American Journal of Educational Research, 2018, Vol. 6, No. 8, 1117-1126
Available online at http://pubs.sciepub.com/education/6/8/9
©Science and Education Publishing
DOI:10.12691/education-6-8-9

Mathematics after School in Ukraine

Mary L. Garner[1,*], Tatiana Rudchenko[2], Virginia Watson[3], Olga Chashechnikova[4]

[1]Division of Computer Science and Mathematics, Oglethorpe University, Atlanta, United States
[2]Scheller College of Business, Georgia Institute of Technology, Atlanta, United States
[3]Department of Mathematics, Kennesaw State Univeristy Kennesaw, United States
[4]Department of Mathematics, Sumy State Pedagogical University, Sumy, Ukraine
*Corresponding author: mgarner@oglethorpe.edu

Received June 08, 2018; Revised August 01, 2018; Accepted August 12, 2018

Abstract It has been shown that mathematics achievement among K-12 students can be improved through quality after-school programs. At the same time, university mathematicians are being encouraged to partner with K-12 schools to improve teaching and learning in mathematics, and after-school programs provide a perfect context for that partnership. Yet few such partnerships exist. This study is a description of extracurricular activities in mathematics for high school students provided by universities and high schools in the Sumy region of the Ukraine, and an exploration of the cooperation between university faculty and high school faculty in providing those activities. In addition, evidence of student and parent satisfaction with those activities is presented. This study provides a positive model for cooperation between universities and high schools for the benefit of all students.

Keywords: *after-school activities, secondary mathematics, Ukraine, school-university partnerships, math circles, math competitions*

Cite This Article: Mary L. Garner, Tatiana Rudchenko, Virginia Watson, and Olga Chashechnikova, "Mathematics after School in Ukraine." *American Journal of Educational Research*, vol. 6, no. 8 (2018): 1117-1126. doi: 10.12691/education-6-8-9.

1. Introduction

After-school programs in the United States are increasingly being seen as effective means of improving achievement in mathematics. Summaries of research conducted by the Afterschool Alliance [1] and the Harvard Family Research Project [2] present clear evidence of the benefits of participation in after-school programs and there is a call for expanding quality programs. Furthermore, research shows that low-income groups particularly benefit from such programs. Little [2] asks why aren't there more programs? Her answer: "The answer is really very simple: Forging partnerships is hard work. It takes time, resources, and a commitment from both sides to making it work" (p. 8).

University faculty members in science, technology, engineering, and mathematics (STEM) disciplines in the U.S. are being encouraged to partner with K-12 schools to improve teaching and learning in STEM disciplines [3]. After-school programs would be a natural context for university faculty to interact with K-12 students and teachers. Yet, in a comprehensive review of school-university partnerships, Walsh and Backe [4] state that among the three major forms of partnerships, student support receives little attention. They call for "school–university partnerships to co-construct new strategies and approaches for addressing the out-of-school needs of students." (p. 597).

In Eastern Europe, there is a strong tradition of after-school programs in mathematics originating in Russia with the *matematicheskiy kruzbok* (mathematics circle) [5]. That tradition has been brought to the United States to provide enrichment for mathematically talented students [6]. What other forms do after-school programs in mathematics take in Eastern Europe? Are the programs for gifted only, or can all students participate? Do students and parents appreciate these programs? How do high school and university faculty work together to provide those programs? In this paper, we begin to answer those questions, and explore strategies and approaches for providing after-school programs, as recommended by Walsh and Backe [4].

1.1. Motivation and Research Questions

In the summers if 2012 to 2014, the first three authors collaborated to offer a mathematics camp for high school students at Kennesaw State University. In the camp, the students spent some time each day participating in whole-group activities such as games and lectures by visiting mathematicians; but they spent most of their time in groups of three to five students, exploring a specific question or area of mathematics in the company of a mathematician from the Department of Mathematics. The groups would end the camp by presenting their work to fellow students and parents. We wanted to find new ways to strengthen our relationship with the students and their schools, and thus increase participation in the summer camp and in activities we wanted to offer during the school year. One of the authors, Tatiana Rudchenko, had connections to Sumy State Pedagogical University and Dr.

Olga Chashechnikova, who is very active in local schools; thus we saw an opportunity to study the Eastern Europe tradition of after-school mathematics programs in Sumy, Ukraine.

Our research questions are:

1. What are the after-school activities in mathematics offered in secondary schools in Sumy and what is the level of involvement?
2. What is college faculty involvement in after-school activities for secondary students in Sumy? What challenges do they face and what benefits do they see in participation?
3. Do students and parents value after-school activities in mathematics in Sumy?

1.2. Literature Review

There is little research focused in particular on interactions between mathematicians and K-12 students under the auspices of a partnership between K-12 schools and universities. In research on after-school activities, the activities are often delivered by the K-12 schools or universities independently. It is often not clear how collaboratively universities and K-12 work in these activities and whether research mathematicians or mathematics educators are involved. The literature most relevant to our research questions is literature on after-school programs, which can be divided into after-school programs designed for the development of mathematical talent and after-school programs for all students, and literature on successful partnerships between K-12 schools and universities in promoting mathematics achievement.

1.2.1. Development of Mathematical Talent

The Study of Mathematically Precocious Youth (SMPY) is a 50-year longitudinal study, begun at Johns Hopkins University by J. R. Stanley in 1971, that includes more than 5,000 individuals identified as gifted mathematically. The SMPY has generated a wealth of information about mathematically talented schoolchildren. One of the findings of the study is that talent development is associated with participation in special educational opportunities, programs, and contests outside the classroom [7,8,9].

