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Uncovering GEMS of Mathematics

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Synopsis

Gateway to Exploring Mathematical Sciences (GEMS) is an outreach program offered by the six mathematics departments of the Claremont Colleges for eighth, ninth, and tenth graders. In this paper, we describe our program (in terms of format, participants, mathematical activities and topics involved) and share why we are so enthusiastic about it.

Gateway to Exploring Mathematical Sciences (GEMS) is an outreach program offered by the six mathematics departments of the Claremont Colleges[1] for eighth, ninth, and tenth graders. Some basic information about our program is available on our website: http://ccms.claremont.edu/GEMS, accessed last on June 5, 2017. In this paper we describe our program and share why we are so enthusiastic about it.

[1]The Claremont Colleges is a consortium of five undergraduate colleges (Pomona College, Scripps College, Claremont McKenna College, Harvey Mudd College, and Pitzer College) and two graduate institutions (Claremont Graduate University and Keck Graduate Institute) situated in Claremont, California, USA, see http://www.claremont.edu. The program described here is run by a collaboration among the mathematicians of the five undergraduate colleges and Claremont Graduate University through the Claremont Center for Mathematical Sciences (CCMS), see http://ccms.claremont.edu/. And to be precise, Pitzer College, one of the contributors to the program, does not have a mathematics department *per se*, but rather, a mathematics field group.

There is evidence that a high proportion of students in the middle school age range become frustrated by regular school mathematics.[2] Our intent in GEMS is to counter these tendencies; instead, we hope to increase their interest in mathematics and to experience the joy of doing it. The program aspires to show that mathematics is relevant and applicable in "real-world" situations. It does so by introducing students to the richness and diversity of the mathematical sciences, creating a context in which middle and high school students can meet other students interested in math, and providing opportunities for them to interact with mathematics faculty and undergraduate and graduate students from our colleges. A high priority for the program is to show students first-hand that STEM subjects can be fun, while illustrating how extensively math is used in the social and natural sciences and in engineering, especially for those students from traditionally under-represented groups. This kind of program is a great antidote for our anti-math culture in which the discipline is generally seen as an antithesis of artistic creativity.

We rate our success on the enthusiasm shown by the students when they do group projects based on the material in the presentation. They relish the challenge of approaching problems and they show delight when they generate ideas on how to get a solution.

Format

GEMS workshops take place three times each semester, once a month on Saturday mornings, from 10 am till 12 noon. Meetings are held in a classroom at one of the Claremont Colleges. Each workshop begins with a forty-five minute presentation by a STEM professor, followed by a snack break. Then comes a forty-five minute breakout session, in which the audience splits into small groups, with each group conducting its own hands-on explorations related to the presentation. Each group consists of approximately six to eight students, and group work is facilitated by Claremont Colleges math students, acting as mentors to each group. Finally, there are group presentations from the participants of their results.

[2]Besides measures of performance which seem to decline as students move through middle school (see for instance the discussion on mathematics performance in such assessments (pages 44–47) in [3]), we also see and hear this from young people we know.

Figure 1: Professors Gizem Karaali (Pomona College) and Blake Hunter (Claremont McKenna College) assisting students with their projects. Photos taken by authors and made available here with permission of the participants.

The main feature of a typical GEMS session is that each workshop provides a mathematical topic that interests the participants and a forum in which they can enhance their understanding, individually or in groups, by completing fun tasks related to the topic. These topics are designed to be accessible to the average student (not just to the math whiz) with relatable themes such as the mathematics of music, love (marriage algorithm), game shows, knots, and elections.

While we know that moving away from a teacher-centered lecture format towards a more active-learning focused format is encouraged by educational research and active learning can indeed be both exciting and effective, uncovering the GEMS of mathematics, we have found, requires both expertise and resources. Thus we have converged on our mixed format, where experts share and then students act; this certainly seems to work well for our context.

The GEMS program has been supervised by five Claremont mathematics faculty: Ellis Cumberbatch (CGU), Jemma Lorenat and Dave Bachman (Pitzer College), Asuman Güven Aksoy and Blake Hunter (Claremont McKenna College). All Claremont faculty involved in GEMS activities volunteer their time. All faculty time is donated; the student program coordinator and the student mentors are paid. Funding came from the MAA in the early years, currently it is provided by the Edison International foundation.

Participants

In 2008, the pilot year of the program, a GEMS event drew approximately forty student participants. By 2014, however, it began to draw over a hundred students per session, too many for the assigned room. Subsequently, we began to require students to register ahead of time online (done through our website at http://ccms.claremont.edu/GEMS) and we cap the attendance at 70. Our outreach fliers specify that we seek participants from the eighth, ninth, and tenth grades, and we advertise the program to students and local area schools in Los Angeles and San Bernardino counties.

