Math Enrichment Resources

While it is important for students to learn basic math facts and procedures, the most important part of mathematics is for most people is experience solving problems. As a teacher you do not need to know everything about a problem to discuss it. Indeed it is good for students to see that there are problems that the teacher (or perhaps anyone) doesn't know (knows) how to solve. The thing here is to make sure to make a distinction between guesses/conjectures and things that are definitely known to be true. (Ask **why?** every chance you get.) You may always use me as a resource. Just send me an e-mail and ask. I'd be happy to help you find mathematical material related to a particular topic, or for a particular grade level. I am also willing to write recommendation letters etc. If you lose track of my e-mail `dav@math.ksu.edu`, just google Auckly my name is fairly unique.

Hopefully this will point you to some of the many math enrichment materials that are available. The first part will list general resources, and the second part will give references for some of the activities that I demonstrated this term.

General Resources

Math Circles are built to introduce people to open-ended mathematical questions. The AMS-MSRI Math Circles Library has a number of texts that include activities as well as advice for running math circles. You can see the list of these publications at `http://www.ams.org/bookstore/mclseries`. Zvonkin [11] is for ages 3 - 7, but the activities may be used with older students. Rozhkovskaya [6] is for the primary grades, and Burago [3] is for grades 5 - 7. The other two books in this series that have good collections of problems for elementary school students are [10, 5]. These publications are the most developed part of the materials associated with the National Association of Math Circles. This association has a webpage listing advice, plus a collection of mathematical activities. See `www.mathcircles.org` A number of activities that we did are documented on this website. Some with video. To make the most of this website you should register as a teacher for an account.

MathPickle is trying to convince every teacher in North America to show their class an open math problem once per year. `http://mathpickle.com/K-12/Videos.html` Gord has produced some wonderful videos and activities. In addition to one problem for each grade K-12, he has many games, puzzles, activities grouped according to grade and content. His extensive website includes professionally prepared hand-outs, video, powerpoint slides. He discusses the value of interesting stories/art to draw people into math.

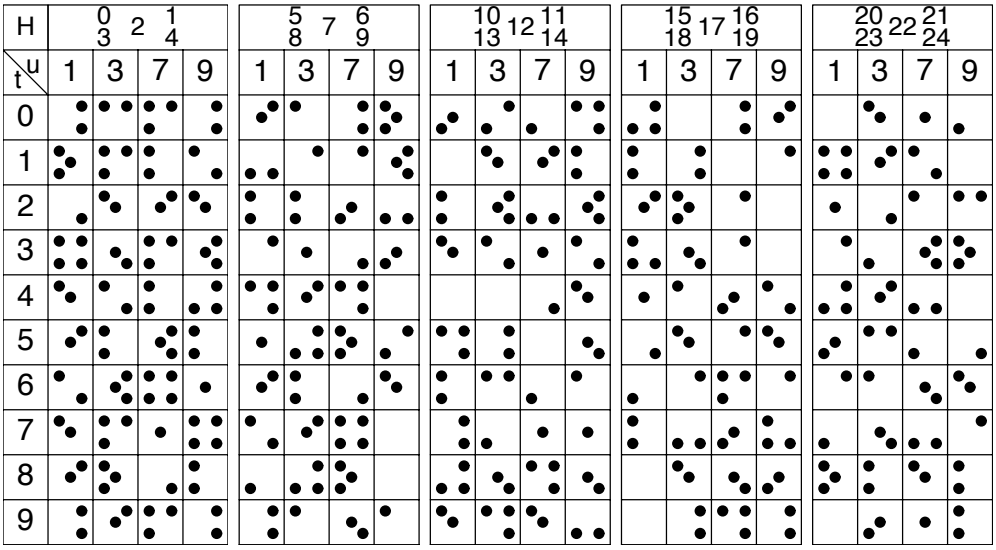
Three Acts are Dan Meyer's approach to mathematics enrichment. The basic idea is to present something so compelling, that the students start asking mathematical questions, and then providing a few tools so the students can answer the questions. The heart of this is his set of videos: https://docs.google.com/spreadsheet/pub?key=0AjIqyKM9d7ZYdEhtR3BJMmdBWnM2YWxWYVM1UWowTEE&output=html. He explains his philosophy in his blog:
http://blog.mrmeyer.com/2011/the-three-acts-of-a-mathematical-story/
Jim Tanton is a force of nature. He is a very dynamic teacher. His book [8] probably has the most activities that are ready for use for elementary school students. It is usually possible to lower the level of an activity by replacing variables by numbers, large numbers by small numbers, looking at special cases etc. Check out his lesson plans and videos. Here are some sites to browse: http://www.jamestanton.com/, http://gdaymath.com/courses/ (The Exploding Dots unit on this site is the best way to introduce students to the idea of place value – you can find many descriptions of exploding dots), http://www.maa.org/math-competitions/teachers/curriculum-inspirations
Vi Hart has wonderful videos that touch on deep mathematical ideas. She is a wonderful role model for young women and is followed by many school girls. You could do much worse than just playing one of these videos once a week and discussing it. (Of course getting materials and copying some of the mathematical constructions would be even better.) Her current website is http://vihart.com/ but you may wish to start with some of the mathematical doodles on her original site http://web.archive.org/web/20130912060754/http://vihart.com/.
Martin Gardner was one of the best expositors of recreational mathematics. Look at any of his materials. His collected works are described at: http://www.amazon.com/Martin-Gardners-Mathematical-Games-Gardner/dp/0883855453. The Gathering for Gardner workshops collect many wonderful puzzles in this spirt. http://gathering4gardner.org/.
The bridges organization is related to the interface between math and art. http://bridgesmathart.org/
The Museum of Math momath.org Check out their activities.
There are many mathematical contests, but fewer for elementary school students. Check out http://www.mathkangaroo.org/mk/default.html. Many more may be found at http://www.mathcircles.org/content/math-competition-listing.
The Julia Robinson Math Festival has many great activities. Most are just lists of questions. The age range is a bit old for many elementary school students, so you might have to make things more specific. See http://juliarobinsonmathfestival.org/ and http://www.msri.org/web/msri/pages/211.
Puzzles and games are a great way to engage students with mathematics without stress