One extracurricular approach to the development of mathematical talent is participation in competitions outside the classroom, competitions such as the Mathematics and Science Olympiads. The first such competition was held in Mathematics in 1934 in Russia [10]; the United States joined the competition in 1972 [21]. In the U.S., the competition involves 250,000 students, although only the top six compete internationally. Other countries may involve as many as a million students. In an article by Campbell and Walberg [11], the authors surveyed 345 American students who had participated in the international Mathematics, Physics, and Chemistry Olympiads, and their parents. Out of the 345 Olympians, 52% completed or were in the process of completing doctorates and had produced 8,629 publications. They also report that 76% of the Olympians and 70% of their parents stated that the Olympians would not have accomplished as much without the program. In addition, 76% of Olympians and 83% of parents stated that participation in the competitions helped increase awareness of educational opportunities.

In a series of studies led by Campbell [12,13,14,15], evidence is presented that we must provide opportunities for gifted students to explore mathematics beyond the school curriculum, and that the cooperation of universities and research mathematicians and scientists is essential. Campbell & Walberg [11] argue as follows.

> Some of the U.S. Mathematics Olympians report intuitively grasping the underlying algorithms of much of the mathematics taught to them in elementary school. These precocious children realized that some of their teachers did not understand this basic information. This realization caused the Olympians to lose respect for these teachers and caused the teachers to view these precocious students as threats.
>
> How can we challenge such advanced children with the regular curriculum that is provided in most elementary and secondary schools? Some of the competitions encourage students to work at college or research labs where the work is far beyond anything being taught in their science classes. Most schools simply do not have the resources to match the facilities and equipment available at these institutions. It is more sensible for schools to funnel such capable students into these advanced labs for the challenges that are not available in the conventional high school. (p. 15)

Competitions have a long history in Eastern Europe, as do "math circles." Math circles began very recently in the United States and are described by the founders of the Berkeley Math Circle, Stankova and Rike [16], as follows:

> Math circles are weekly math programs that attract middle and high school students to mathematics by exposing them to intriguing and intellectually stimulating topics, rarely encountered in classrooms. Math circles vary in their organization, styles of sessions, and goals. But they all have one thing in common: to inspire in students an understanding of and a lifelong love for mathematics. (p. 5)

Stankova [16] provides quotes from a variety of mathematically talented students in the United States who talk about how they benefited from participation in math circles, and echoes Campbell and Walberg's [11] contention that mathematically talented students are often bored with the regular curriculum. She also provides a personal account of her experience with math circles in Eastern Europe, her passion to start such circles in the U.S. and her disappointment about the support from secondary math teachers in the U.S. At the conception of the Berkeley Math Circle in 1998, she hosted approximately 30 teachers. She says the circle was well received, but when she asked how many teachers were interested in starting a math circle at their own school, she states "There was not a single hand up in the air!"

Burns, Henry, McCarthy, and Tripp [6] provide evidence for the success of their Math Circle for middle school students through surveys indicating student and parent satisfaction. They acknowledge the possibility that math circles could be of benefit to all students, even those not viewed as gifted in mathematics. They also report, however, that their math circle failed to attract high school students and call for research on why high school students do not participate in such a circle. We have also found it difficult to attract high school students to a math circle.

1.2.2. Enrichment for All Students

Baker, Akiba, LeTendre, and Wiseman [17] use the term "shadow education" to describe the use of "structured, supervised, outside-school learning in the form of tutoring, review sessions, proprietary cram schools, and related practices in order to increase students' mastery of academic subjects in school." (p. 2) The authors used data from the 1994-1995 Third International Mathematics and Science Study (TIMSS) on seventh and eighth graders' participation in shadow education to study cross-national patterns in the use of shadow education and its relationship to mathematics achievement. They found that shadow education was widespread among all the countries participating in TIMSS. They unfortunately differentiated between remedial and enrichment activities by the math ability of participating students, classifying the shadow education as remedial if more low ability than high ability students participated, and classifying the shadow education as enrichment if more high ability than low ability students participated. They conclude that remediation is the most common purpose of shadow education, since more low ability students participate; however, they do find that the participation of low vs. high ability students does vary significantly across countries. Their classification of remedial vs. enriching shadow education reinforces the widely held misconception that low ability students cannot participate in enrichment activities in mathematics.

In more recent studies, Stonehill et al [18] and the Afterschool Alliance [1] have published comprehensive reviews of research investigating successful after-school programs. The studies include both secondary and elementary populations and document increases in passing rates on state mathematics tests and improved performance in the classroom, with the greatest gains achieved by low-income students. Sheldon and Epstein [19] provide evidence that family involvement in the mathematics that students were learning, as in math circles, also increased achievement in mathematics.

