to the strength of boys, who are socialised to compete, but often intimidates girls, who are more often socialised to collaborate.

The third way to address the gender gap in mathematics is to investigate the influence of socio-cultural factors. With regards to mathematical performance, parents tend to have greater expectations for sons than they have for daughters, and this influences the students' results (Leder, 1993). Even talented and motivated girls 'are not immune to the ill effects of gender bias' (Leedy & al.,2003, p. 290). In this respect, it is unfortunate that the stereotypes that girls and women lack mathematical ability persist and are widely held by parents and teachers (Hyde & al., 2008).

Leedy & al. (Leedy et& al., 2003) studied the beliefs held by students participating in regional math competitions, as well as those held by 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. Other researchers have found interesting results showing that gender differences in mathematics performance are declining, or non-existent in gender-equal countries (Else-Quest, Hyde, & Linn, 2010); (Guiso, Monte & Sapienza, 2008). Leedy & al. (Leedy et& al., 2003) also argue that the task of the school is not to ignore or deny differences in learning styles, attitudes and performance, but acknowledge and use them to develop strategies aimed at providing gender-equitable education.

In conclusion, in all three perspectives in research on gender in mathematics – cognitive, instructional and socio-cultural – careful consideration of how the data are collected, examined and interpreted is necessary. This is because no single approach provides a fully consistent theory that could explain the existing gender differences observed at a higher level of mathematical tasks. As Halpern et al. (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 mathematics competitions?

While the previous section summarises research related to gender issues in mathematics education that show no conclusive findings, similar observations can be drawn from technology-related studies that we will review briefly. Forgasz (Forgasz, 2006) reports that when referring to classroom practices that involve computers as a learning tool, mathematics teachers held gender-based beliefs about their students. They assumed that the incorporation of technology has more positive effects on male classroom engagement and their affective responses, and thus, the technological approach was more beneficial to learning in boys.

At the same time, Wood and Viskicand Petocz (Wood & Viskicand Petocz, 2003) found no gender differences in the use of computers among students, nor in their attitudes towards the use of computers. This agrees with ideas expressed by Williams (Williams, 2006) quoted above, who reviewed studies, which showed that girls are just as confident and active as boys in creating webpages, writing blogs, reading websites, and chatting online, among other activities.

As mentioned in the publications (Freiman, Kadijevich, Kuntz, Pozdnyakov & Stedoy, 2009 and Freiman & Applebaum, 2009), the internet can be a suitably challenging environment on which mathematics competitions and problem-solving activities can be organised, and can potentially contribute to the development of mathematical ability and giftedness. In a recent analysis of middle-school students participating in a web-based mathematics competition, Jacinto and Carreira (Jacinto & Carreira, 2013) argued that although one cannot conclude that by solving problems online, students do better in mathematics, their data provides evidence that the use of technology tends to involve more complex mathematical thinking.

As one among a powerful set of extra-curricular activities, such as mathematical clubs, mathematical camps and mathematics competitions (Olympiads), online mathematics competitions play a significant role in nurturing interest and motivating young learners of mathematics, as well as identifying and fostering the most capable and talented (Bicknell, 2008); (Karnes & Riley, 1996); (Skvortsov, 1978).

The choice of appropriately challenging tasks is also an important condition for the success of mathematics competitions in developing the learning potential of students. The tasks should motivate students to persevere with task completion and develop mathematical curiosity and interest in the subject. Furthermore, tasks 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. They should also support individual learning styles and the further development of knowledge.

Gender issues among Israeli students in Israeli national and international tests

In National Israeli Math tests, for Grade 5, gaps were found in favour of boys (about a quarter of standard deviation on average), which seemed to have expanded somewhat over the years 2012 – 2017. For Grade 8, the achievements of boys and girls In the National Israeli Math tests were similar during the years 2012 – 2017. A similar trend is observed when comparing the achievements of Israeli boys and girls in the Trends in International Mathematics and Science Study (TIMSS) (2007, 2011 and 2015).

The gap in favour of boys by an average of 16 points (about 1/6 of standard deviation on average) was again observed in the PISA (Programme for International Student Assessment) tests in mathematics literacy in the years 2006, 2009 and 2012 (Rapp, 2015).

In the following section we describe the structure of the Kangaroo Contest Virtual Training (KCVT), which allowed us to collect the appropriate data.

Structure of the Kangaroo Contest Virtual Training (KCVT)

The official aim of the KCVT is to motivate students to prepare themselves for the International Kangaroo Contest. The hidden aim of the KCVT is to get students more involved in mathematical activities and improve their mathematical thinking skills.