or sometimes even letting them know that they are working on math. You could give a puzzle of the day or a puzzle of the week. NumberPlay http://wordplay.blogs.nytimes.com/category/numberplay/?_r=0 lists one per week. Also see http://www.mathsisfun.com/puzzles/, and http://www.thinkfun.com/.

Other nice math sites include: NRich http://nrich.maths.org/frontpage is a site dedicated to math enrichment. It is written with teachers in mind. Cut-the-knot http://www.cut-the-knot.org/, Art and Math http://mathartist.wordpress.com/. Math Teacher's Circle Network http://www.mathteacherscircle.org/resources/session-materials/. Numberphile http://www.numberphile.com/. Moebius noodles for the really young http://www.moebiusnoodles.com/ and Natural Math http://www.naturalmath.com/ are both nice sites. Henri Picciotto is aimed more for older students, but is worth a look: http://www.mathedpage.org/. Here is a math radio show: http://mathfactor.uark.edu/. See also http://mathbun.com/main.php. There are many more references. Let me know if there are any that you think I should add. I'll probably put this in a more public place now that it exists.

If you have a really advanced student ask for help. Make sure that all of your students are challenged. You can give problems with easy entry and high ceiling. The Art of Problem Solving http://www.artofproblemsolving.com/, Stanford Program for Gifted Youth http://www.artofproblemsolving.com/, and John Hopkins Center for Talented Youth http://cty.jhu.edu/ are good places to start.

Prime Numbers to 2500 (+2,5)



Specific activities from this term

Balloon Animals http://www.mathcircles.org/node/771

SET https://www.mathcircles.org/content/ovals-and-diamonds-and-squiggles-oh-my-mathematics-game-set
http://www.nytimes.com/ref/crosswords/setpuzzle.html
http://www.math.rutgers.edu/~maclagan/papers/set.pdf
http://mathtourist.blogspot.com/2010/07/set-math.html

Frieze Patterns See [4] for a very complete description.

Hand-Cuffs, pants This is a classic problem. Tanton has a number of interesting variations in *Solve This* [8]. See chapters 8, 10, 17, 18 together with the hints and solutions. The handcuff answer is on page 163. Knot theory offers much room for exploration, but many will find it weird. The books by Adams are a wonderful place to start, [1, 2].

Polyminos The SOMA cube may be built from the non-parallel piped trionimo and tetronimos. See http://www.msri.org/attachments/jrmf/activities/SomaCube.pdf Chapter 19 of *Solve This* [8],

Cube slicing Lab 6.5 of http://www.mathedpage.org/geometry-labs/.

Cutting Pizza See materials plus video at http://www.mathcircles.org/node/788. Make sure to follow the link to Clip Theory as well. The two go together well.

Rational Tangles See http://www.mathcircles.org/node/798.