1.2.3. School-University Partnerships

There is a vast amount of literature on partnerships between K-12 schools and universities. Walsh and Backe [4] state that such partnerships can be divided according to purpose: teacher training and development, co-construction and evaluation of school materials and methods, and student support. The authors point out that student support receives the least attention and has the greatest need. They characterize effective school-university partnerships as those that have a "shared conceptual understanding, mutuality in roles and relationships, sound operational strategies, and evaluation of both the partnership and its outcomes." (p. 599) Challenges to the partnerships include cultural differences between the university and the school system, lack of institutional support, competing professional pressures, funding, and "insider/outsider dynamics." (p. 605)

Literature specifically about school-university partnerships in mathematics that focus on student support is rare and most often involves tutoring services. In an effort to bring mathematicians, teachers, and students together, the National Science Foundation initiated the Math and Science Partnerships Program (MSP) in 2002 with the following purpose in its solicitation:

> In the MSP effort to improve teaching and learning in mathematics and science education, all comprehensive and targeted partnerships will … further cultural change within the collaborations such that all partners, including higher education faculty among education, engineering, mathematics and science departments, make commitments to working together with pre-K-12 educators and are accountable for student performance. (p. 10)

Alligood, Moyer-Packenham, & Granield [3] studied 15 partnerships funded by the MSP over three years. In particular, they examined how mathematics researchers (mathematics faculty whose main research area is mathematics, not mathematics education) were involved in the partnership. Mathematics researchers most often participated in study groups with teachers (as many as 14 researchers in one year) and classroom visits (as many as 12 in one year). Under the category "worked with students" only 5, 8, and 6 participated in each year; thus, most of the work was with teachers not students. The authors echo Walsh and Backe [4] in describing the challenges of engaging mathematicians as overcoming a clash of cultures and different priorities:

> If a cultural change is to be achieved within STEM disciplinary departments, many of these departments may require an attitudinal change among the research faculty, due to the value of research weighed against that of teaching and service/outreach in the tenure and promotion process. (p. 605).

2. Materials and Methods

2.1. Background

There are five types of schools in Ukraine: secondary comprehensive schools, specialized schools, gymnasiums, lyceums, and school educational complexes. Secondary comprehensive schools and specialized schools are comprehensive educational institutions that include 1st through 11th grades, with specialized schools including intensive study of certain subjects and courses. Gymnasiums include 5th through 11th grades, with enhanced study of certain subjects. Enrollment in a gymnasium is based on testing and only gifted students are accepted. Lyceums include 10th and 11th grades with specialized training and professional training. Finally, school educational complexes combine courses from secondary comprehensive schools and gymnasiums.

High school teachers have four different classifications: specialist (S), specialist of category II (II), specialist of category I (I), and specialist of the highest category (H). The categories represent increasingly sophisticated levels of expertise and practice. A specialist of the lowest classification has completed a program in higher education and knows the principles of pedagogy, psychology, child and age physiology; knows the theoretical principles and modern science of the subject they teach; can use information and communication technologies; has the ability to communicate with students, parents, and co-workers; and observes principles of teaching ethics and morality. A specialist of the highest category uses innovative educational methods and technologies, has a wide range of learning strategies, is able to produce and

disseminate innovative ideas, and makes proposals to improve the educational process in the school.

2.2. Webinar

On April 3 and 4, 2014, the authors participated in a Webinar hosted by Sumy State Pedagogical University (SSPU). On the first day we interviewed faculty from three universities, Sumy State Pedagogical University, the Ukrainian Academy of Banking (Sumy) (UAB) and Sumy State University (SSU). On the second day we interviewed high school teachers who were attending a professional development day. The interpreters for the interviews were Tatiana Rudchenko and Golubkova Natalia Leonidivna, Vice-Director for Research and Social Work at the Institute of Philology of Sumy State University and Senior Lecturer of the English Language Practice Chair.

The participants had been given the interview questions ahead of time. The four interview questions for both groups were the same except for question 4. The question was changed to reflect whether the interviewee was a high school teacher or a university professor.

1. What extracurricular activities in mathematics for high school students do you support? Please describe the activities and your involvement.
2. What obstacles do you face in supporting extracurricular activities in mathematics for high school students?
3. What do you find most rewarding about your involvement in extracurricular activities in mathematics for high school students?
4. How would you describe your relationship with high school teachers (university professors)? Are they involved in your activities with high school students? How are they involved? Would you like to see more involvement or less involvement?

Participants in the webinars are identified with letters as either a university professor (Professor A), a high school teacher (Teacher J) or an administrator (Administrator X). We list all participants in the Webinar in Table 1. Not all the participants spoke; some were in groups and had a main spokesperson. As shown, there were 11 university faculty members, 12 teachers, and one "methodologist." Most of the teachers are specialists of the highest category. Among the university faculty, there were 3 lecturers, 3 associate professors, and 2 full professors

The translations of each participant's comments were examined by M. Garner and V. Watson separately to determine the answers to each of the four interview questions and extract representative quotes.

2.3. Questionnaires

In the summer 2014, the authors collaborated on constructing questionnaires for students and parents. These questionnaires were administered in fall 2014 and contained many questions that were part of a larger study being conducted by Dr. Chashechnikova, who invited 29 schools in the city Sumy and Sumy area to participate in the survey and seven schools responded, five city schools numbered 1 through 5 and two schools from surrounding villages numbered 6 and 7. Table 2 provides the characteristics of each school. There were two gymnasiums, three specialized schools, and two comprehensive schools.