Our Goals

By exposing students to areas of the mathematical sciences seldom introduced in middle and high school curricula, GEMS has the potential to attract students to the mathematical sciences, students who might otherwise pursue other non-STEM fields. Further, by allowing students interested in math to interact with their peers, the program helps foster small collectives that share interests, attract other students, and disseminate information about potential STEM-related learning opportunities.

Our primary goals with GEMS revolve around creating a context within which middle and high school students can:

- explore the richness and diversity of the mathematical sciences;
- meet other students interested in the field;
- interact with STEM faculty; and
- engage in mathematical exploration activities on a university campus.

Each goal, if achieved, has potential outcomes that are of great importance to the development of a mathematically literate society and the creation of the technological workforce needed for the 21st century.

A final goal of GEMS is to introduce middle and high school students from underrepresented communities to scholarly work on a university campus.

Historically, the unfamiliarity of the university setting has acted as a barrier to pursuing a degree for some student populations. By familiarizing students with faculty and students within a university setting, the program makes higher education seem accessible and possible. The GEMS collaborative experiences may help these students see how to avoid isolation in later years.

Finally, we note that the national emphasis in more gender-equal participation in high school and college mathematics has coincided with and probably led to positive results in women gaining more mathematics PhDs.[3] We continue to stress to the math teachers that we are in touch with to especially urge their minority and female students to participate, and to spread the word to teachers at other schools. We haven't asked program participants about their race or ethnicity; we can see however that they reflect the diversity of the local schools. They are also over 40 % female.

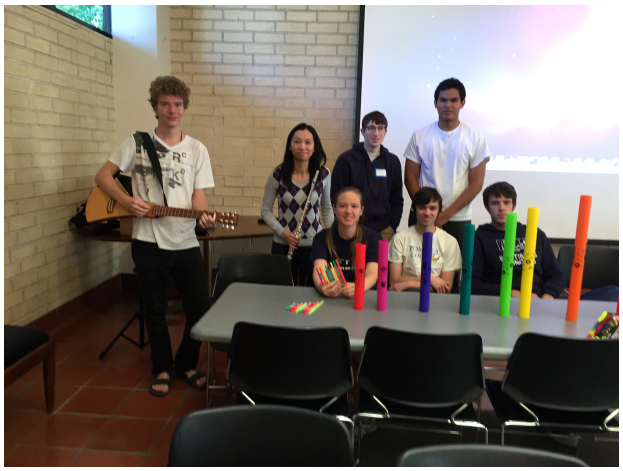

Figure 2: Professor Chiu-Yen Kao (Claremont McKenna College) with student helpers. Photos taken by authors and made available here with permission of the participants.

In a recent survey we conducted, 88% of students said that their STEM skills had improved as a result of their GEMS participation, 98% said they would attend the following year's sessions, and 100% said they would recommend the program to their friends.

[3]Percentage of women receiving PhDs is increasing across many disciplines [2]. We believe that the change in mathematics in particular has come about by the efforts of many intentionally working to help women overcome the prevalent gender gap; see [1].

However, the clearest measure that we are achieving our goals is the continued high attendance. We also can see clearly the enthusiasm among the participants and the joy and excitement in the air when they are working on various mathematical projects during any given session.

Sample Presentations

The following are descriptions of some of the GEMS presentations led by Claremont professors:

Knotted or Not: *Knot theory is a field of mathematics that studies how strings can be tied in different kinds of knots. Knots have applications in many different areas of science and technology, from chemistry and biology to physics and engineering. In this activity, we will see some of the tools mathematicians use to distinguish different kinds of knots.*

Faculty facilitator: Sam Nelson (Claremont McKenna College).

The Music In The Math: *We usually think of math in terms of numbers, equations, and graphs. Sometimes we can make mathematical discoveries by listening to mathematics. In this presentation, we will see how rhythms and melodies can be created from mathematical formulas. No prior training required!*

Faculty facilitator: Ami Radunskaya (Pomona College).

Let's Make A Deal: *Using information to make decisions: Understand how extra information affects our knowledge about outcomes can be tricky. In this project we'll look at a popular TV game show called* Let's Make A Deal *and show how information given by the host can help a player to make better decisions.*

Faculty facilitator: Mark Huber (Claremont McKenna College).

Should We Vote On How We Vote? *Voting is something we do in a variety of settings, but how we vote is seldom questioned. In this workshop, we'll explore a few different voting procedures from a mathematical perspective as we try to make sense of the paradoxical results that can occur when we vote in more than one way.*

Faculty facilitator: Michael Orrison (Harvey Mudd College).

The Mathematics of Love: *In mathematics, the stable marriage problem is the problem of finding a stable matching between two sets of elements given a set of preferences for each element. It is commonly stated as: Given n men and n women, where each person has ranked all members of the opposite sex with a unique number between 1 and n in order of preference, marry the men and women together such that there are no two people of opposite sex who would both rather have each other than their current partners. If there are no such people, all the marriages are "stable." Algorithms for finding solutions to the stable marriage problem have various applications in real life, perhaps the best known of these being in the assignment of graduating medical students to their first hospital appointments. During the breakout session students will develop skills of finding the stable matching in different real-world situations.*

Faculty facilitator: Marina Chugunova (Claremont Graduate University).

