4-10-2015

Changing the Culture: Developing Creative Problem Solvers

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Joint MAA/MichMATYC Meeting

Hope College

April 10, 2015

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A Quick Introduction

BA	Mathematics, Albion College
MS	Systems Management, University of Southern California
MAT	Elementary Education, The Colorado College
PhD	Educational Psychology, University of Connecticut

1975 – 1996	United States Air Force
1997 – 2002	Middle School Math and Science Teacher Colorado, New Hampshire & Connecticut
2003 – 2005	Research Associate, The National Research Center on the Gifted and Talented, University of Connecticut
2005 – 2007	Visiting Asst. Professor, College of Education, Curriculum and Instruction, Purdue University
2008 – 2013	Asst. Professor, College of Education, Educational Studies, Purdue University
2013 -	Asst. Professor, Mathematics Department, Hope College

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Overheard in math class: "Oh God why is this happening to me? I go to church!"

"We have known for some years now…that most children's mathematical journeys are in vain because they never arrive anywhere, and what is perhaps worse is that they do not even enjoy the journey."

Whitcombe, A. (1988), Mathematics creativity, imagination, beauty. *Mathematics in School, 17,* (2), 13-15

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The U.S. does not need fast procedure executors anymore. We need people who are confident with mathematics, who can develop mathematical models and predictions, and who can justify, reason, communicate, and problem solve. We need a broad and diverse range of people who are powerful mathematical thinkers and who have not been held back by stereotypical thinking and teaching.

Jo Boaler, Professor, Mathematics Education, Stanford University

The Stereotypes That Distort How Americans Teach and Learn Math

The Atlantic Online (12 Nov 2013)

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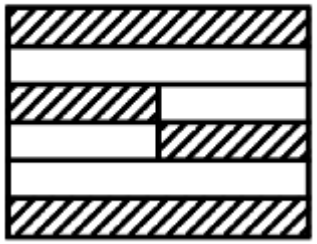
The 3Rs: Recite, Replicate, Regurgitate

Fraction Grade 6 Draw a rectangle with a 3 cm base and a 4 cm height. Shade $3/6^{th}$ thereof.

Solution of a pupil:



While going through the classroom, that pupil asked me [the teacher] whether or not his solution was correct. *I was forced* to *admit that it was*. That is *what you get when you don't tell the pupils exactly what to do* . . . The teacher now reproaches himself for *not having prevented this solution.* He is obviously influenced by an insufficient understanding of what is mathematics, by the image of school as an institution for stuffing of brains . . . (p. 88)

Köhler, H. (1997). Acting artist-like in the classroom. *ZDM Mathematical Education, 29*(3), 88–93.

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Learning Mathematics

- "It doesn't make much sense. But, we are in math class, so I guess it does here," (sixth grader)[1]
- "In math, I do things just the opposite way from what I think it should be and it almost always works" (high school calculus student) [1]
- Constant emphasis on sequential rules and algorithms may prevent the development of creativity, problem solving skills and spatial ability[2]

[1] Mary Linquist, Past-President (1992-94) , NCTM, in her preface to *Making Sense: Teaching and Learning Mathematics with Understanding* (Hiebert et al., 1997).
[2] Pehkonen, E. (1997). The state-of-art in mathematical creativity. *ZDM Mathematics Education, 29* (3), 63-37.

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2007 bi-annual conference: International Community of Teachers of Mathematical Modeling and Applications

Co-hosts: Indiana University, Purdue University's INSPIRE, USAFA

"The Air Force Academy is a good example...where they came to us with a problem and they said **'our cadets come in here; they're smart kids. They come out knowing more, and they get worse on absolutely every scale of being good problem solvers, of being creative.'** They know more and can function less, in a way. And they're very worried, because **the person that they need** in the military just like other things, for the future, **isn't somebody who just follows rules. They need to understand those and be able to create their own flow of them.** So having them engaged helps us get on the forefront of things."

Richard Lesh, Professor of Learning Sciences, Cognitive Science, and Mathematics Education, Indiana University

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Teaching and Learning of Mathematics 1894*

The method of teaching should be throughout objective, and such as to call into exercise the pupil's mental activity. The text-books should be subordinate to the living teacher. ***The illustrations and problems should, so far as possible, be drawn from familiar objects, and the scholar himself should be encouraged to devise as many as he can. So far as possible, rules should be derived inductively, instead of being stated dogmatically. On this system the rules will come at the end, rather than at the beginning, of a subject.***

* National Educational Association (1894). *Report of the Committee of Ten on secondary school studies with the reports of the conferences arranged by the committee.* New York: American Book Company. (pg. 105).

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Teaching and Learning of Mathematics 2012

Common Core State Standards for Mathematical Practice (NGA & CCSSO, 2010)

1. Make sense of problems and preserve in solving them
2. Reason abstractly and quantitatively
3. Construct viable arguments and critiques the reasoning of others
4. Model with mathematics
5. Use appropriate tools strategically
6. Attend to precision
7. Look for and make use of structure
8. Look for and express regularity in repeated reasoning.