Table 1. Webinar Participants

Participant	School	Position
Professor A	Sumy State Pedagogical University	Associate Professor, PhD in Mathematics
Professor B	Sumy State Pedagogical University	Lecturer in Mathematics
Professor C	Sumy State Pedagogical University	Lecturer in Mathematics
Administrator D	Sumy State Pedagogical University	Professor, PhD in Teaching Mathematics and Physics, PhD in Mathematics and Methods of Teaching Mathematics
Administrator E	Ukrainian Academy of Banking	Math Department Chair, Associate Professor, PhD in Technical Science
Professor F	Ukrainian Academy of Banking	Senior lecturer in Mathematics, PhD in Pedagogical Sciences
Administrator G	Sumy State University	Math Department Chair, Associate Professor, PhD in Mathematics
Administrator H	Sumy State University	Math Department Assistant Chair, Associate Professor, PhD in Mathematics
Professor I	Sumy State University	Associate Professor, PhD in Pedagogical Sciences
Teacher J	Secondary comprehensive school	Specialist highest category
Teacher K	Secondary comprehensive school	Specialist highest category
Teacher L	Specialized school	Specialist highest category
Administrator M	Specialized school	Principal, Specialist highest category
Teacher N	Specialized school	Specialist highest category
Teacher O	Specialized school	Specialist highest category
Teacher P	Specialized school	Specialist highest category
Teacher Q	Specialized school	Specialist highest category
Teacher R	Specialized school	Specialist
Teacher S	Gymnasium	Specialist highest category
Teacher T	Private Christian school	
Teacher U	Gymnasium	Specialist highest category
Administrator X	Sumy State Pedagogical University	Math Ch1ir, Professor, PhD Physics & Mathematics
Administrator Y	Sumy State Pedagogical University	Dean Physical and Math Department, Associate Professor, PhD Physics and Mathematics
Administrator Z	Sumy Regional In-Service Institute	Methodologist of Mathematics

Table 2. Schools Involved in Questionnaire and Student Response

School & Classification		Number Seniors	Faculty	Student Responses (%)	Specialist Categories (Number)
1	Gymnasium	150	9	71 (47%)	S(1), 1 (1), H (7)
2	Gymnasium	105	9	38 (36%)	S(1), II(1) H(7)
3	Specialized School	145	14	34 (23%)	S(3), II(2), I(4), H(5)
4	Specialized School	68	7	37 (54%)	S(1), I(1), H(5)
5	Comprehensive School	90	5	25 (28%)	I(2), H(3)
6	Comprehensive School	27	2	21 (78%)	I(1), H(1)
7	Specialized School	74	4	72 (97%)	S(2), I(1), H(1)

The questionnaires were voluntary for senior students (the U.S. equivalent of high school students) and their parents and teachers. The number of seniors in each school, along with the student response rate for each school, is shown in Table 2. Overall response rate was 45%; the rates varied from 23 to 97% for each school. Parent response rates are shown in Table 3. Overall response rate for parents was only 20%. The surveys were translated into English by Golubkova Natalia Leonidivna and Tatiana Rudchenko.

Table 3. Parent Response

School & Classification		Number Seniors	Parent Responses (%)
1	Gymnasium	150	0
2	Gymnasium	105	5(4.8%)
3	Specialized School	145	36(25%)
4	Specialized School	68	27(40%)
5	Comprehensive School	90	24(27%)
6	Comprehensive School	27	26(96%)
7	Specialized School	74	15(20%)

3. Results

3.1. Ukrainian System

Several participants in the webinar provided explanations of how mathematicians and mathematics teachers are trained in the Ukraine. In particular, Administrators X and Y explained the difference in the training of mathematicians who do research in mathematics as compared to mathematicians who teach mathematics. Administrator X began:

> The system of training teachers in Ukraine differs from the system of training teachers of mathematics in the United States of America. The first thing is that we combine here mathematics as a science and didactics. And there are certain advantages; first students are taught mathematics as a science and then didactics how to apply it.

Administrator Y continued:

> In the USA, classical universities train teachers. We have pedagogical universities, teacher training universities who train teachers for schools. The difference between classical American universities is that our universities are a bit smaller, and we train teachers so we focus our attention on education. . .
>
> There are three levels of training, the first level is bachelor, then one year specialist plus one year master … The whole cycle of training a teacher includes six years: four years to get bachelor's degree, one year to get specialist and one year to get master's degree.

Administrator Y also explained that the bachelor's degree in mathematics education is different from the bachelor's degree in mathematics. The bachelor's degree in mathematics is designed to produce mathematicians who can do research. The bachelor's degree in mathematics education is designed to produce mathematicians who are specially trained for teaching. In addition, future teachers are trained to conduct extracurricular activities according to Administrator X: "At the mathematics department they train students who are future teachers to conduct these extracurricular activities and when they come to school to teach they know how to do it."

Another participant in the webinar (Administrator Z) described the role of the Sumy Regional In-Service Institute. The institute provides professional development for teachers, bringing university faculty and high school teachers together. The institute also provides help in designing tasks for Olympiad competitions.

Administrator D emphasized that the three universities represented at the webinar, two of which are not pedagogical universities, work together closely to help high school teachers train students for competitions and enhance their understanding of mathematics. Administrator D explained why university participation in extracurricular activities in mathematics is particularly important to the pedagogical university:

> The profession of a teacher is not very prestigious nowadays in Ukraine; that's why not the best high school graduates enter pedagogical universities and it means that we suffer from it, as they lack knowledge.

Through the extracurricular activities, the pedagogical university can attract the best students. Administrator D emphasized that university faculty do not get paid for working with high school students.