The Mathematics of Musical Instruments: *Mathematics is involved in some way in almost every aspect of daily life. In this talk, we will explore the mathematics behind the construction of musical instruments. The main focus will be on the relationship of wavelengths and pitches of the sound. Students will have hands-on experience of making a simple instrument. No prior training of music required!*

Faculty facilitator: Chiu-Yen Kao (Claremont McKenna College).

Weird Geometry — On Doughnuts and Coffee Mugs: *Though the stereotype of the absent-minded mathematician is not totally accurate, there is a subgroup of mathematicians who tend to confuse their coffee mugs with their doughnuts. Today we will travel to their world, the land of Topology, where lengths and distances no longer matter and mugs and doughnuts smoothly transform into one another. We will study maps, play games, and learn some party tricks along the way; underneath them all lays some really cool mathematics! But heed my warning: At the end of the session, you may find yourself trying to eat your mug with a doughnut!*

Faculty facilitator: Gizem Karaali (Pomona College).

Mathemagics! *Arthur Benjamin will demonstrate and explain the secrets of rapid mental calculation. Dr. Benjamin teaches mathematics at Mudd and is one of the world's fastest " calculators." He is also a professional magician, the author of several books, and has received national recognition for his teaching of mathematics. He has presented his mixture of math and magic to audiences all over the world. Benjamin will demonstrate and explain: How to multiply numbers in our head faster than a calculator! How to figure out the day of the week of any date in history! How to memorize 100 digits of pi!*

Faculty facilitator: Artur Benjamin (Harvey Mudd College).

Reflections: Why It Works

In the above we have described how GEMS is organized and we have given descriptions of several presentations. We have also told you that we think things are going really well. But you might still ask: Why do we think this all works successfully? Here is some operating evidence.

- The students arrive with chatty, smiley demeanors—not as though they resent the time to be spent as a waste.
- They leave thanking everyone, and, when asked, do not want to change anything.
- They participate in the small group sessions, mixing together quite readily and willing to join a group of two to six or seven without argument. Often these groups are diverse, not just their friends from the same school.
- We observe the same enthusiasm from parents. For some presentations we have to ask them to depart from the room as they seem as interested as their children to listen to the talk. For a few parents, we feel that this was their first experience of being on a college campus.

We have also been quite lucky in terms of our team. Both our student helpers and faculty lecturers have put in significant amounts of time and energy into helping the program run smoothly.

We believe that GEMS creates an opportunity for college students to offer their help, in return for the excellent mathematical education that they are receiving in Claremont, to younger students with less experience. Also, it gives them an idea about just how difficult it is to communicate mathematical concepts. They accept these challenges cheerfully and mix with the next generation of younger people interested in mathematics. By example, they are showing social responsibility.

Our faculty presenters have generously given their time and expertise to organize suitable projects and have been pleased with the response they have received. We are grateful to them.

All in all we have been very happy to organize GEMS during these years as coordinators—time well spent!

Conclusion

The high level of engagement, participation and, indeed, enjoyment of students in GEMS events helps all involved realize that this format is effective in meeting our goals of showing students that mathematics is something they can do and be successful at. Moreover it becomes clear to them that mathematics is useful in a wide range of practical areas and is relevant to many themes and ideas that impinge on our daily lives. The students, arriving with a parent, are obviously not intimidated by the environment and cheerfully settle in to something they have been looking forward to. They quickly get used to working in groups and being in a situation where suggestions are worth putting forward and discussed.

We have asked the whole group for evaluations and suggestions for improvements in structure and so on, and we have done this with individual students and parents. We always receive the common reply of "Keep it up. We like it." The availability of a wide range of mathematicians and other mathematical scientists in the Claremont Colleges, both faculty and students, all willing to provide an opportunity to transfer their enjoyment of their disciplines to a young audience is a great resource; GEMS brings them together in an effective combination. In summary, this has been a most exciting endeavor for us, and we look forward to many more years of discovering new GEMS with our students!

References

[1] Hu, Kendra D., "Women in Mathematics: An Historical Account of Women's Experiences and Achievement" (2011). CMC Senior Theses. Paper 150. Available at http://scholarship.claremont.edu/cmc_theses/150, accessed on June 7, 2017.

[2] Jaschik, Scott, "Women Lead in Doctorates", *Inside HigherEd*, September 14, 2010. Available at https://www.insidehighered.com/news/2010/09/14/doctorates, accessed on June 7, 2017.

[3] National Center for Education Statistics (NCES), *The condition of education 2005*, NCES 2005-094, Washington, DC: U.S. Government Printing Office. Available at https://nces.ed.gov/pubs2005/2005094.pdf, accessed on June 6, 2017.