According to our model of the KCVT, one set of eight non-routine challenging problems was posted every week on a specific website (www.kangaroo4u.tik-tak.co.il) over 16 weeks, from November 2018 to March 2019. In total, 16 sets of eight problems were offered to the participants. All problems were ordered according to increasing difficulty: sets 1–6 were defined as the 'easy level'; sets 7 – 12, the 'average level'; and sets 13–16, the'high level'.

Every registered member was able To login, to choose a problem, to solve it and to submit an answer by selecting it from a multiple-choice menu (with five distractors). The automatic scoring system immediately evaluated the performance of the students by producing a score for the problems and adjusting the total score, which affected the overall standing.

Participants could join the KCVT, solve as many problems as they wished, withdraw, and return at any time. The tasks were selected by a team of experts in mathematics and included material from previous tests of the International Kangaroo Contest.

The study

Research questions

In this study, we used data from the KCVT stage to investigate the following research questions:

– Are there any differences between boys and girls regarding their persistence in participation in the KCVT?

– Are there any gender-related patterns in the participation of boys compared with that of girls according to different levels of difficulty?

Methods

A quantitative methodology was followed based on the analysis of an external database software. The implementation of *t*-tests and descriptive statistics enabled the researchers to compare several variables between the performance of girls and boys, respectively.

Participants

Every student who opted to participate in the contest (possibly due to the encouragement of parents) was able to do so without conditions (such as a test or interview). The only requirement was the payment of a very low registration fee by the student. The age range of the students was between 11 and 12 years, and they came from various regions of Israel, including large cities as well as smaller cities and villages, and different socioeconomic backgrounds. In total, there were 1005 children, 546 boys and 459 girls, who took part in the KCVT.

Results

In order to investigate the first sub-question, we collected and analysed data about the participation of boys and girls in each of 16 sets (N1 – N16). We collected and compared the numbers of website visits for boys and girls separately.

In order to address the second sub-question, we analysed data about the attempts of boys and girls to solve either all or some particular problems from each set. For example, some students could have attempted only the questions from the easy level (sets 1 – 6). We were interested in whether the student tried to remain in a safe zone or take greater 'risks'by solving average-level problems (sets 7 – 12), or even high-level problems (sets 13 – 16). In this respect, we wanted to determine whether a virtual problem-solving environment allowed girls to exhibit risk-taking behaviour at a rate comparable to that of boys. We compared the number of girls and boys among this group. The next section presents our findings.

Regarding the first research question, in Figure 1, we present the descriptive data regarding the participation of boys and girls in the KCVT. According to our findings, no significant differences were observed between the behaviour of boys and girls in the KCVT. For each set, the level of participation was approximately the same for boys and girls.

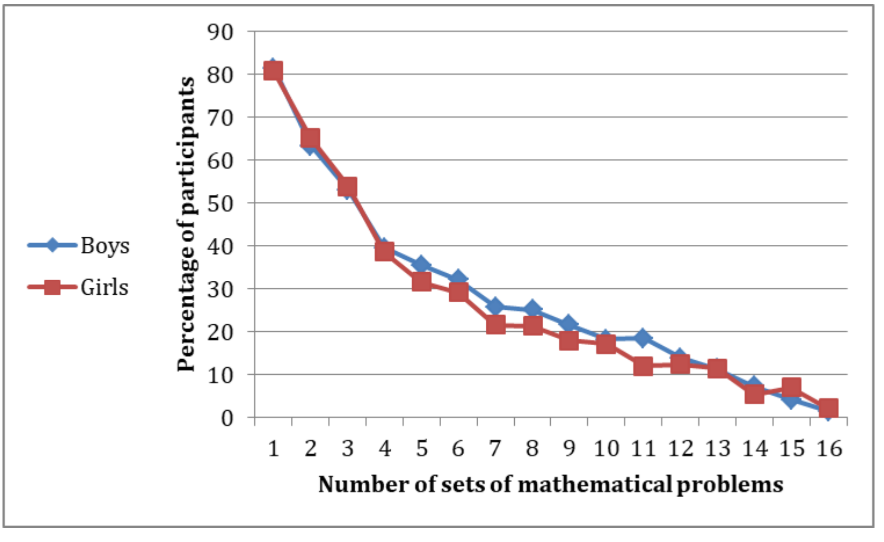

Figure 1. Level of participation

The percentage of participants among boys and girls showed similartrends, and decreased in a similar pattern as follows: in the N1 set 82.2% of the boys and 81.1% of the girls participated; in the N4 set, 41.4% of the boys and 40.1% of the girls participated; in the N8 set, 26.9% of the boys and 22.7% of the girls participated; in the N12 set, 14.7% of the boys and 13.1% of the girls participated, and at the end, in the N16 set, 1.8% of the boys and 2.2% of the girls participated.