Administrator M, who is a school principal, described what happens after teachers graduate from the pedagogical university:

> After graduating from the pedagogical university a young teacher comes to work at school and has a qualification of a specialist. During the first five years of work the administration of the school observes the way a young teacher conducts classes. The teacher is encouraged to participate in various conferences, workshops, seminars and other activities. There are so-called schools of young teachers and each young specialist has a supervisor. Reaching certain results in his/her work, every five years there is a so-called state attestation of teachers and a teacher has the right to apply for promotion to get higher qualification. Getting promotion and getting higher qualification has some

benefits: the first benefit is financial, the higher qualification you have the higher salary you will have, and the prestige if the teacher's qualification becomes higher. While distributing classes among the teachers of school the preference is give to the teachers with higher qualification, so teachers are interested in getting higher qualifications.

Table 4. Student Response to the Question: "Do you attend extracurricular classes in mathematics?"

School	No	Yes	Blank	Total
1	20(28%)	51(72%)	0	71
2	17(45%)	21(55%)	0	38
3	7(21%)	27(79%)	0	34
4	1(3%)	36(97%)	0	37
5	17(68%)	8(32%)	0	25
6	19(90%)	0	2(10%)	21
7	51(71%)	15(21%)	6(8%)	72
Total	132(44%)	158(53%)	8(3%)	298

3.2. Types of Extracurricular Activities and Participation

As shown in Table 4, 158 out of the 298 (53%) students surveyed stated that they participate in extracurricular classes in mathematics. When students were asked whether they participate in school, regional, or international competitions in mathematics, 226 (76%) stated that they participate in some competition in mathematics, the most frequent competition being Kangaroo. Consistent with the student reports, 20 out of the 21 teachers reported that they have their students participate in competitions. Sixty-five (22%) students stated that they participate in "elective work" or some "work group" in mathematics. Twenty-three (8%) students reported attending math courses at a university and another 26 (9%) students specifically mentioned math circles. Thirty-four (11%) students stated that they participate in scientific research in mathematics, with another 29 (10%) saying they occasionally participate in scientific research in mathematics. When asked if they read supplemental literature in mathematics, 127 (43%) answered "yes".

There appears to be a big difference between the village schools and the city schools in participation in extracurricular activities. In the two village schools, 70 out of 93 students (75%) stated they did not attend extracurricular classes in mathematics. In the other five schools, however, only 62 out of 205 (30%) said they did not attend extracurricular classes. Among the five city schools, school 5 seems to be an outlier with 68% of students saying they do not attend extracurricular classes.

During the webinars, all those interviewed described preparing for competitions as the main focus of extracurricular activities. Professor I from SSU also mentioned collaboration with the Minor Academy of Science. The Minor Academy of Sciences is an out-of-school educational experience for gifted students in Ukraine. The Academy's goal is to develop students' skill at research and experimental work in the sciences, technology, culture, and art. The students participate in activities that progress from initial skills such as writing a creative abstract and searching previous work, to basic skills such as active participation in scientific experiments, exhibitions, and competitions, and finally to higher skills of conducting one's own work and reporting results at international conferences and in publications.

Professor F from UAB described 14 projects at their university including competitions, camps, lectures, access to interactive learning resources, scientific projects, and participation in the Minor Academy of Science. In addition, Professor B organizes mathematical competitions for high school students who major in the humanities.

The high school teachers described a variety of activities in addition to competitions including participation in a "week of mathematics," summer camps, and special elective classes. Teacher S specifically described a math circle that involves teachers, students, and parents, and is designed to prepare for the Olympiads.

The most frequently mentioned difficulties university faculty face in supporting extracurricular activities included student and teacher motivation, and the level of knowledge of the students. Professor I stated:

> There are a lot of difficulties. So, first of all, high school students should have strong motivation to study this subject. Secondly, to give classes for high school students is a bit more difficult than to give classes for university students. There are some difficulties of psychological character.

Professor B expressed concern over making sure students who submit material to competitions are really doing their own work.

One university faculty member and five of the high school teachers stated that time was the greatest difficulty. Both students and teachers tend to be overcommitted. Two of the high school teachers said there are no difficulties. Only one teacher cited differences in student motivation and level of knowledge as problems.

The most rewarding aspects of participating in extracurricular activities included the following:

- Stimulating student's interest in mathematics.
- Cultivating creativity in students and teachers.
- Promoting life skills and communication skills.
- Promoting skills in mathematics.

Teacher T said, "People who succeed in mathematics succeed in life." Personal satisfaction was also expressed by both university and high school faculty. Professor A said:

> The most rewarding thing is just to fill the gap that high school students experience, and when a teacher helps students to fill these gaps and it helps them to succeed in life that is the most important reward for any teacher.

Teacher J said:

> The most rewarding thing is that while preparing for conducting any event a teacher learns something, a teacher receives something from her students and she really enjoys and she puts her heart and soul into these events.

3.3. Student and Parent Attitudes

Tables 6a, 6b, 6c, and 6d show how 133 parents responded to questions about the value of extracurricular activities in mathematics. A majority (53%) of parents indicated that it is necessary for a child to participate in extracurricular activities in mathematics, and 65% indicated that such participation influences the child's level of knowledge. In addition, 78 parents (59%) stated

that participation in extracurricular activities in mathematics helps children learn other school disciplines. A majority (54%) of parents stated that they do see a place for mathematics in their child's future.