Penny Pyramid http://mrmeyer.com/threeacts/pyramidofpennies/
http://www.maa.org/sites/default/files/Siu15722.pdf

Area and Volume formulae http://www.mathcircles.org/node/964

Grid Luck -Pythogrean's theorem Here is a formal lesson plan on this topic: http://map.mathshell.org/materials/download.php?fileid=1206. More problems about grid geometry: http://www.math.ucla.edu/~radko/circles/lib/data/Handout-153-182.pdf

String Polytopes See [7] and http://www.msri.org/attachments/jrmf/activities/StringPolyhedra.pdf
It is difficult to see the strings in this video, but you can tell that young children

like it. https://www.youtube.com/watch?v=-DpKPNfZemo
I'm missing the url for the really good video of the platonic sextet. I'f I find it, I'll add it. The following are better videos showing more string geometry.
http://www.youtube.com/watch?v=RM-SRGnJUT8&feature=related
http://www.youtube.com/watch?v=dwyR95c_jQ0&feature=related
http://youtu.be/SqOHUoqse74
http://www.youtube.com/watch?v=HTqfTwD6_J8&feature=related
http://youtu.be/hCZsl9AkZw0
http://youtu.be/r_NHxLYFFMY
https://www.youtube.com/watch?v=1CRIuwb0-0o
https://www.youtube.com/watch?v=NupWZSRxspg
http://youtu.be/Y3tGHBZct40
http://youtu.be/l96gtIRoObo
http://youtu.be/T0EmNHoF1-c
http://youtu.be/z9cMiOSIzSY
http://www.youtube.com/watch?v=xvR1ZovYY48&feature=related
http://www.youtube.com/watch?v=QX2OWvNC7cQ&feature=related
http://www.youtube.com/watch?v=nz5dIZPBNUk&feature=related
http://youtu.be/LhzTagpBIsw

Euler Formula http://math.berkeley.edu/~giventh/difgem.pdf
http://www.mathcircles.org/files/NAMC2012-AngleDefectCurvatureAndTheGaussBonnetForm
06252012_WithAnswers.pdf
https://www.mathcircles.org/content/curvature-and-euler-characteristic
http://www.ics.uci.edu/~eppstein/junkyard/euler/

Wall Paper Groups See [4] for a very complete description.

Pick's Theorem https://www.mathcircles.org/content/picks-theorem but there is no connection to Euler's Theorem there. The following link on the following page is short but shows the connection: http://jwilson.coe.uga.edu/emt669/student.folders/bailey.heather/BaileyHeather.html

Activities that I won't get to, but you might like

Instant Insanity is a nice application of graph theory. See http://www.msri.org/attachments/jrmf/activities/InstantInsanity.pdf

Stomp This is a cute class of puzzles. See http://www.msri.org/attachments/jrmf/activities/Stomp.pdf and http://www.msri.org/attachments/jrmf/activities/

StompGrids.pdf (Note: You need to hold the grids in landscape orientation when you read the instructions.)

Tiling Torment See Chapter 6 of [8] as well as: http://www.msri.org/attachments/jrmf/activities/TilingTorment.pdf

45 degree billiards OK Here is another formal lesson plan http://www.ohiorc.org/orc_documents/orc/richproblems/discovery-pool_table_geometry.pdf

Zome bact.mathcircles.org/files/Summer2010/zomes-6-2010.pdf is a great worksheet to get students thinking math while they play with a cool toy http://www.zometool.com/

Of course if I take the time to type it, I hope you read it. Here are a few questions to encourage you to look at this stuff.

1. Is there enough material here that you could run one enrichment activity per week while teaching math? one every other week?

2. Look at some of the references or urls that are described in this hand-out. Would you be able to use the materials that you look at *as is* in a classroom? If not, what would you need to do before using them? Would you be able to work something out with the given information?

References

[1] Adams, C. : *Why Knot: An Introduction to the Mathematical Theory of Knots with Tangle*, 62 pp., Wiley, Hoboken, 2008

[2] Adams, C. : *The Knot Book*, 307 pp., AMS, Providence, 2004

[3] Burago, A. : *Mathematical Circle Diaries, Year 1: Complete Curriculum for Grades 5 to 7*, 335 pp., AMS, Providence, 2012

[4] Burgiel, H.; Conway, J.; Goodman-Strauss, C. : *The Symmetries of Things*, 448 pp., CRC, Boca Raton, 2008.

[5] Dorichenko, S. : *A Moscow Math Circle: Week-by-week Problem Sets*, 240 pp., AMS, Providence, 2012

[6] Rozhkovskaya, N. : *Math Circles for Elementary School Students*, 166 pp., AMS, Providence, 2014

[7] Schafer, K.; Kim, S. : *A Platonic Sextet*, College Math J., **43:1** p 64–69.

[8] Tanton, J. : *Solve This: Math Activities for Students and Clubs (Classroom Resource Materials)*, 240 pp., MAA, Washington, DC, 2001

[9] Tanton, J. : *Mathematics Galore! (Classroom Resource Materials)*, 271 pp., MAA, Washington, DC, 2012

[10] Yashchenko, I. : *Invitation to a Mathematical Festival*, 172 pp., AMS, Providence, 2013

[11] Zvonkin, A. : *Math from Three to Seven: The Story of a Mathematical Circle for Preschoolers*, 300 pp., AMS, Providence, 2011