No significant differences were found between the participation of boys and girls among specific sets of different levels of difficulty, including the easy (sets 1 – 6), average (sets 7 – 12), and high (sets 13–16) levels. We also evaluated the percentage of boys and girls who submitted different numbers of tasks in total (1 – 16).In Figure 2, we present the collected data.

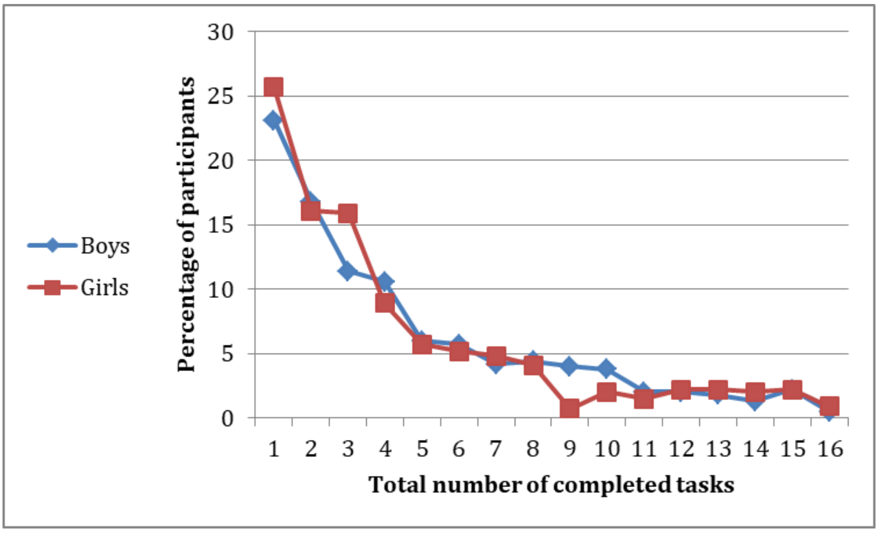

Figure 2. Total number of completed tasks

The percentage of girls who submitted only one task (out of 16) was larger (but not significantly so) than that of boys (25.7% [girls] vs. 23.1% [boys]). In general, this means that about a quarter of all participants left the training after the first set of problems. After the first two sets of problems, an additional 16.1% of the girls and 16.8% of the boys left the training. After submitting a total of three sets, 57.7% of the girls and 51.3% of the boys left the training. No gender differences were observed in the persistence of participants in the KCVT.

In order to address the second sub-question, we analysed the data regarding the mean values for boys and girls among all sets, and then evaluated the means among sets of the same difficulty level. In Table 1, we present the data based on the gender differences among all participants who attempted the tasks over 16 weeks.

Table 1. Success rates of boys and girls for each set of mathematical problems

		Gender								
		Boys			Girls					
		N	Mean (of 40)	S. D.	N	Mean (of 40)	S. D.	t	df	p - value (2-tailed)
Easy level	Set 1	449	25.66	10.048	372	26.26	10.128	-0.858	819	0.391
	Set 2	355	22.68	11.862	303	23.63	11.681	-1.036	656	0.301
	Set 3	293	26.59	11.398	250	27.34	11.014	-0.779	541	0.436
	Set 4	226	22.04	12.241	184	20.92	12.009	0.922	408	0.357
	Set 5	197	25.48	12.233	147	24.76	11.767	0.549	342	0.583
	Set 6	177	25.93	12.368	136	24.34	11.528	1.175	300	0.241
Average level	Set 7	148	22.87	14.047	104	21.63	13.062	0.717	231	0.474
	Set 8	147	21.56	12.792	104	20.58	13.534	0.588	249	0.557
	Set 9	126	21.75	13.059	83	22.77	11.589	-0.580	207	0.562
	Set 10	102	25.29	13.694	81	21.85	13.144	1.719	181	0.087
	Set 11	108	21.57	13.319	62	19.52	14.249	0.945	168	0.346
	Set 12	80	19.94	13.745	60	22.33	14.186	-1.007	138	0.316
High level	Set 13	65	19.62	12.909	55	19.18	12.389	0.187	118	0.852
	Set 14	42	18.57	13.981	29	17.41	14.244	0.340	69	0.735
	Set 15	24	23.75	13.126	33	19.39	12.104	1.295	55	0.201
	Set 16	10	12.00	14.181	10	15.50	13.427	-0.567	18	0.578

Based on the data presented in Table 1, no significant gender differences were found in any of the 16 sets. In Table 2, we present the data based on gender differences among the different levels of difficulty of the tasks.