There was again a gap between the two village schools and the other schools in the parents' appreciation for extracurricular activities. Nineteen out of 41 parents from village schools (46%) stated that they thought it was necessary for a child to participate in extracurricular activities in mathematics, compared to 51 out of 92 (55%) parents from the four other schools. Twenty parents from the village schools out of 41 (49%) stated that participation in extracurricular activities in mathematics influences their child's level of knowledge, as compared to 66 out of 92 (72%) parents from the other schools. In addition, 23 out of 41 parents from village schools (56%) stated they do not see a place for mathematics in their child's future, as compared to 29 out of 92 (32%) parents from the other schools. Note that school 5 again differs from the other city schools in that parent responses reflected a lack of appreciation for extracurricular activities in mathematics.

Tables 5a, 5b, and 5c show student response to questions about the value of after-school activities in mathematics. As shown, 124 out of 298 (42%) students felt that extracurricular activities in mathematics helps you learn other school disciplines, compared to 59% of parents. The village schools differed from city schools in that only 18% of the students in the village schools felt that extracurricular activities in mathematics helps you learn other school disciplines, compared to 53% of the students in the five other schools. A consistent majority of the students stated that mathematical skills will be useful in their future life and stated that they like mathematics. Specifically, 244 out of 298 (82%) students stated that mathematics will be useful in their future life, and 228 (77%) stated that they like mathematics.

Table 5a. Do extracurricular activities in mathematics help you to learn other school disciplines?

School	No	Yes	Blank	Total
1	43(61%)	28(39%)	0	71
2	18(47%)	17(45%)	3	38
3	11(32%)	22(65%)	1	34
4	9(24%)	28(76%)	0	37
5	11(44%)	12(48%)	2	25
6	1(5%)	1(5%)	19(90%)	21
7	44(61%)	16(22%)	12(17%)	72
Total	137(46%)	124(42%)	37(12%)	298

Table 5b. In your opinion will mathematics (mathematical skills) be useful to your future life?

School	No	Yes	Blank/Maybe	Total
1	14(20%)	54(76%)	3(4%)	71
2	0	37(97%)	1(3%)	38
3	3(9%)	29(85%)	2(6%)	34
4	3(8%)	32(86%)	2(5%)	37
5	3(12%)	21(84%)	1(4%)	25
6	4(19%)	14(67%)	3(14%)	21
7	13(18%)	57(79%)	23(%)	72
Total	40(13%)	244(82%)	14(5%)	298

Table 5c. Do you like mathematics?

School	No	Yes	Blank/Maybe	Total
1	15(21%)	53(75%)	3(4%)	71
2	2(5%)	36(95%)	0	38
3	2(6%)	32(94%)	0	34
4	2(5%)	35(95%)	0	37
5	3(12%)	21(84%)	1(4%)	25
6	0	21(100%)	0	21
7	34(47%)	30(42%)	8(11%)	72
Total	58(19%)	228(77%)	12(4%)	298

Table 6a. Does participation in extracurricular activities in mathematics help your child to learn other school disciplines?

School	No	Yes	Blank	Total
2	0	5(100%)	0	5
3	3(8%)	31(86%)	2(6%)	36
4	1(4%)	22(81%)	4(15%)	27
5	9(38%)	4(17%)	11(46%)	24
6	1(4%)	8(31%)	17(65%)	26
7	2(13%)	8(53%)	5(33%)	15
Total	16(12%)	78(59%)	39(29%)	133

Table 6b. Do you believe it is necessary for a child to participate in extracurricular activities in mathematics?

School	No	Yes	Blank	Total
2	0	5(100%)	0	5
3	14(39%)	21(58%)	1(3%)	36
4	8(30%)	19(70%)	0	27
5	17(71%)	6(25%)	1(4%)	24
6	16(62%)	10(39%)	0	26
7	6(40%)	9(60%)	0	15
Total	61	70	2	133

Table 6c. Does participation in extracurricular activities in mathematics influence your child's level of knowledge?

School	No	Yes	Blank	Total
2	0	5(100%)	0	5
3	3(8%)	33(92%)	0	36
4	3(11%)	24(89%)	0	27
5	18(75%)	4(17%)	2	24
6	4(15%)	11(42%)	11(42%)	26
7	6(40%)	9(60%)	0	15
Total	34(26%)	86(65%)	13(10%)	133

Table 6d. Do you see a place for mathematics (mathematical skills) in your child's future?

School	No	Yes	Blank	Total
2	0	5	0	5
3	9(25%)	24(67%)	3(8%)	36
4	7(26%)	19(70%)	1(4%)	27
5	13(54%)	7(29%)	4(17%)	24
6	16(62%)	9(35%)	1(4%)	26
7	7(47%)	8(53%)	0	15
Total	52(59%)	72(54%)	8(6%)	133

3.4 Role of University Faculty

When asked about relationships between high school teachers and college faculty, all webinar participants responded positively. The high school teachers in particular praised the leadership at SSPU. Teachers J and U stated that leadership at SSPU has helped them write and publish research. Teacher N said that her students attend courses at SSPU for free and she often invites college faculty to the school. Teachers L and M talked about working with faculty from Sumy State University as well as other universities. Teacher N said:

> We invite university teachers not only to develop professional skills of our teachers but also to develop mathematics skills of our students and to prepare them for Olympiads and other competitions.

Teacher S explained why collaboration with college faculty is necessary in the math circle she runs:

> We work at very advanced topics - number theory, game problems for Olympiads, Diophantine equations. We need much support and help of the university teachers to learn the topics deeply. More and more students have a wish to get this additional knowledge … They (university faculty) are interested in preparing students who will be their future students, while we are working with every student, those who already show some interest and have mathematical ability as well as those have yet to develop interest.

Administrator M, a school principal, echoed the need for university faculty:

> We invite university faculty not to develop our teachers professionally but we need their assistance in preparing our high school students for participating in various competitions and Olympiads, because the tasks students are given in these kinds of contests are of advanced level. So students should be given scientific explanation of many tasks, phenomena and many things in mathematics. One more aspect of involving university faculty to work with high school students is that they prepare their future students. They prepare them to conduct research for the time when they become university students.

The university faculty expressed a desire to have more interaction with high school students and teachers. Professor I said:

> Speaking about high school teachers' involvement, they are involved, but very often they remain passive and their main role is just counseling, - just giving pieces of advice – what to do and what not to do … We want to involve high school teachers more actively. We would like to have assistance from high school teachers to design tasks, because in your country you have special bodies that conduct the Olympiads and design the tasks, but not here.

Professor F said:

> We wish they (high school teachers) would be more active, show more initiative, challenge youth. It is better for us because if we cooperate with them their pupils will get better results when they are students. We work mainly with the students during those first two years. It is like a raw material – we work with it to get the product. So it takes time. If we start working with them from school age, we will get the best results.

Professor A suggested a reason for the teachers' passivity:

> High school teachers invite university faculty to their classes in order to explain some complicated things to their students. The problem is that not all high school teachers can solve Olympiad mathematics problems and they are not interested in solving these problems. They need knowledge of very high level and sometimes they don't have this knowledge and that's why they remain passive. Perhaps these teachers don't want to show their weak point.

However, professor C emphasized the need for collaboration, saying "Only our joint activity and regular work aimed at students' skills and their creative thinking development can be effective."

4. Discussion

The first research question was "What are the after-school activities in mathematics offered in secondary schools in Sumy and what is the level of involvement?" Extracurricular activities in mathematics in this region take on quite a variety of forms:

- School-based activities such as a "week of mathematics," contests, summer camps, and special elective courses.
- Research in mathematics at the Minor Academy of Sciences, where students have the opportunity to conduct, write, and present research in mathematics in collaboration with mathematicians.
- University-based activities including preparation for national and international competitions, camps, lectures, and scientific projects. Students can attend courses at SSPU for free.

Even students whose interest is not in mathematics are provided an activity, such as the contest organized by a faculty member from SSPU specifically for students majoring in the humanities. Most of the activities involve some kind of competition. Teacher S explained "all children love games."

A majority of students (53%) across the seven schools stated that they participate in extracurricular activities in mathematics; and 76% said they participate in competitions, indicating that many teachers include participation in competitions as a regular part of classes. The level of participation varied across the schools, from 97% in school 4 to a low of none in school 6. Perhaps since schools 6 and 7 are outside the city of Sumy, access to after-school opportunities at those schools is limited. In addition, schools 6 and 7 had the highest ratio of student to mathematics teacher (13.5 and 18.5 respectively) compared to school 4 with a ratio of 9.7. School 5 also had a high ratio of student to teacher (18) and also exhibited lower participation in extracurricular activities. Those schools may also have less of an emphasis on mathematics study.

It is particularly surprising that 11 percent of students said they participate in scientific research in mathematics and another 10 percent said they occasionally participate in scientific research. Another surprising result is that 43 percent stated they read supplemental literature in mathematics.

The third research question was "Do students and parents value after-school activities in mathematics in

Sumy?" Surprisingly, 82% of students agreed that mathematical skills will be useful in their future, a higher percentage than the parents, and 77% said they liked mathematics. These percentages are comparable to those obtained by Campbell and Walberg [11] in their appreciation of participation in Olympiads, even though the students in this study are not necessarily gifted. A majority of parents (53%) agreed with the statement that it is necessary for a child to participate in extracurricular activities, and this included 46% of the parents in the village schools. Another piece of evidence for the value of extracurricular activities in mathematics is the fact that the universities train prospective teachers in how to conduct extracurricular activities, a practice that might be useful to adopt in US training of teachers.

The second research question was "What is college faculty involvement in after-school activities for secondary students in Sumy? What challenges do they face and what benefits do they see in participation?" Both university faculty and high school faculty appear to be highly involved in providing quality extracurricular activities in mathematics for the high school students. Many of those interviewed expressed how essential is the collaboration between university faculty and high school teachers. Professor C said "Only our joint activities and regular work aimed at students' skills and their creative thinking development can be effective." Teacher S said "We need much support and help of the university teachers." There appeared little of the culture clash addressed by Walsh and Backe [4] or the MSP solicitation [20]. Furthermore, there was a clear focus on student support in contrast to the U.S. as reported by Alligood, Moyer-Packenham, and Granfield [3].

The difficulties in providing extracurricular activities included time, motivation of students, and student level of knowledge. There was no mention of the difference in priorities in the schools vs. the universities as reported by Walsh and Backe [4]. The university faculty seemed as committed as school faculty to stimulating interest in mathematics, cultivating creativity, improving knowledge and skills. University faculty often cited attracting good students to the universities as a benefit. Administrator X explained pedagogical benefits for conducting extracurricular activities in mathematics:

> When we conduct our classes the atmosphere is very efficient, because we have tasks, problems, marks and we have to fulfill our tasks. But when we conduct extracurricular activities we create friendly relations, warm atmosphere in the classroom and then we bring this atmosphere in our classes.

Administrator D stated:

The fact is that the university really works with many students of different institutions and the work is free. University teachers don't get any payment. School teachers provide great help during university students' teaching practice. School teachers help, develop, guide our students and they do it free of charge. So they only get spiritual reward. That's why we have such close relations, such fruitful cooperation, and this cooperation has quite a long history.