Table 2. Success rates of boys and girls at each difficulty level of mathematical tasks

	Gender					
	Boys			Girls		
Sets	N	Mean (of 40)	Std. Deviation	N	Mean (of 40)	Std. Deviation
Easy 1–6	506	24.722	11.483	433	24.829	11.206
Average 7–12	248	22.220	13.425	163	21.456	13.240
High 13–16	82	19.469	13.365	68	18.541	12.847

Based on the data presented in Table 2, no significant gender differences in scores were found when students attempted tasks of different levels of difficulty. We also compared the total number of boys and girls who achieved scores in four quartiles (out of a total of 640). In Table 3, we present those findings. No significant gender differences were found in this data.

Table 3. Percentage of boys and girls within four quartiles of scores

		Gender	
		Boys	Girls
1–160	Number	445	379
	%	81.5	82.6
161–320	Number	54	52
	%	9.9	11.3
321–480	Number	35	15
	%	6.4	3.3
481–640	Number	12	13
	%	2.2	2.8
		546	459

Preliminary Results and Discussion

A total of 1005 students participated in at least one round (out of a total of 16 rounds) of the KCVT. More boys (546, or 54.33%) participated than girls (459, or 45.7%). Our data showed no significant differences in participation based on gender; girls seemed to have been just as active as boys.

Furthermore, Figures 1 and 2 show the change in the level of participation over each round. We can conclude that the numbers of boys and girls who participated in the training were nearly the same in each set. Thus, the girls who decided to continue participation were just as persistent as the boys.

The number of tasks submitted by gender, according to Figures 1 and 2 showed no significant differences between girls and boys in the number of attempts, as it related to the level of difficulty. This observation is particularly important, in view of the fact that in a regular classroom setting 'teachers perceived that girls … produced fewer exceptional, risk-taking behaviours than did boys' (Williams, 2006).

The dynamics of the success rates were similar between the girls and boys in all rounds (Tables 1 and 2). In addition, both sexes were more successful on easier levels and less successful in the more difficult levels (average and high).

Conclusions

The gender issue in mathematics, i.e., girls being under-represented in the STEM-related fields, remains unresolved. Thus, every inclusive endeavour to popularise mathematics by attracting all students merits particular attention. The KCVT is a fine example of such inclusive competitions. With limited research available on the patterns of participation and the results of the contest, it is important to investigate the gender-related issues. Following our analysis of the results of participants from Grades 5 – 6 in the 2018 Israeli KCVT, we found no significant differences between the behaviour of boys and girls during the training.

We also found no differences between the achievements of boys and girls who attempted problems with different levels of difficulty. These results are consistent with earlier studies that have also shown no gender differences in mathematical performance (Ajai & Imoko, 2015), (Applebaum & al., 2013), (Devine, Fawcett, Szűcs & Dowker, 2012).

However, the data yield no far-reaching conclusions about the factors that might explain these findings. Other aspects, such as encouragement from parents to participate and gender issues in the use of technology should be considered in future studies. Furthermore, further research and analysis over the next few years would be worthwhile, to determine whether the pattern re-appears. Deeper analysis is required regarding the tasks that were solved more efficiently by girls and the methods they used to solve those tasks.

Our preliminary data analysis has several limitations. The major limitation is our inability to see the solutions of the students. We also are not aware of the reasons for the early departure of some students from the training. Furthermore, we do not know whether participants were assisted by family members/internet / books or other sources. Nevertheless, we observed similar participation rates, risk-taking behaviours and persistence among both genders. This similarity is consistent with the findings of other researchers (Lloyd & al., 2005), (Williams, 2006), who reported non-significant gender differences in mathematics at the junior high-level, as well as equal abilities and interest among both boys and girls during their participation in online activities.

Our future work will use more data and look at more detailed analyses, including interviews with students, which could reveal the reasons for their behaviour, and insightful comments about their thoughts and attitudes during this online problem-solving activity.

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