High school teachers expressed the need for university faculty and university faculty expressed a desire for more high school teacher participation. Both university and high school faculty stated that the perspective of university faculty, both those in mathematics and those in mathematical pedagogy, was valuable. Three university faculty who were interviewed did express a desire for more high school teacher involvement in the form of initiating more projects and designing tasks. One university faculty referred to lack of knowledge of the teachers as an impediment, but several teachers admitted that they did not have the knowledge to tackle some Olympiad problems. Professor I, from a non-pedagogical university, referred to the special pedagogical and psychological knowledge required to work with high school students.

5. Conclusion

This study is a description of extracurricular activities in mathematics for high school students provided by universities and high schools in the Sumy region of the Ukraine, and an exploration of the cooperation between university faculty and high school faculty in providing those activities. A majority of students participate in after-school activities in the Ukraine, and the majority of both parents and students see participation in after-school activities in mathematics as necessary and useful. Most of the after-school activities center around competitions, but students also have the opportunity to work with mathematicians on mathematical research. The cultural clash that is reported in the US is not evident in Sumy. The study provides a positive model for cooperation between universities and high schools, and between those university faculty involved in educating teachers and those involved in mathematics research and education of college students.

Statement of Competing Interests

The authors have no competing interests.

References

[1] Afterschool Alliance, "A summary of formal evaluations of the academic impact of afterschool programs," Afterschool Alliance. Retrieved from www.afterschoolalliance.org. 2008.

[2] Little, P. M. *Supporting student outcomes through expanded learning opportunities*, Harvard Family Research Project, Indiana Wesleyan Center for EducationalExcellence (ED504234), Marion, Indiana. 2009.

[3] Alligood, K.T., Moyer-Packenham, P.S. and Granfield, P.G., "Research mathematicians'participation in the MSP program," *Journal of Educational Research & Policy Studies*, 9 (2). 23-42. 2009.

[4] Walsh, M.E. and Backe, S., "School-university partnerships: Reflections and opportunities," Peabody Journal of Education, 88 (5). 594-607. 2013.

[5] Kennedy, S., "The math circle," *Math Horizons*, 10 (4). 9-10, 27-28. 2003.

[6] Burns, B., Henry, J., McCarthy, D. and Tripp, J., "The value of the math circle for gifted middle school students," *Gifted Child Today*, 40 (4). 198-204. 2017.

[7] Benbow, C.P. and Lubinski, D. (Eds.), *Intellectual talent: Psychometric and social issues,* Johns Hopkins University Press, Baltimore, 1996.

[8] Lubinski, D. and Benbow, C. P., "Study of mathematically precocious youth after 35 years: Uncovering antecedents for the development of math-science expertise," *Perspectives on Psychological Science*, 1 (4). 316-345. 2006.

[9] Stanley, J., "Making the IMO team: The power early identification and encouragement," *Gifted Child Today*, 22-23. March/April 1987.

[10] Kukushkin, B., "Olympic movement in Russia," *International Journal of Educational Research,* 25. 553-562. 1996.

[11] Campbell, J. R. and Walberg, H. J., "Olympiad studies: Competitions provide alternatives to developing talents that serve national interests," *Roeper Review*, 33. 8-17. 2011.

[12] Campbell, J. R., "Secrets of award winning programs for gifted in mathematics," *Gifted Child Quarterly, 32*. 362-365. 1988.

[13] Campbell, J. R., "Early identification of mathematics talent has long-term positive consequences for career contributions," *International Journal of Educational Research,* 25. 495-534. 1996.

[14] Campbell, J. R., Wagner, A. and Walberg, H., "After school and summer programs, competitions and academic olympics" in K. Heller, F. Monks, R. Sternberg, and R.Subotnik (Eds.), *International handbook for research on giftedness and talent* (2nd ed.), Pergamon Press, Oxford, England, 2000, 523-535.

[15] Campbell, J. R., "Academic competitions: One of the secrets of America's success at developing exceptional talent," paper presented at the International Conference on Education for the Gifted in Science, Busan, Korea, August, 2002.

[16] Stankova, Z. and Rike, T., *A Decade of the Berkeley Math Circle: The American Experience Volume I*, Mathematics Sciences Research Institute, Berkeley, California, 2008.

[17] Baker, D. P., Akiba, M., LeTendre, G. K. and Wiseman, A. W., "Worldwide shadow education: Outside-school learning, institutional quality of schooling, and cross-national mathematics achievement," *Educational Evaluation and Policy Analysis*, *23* (1). 1-17. 2001.

[18] Stonehill, R. M., Little, P. M., Ross, S. M., Neergaard, L., Harrison, L., Ford, J., Deich, S.,Morgan, E., and Donner, J., *Enhancing School Reform Through Expanded Learning*, 2009. www.kearningpt.org.

[19] Sheldon, S. B. and Epstein, J. L., "Involvement counts: Family and community partnerships and mathematics achievement," *The Journal of Educational Research,* 98 (4). 196-206. 2005.

[20] National Science Foundation, "Math and science partnership program: Program solicitation NSF02-061," National Science Foundation. 2002. Retrieved from http://www.nsf.gov/pubs/2002/nsf02061/nsf02061.html.

[21] Turner, N. D.,"A historical sketch of the Olympiads, national and international," *The American Mathematical Monthly*, 85, 802-807. 1978.