Using the Common Core State Standards for Mathematics with Gifted and Advanced Learners (Johnsen & Sheffield, 2012)

9. Solve problems in novel ways and pose new mathematical questions of interest to investigate.

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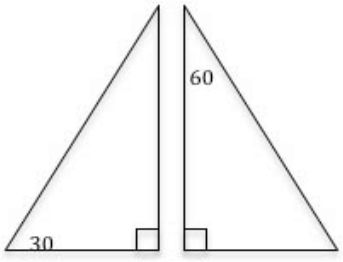
Key Shifts in the CCSS-M

- Greater focus on fewer topics
- Rigor: Pursue conceptual understanding, procedural skills and fluency, and application with equal intensity
- Coherence: Linking topics and thinking across grades
  - Progressions Documents for the Common Core Math Standards
    - Work in progress at the University of Arizona's Institute for Mathematics and Education
      - explain why standards are sequenced the way they are,
      - point out cognitive difficulties and pedagogical solutions, and
      - give more detail on particularly knotty areas of the mathematics

Impact of CCSS-M on Standardized Tests

1. Which of the following **best** describes the triangles shown below?



A both similar and congruent

B similar but not congruent

C congruent but not similar

D neither similar nor congruent

California Standards Test, released test questions, geometry, 2009

2. Triangle ABC undergoes a series of some of the following transformations to become triangle DEF:

- Rotation
- Reflection
- Translation
- Dilation

Is DEF always, sometimes, or never **congruent** to ABC? Provide justification to support your conclusion.

Common Core Smarter Balanced Grade 8 Sample Item, 2013

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Teaching and Learning of Mathematics 2012

21st Century Skills Math Map	
Mathematical Association of America National Council of Teachers of Mathematics The Partnership for 21st Century Skills	
Learning and Innovation Skills	**Creativity and Innovation:** Students use a wide range of techniques to create new and worthwhile ideas, elaborate, refine, analyze and evaluate their own ideas in order to improve and maximize creative efforts, and demonstrate originality and inventiveness.
	Critical Thinking and Problem Solving: Students reason effectively, use systems thinking and understand how parts of a whole interact …make judgments, decisions and solve problems in both conventional and innovative ways.
	Communication and Collaboration: Students know how to articulate thoughts and idea effectively…listen effectively to decipher meaning…(communicate) for a wide range of purposes.

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Mindsets The power of believing that you can improve

- Theories of Intelligence
  - An unchangeable entity – a fixed mindset
  - A malleable quality that can be developed – a growth mindset
- "Research has shown that, even when students on both ends of the continuum show equal intellectual ability, their theories of intelligence shape their responses to academic challenge" (p. 251)

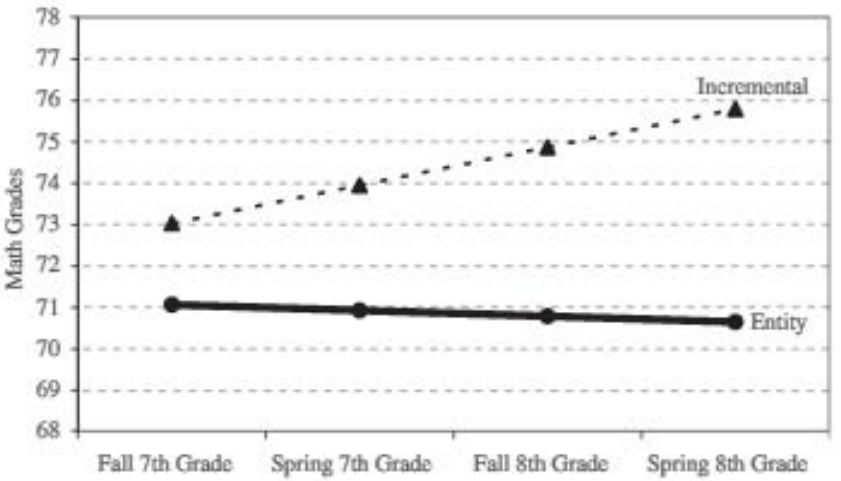

Figure 1. Graph of interaction effect of theory of intelligence and time on math achievement: Growth curves of predicted mathematics grades over 2 years of junior high school for students with incremental (+1 *SD* above the mean) and entity (−1 *SD* below the mean) theories of intelligence.

Blackwell, L.S., Trzesniewski, K. H. & Dweck, C. S. (2007) Implicit theories of intelligence predict achievement across an adolescent transition: A longitudinal study and an intervention. Child Development, 78, 246-363. DOI: 10.1111/j.1467-8624.2007.00995.x

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Conversation

- Project Challenge (Chapin & O'Conner, Boston University)
- 4 year intervention focusing on discourse-based teaching in the lowest performing school district in Massachusetts
  - 400 4th graders, 70% low-income, 60% ELL
  - Teachers trained to use a variety of talk moves to encourage student to explain their reasoning and build on one another's thinking
  - After 2 years the proportion of student showing a "high probability of giftedness in mathematics" as measure on the Test of Mathematical Abilities (TOMA) rose from 4% to 41%
  - After 3 years 82% of Project Challenge students scores "Advanced" or "Proficient" on the state assessment (state average proficiency was 38%)

Resnick, L. B., Michaels, S. & O'Conner, M.C. (2010). How (well-structured) talk builds the mind R. J. Sternberg & Priess D.D. (Eds*). Innovations in Educational Psychology,* (163-194). New York: Springer.

Creative Ability in Mathematics

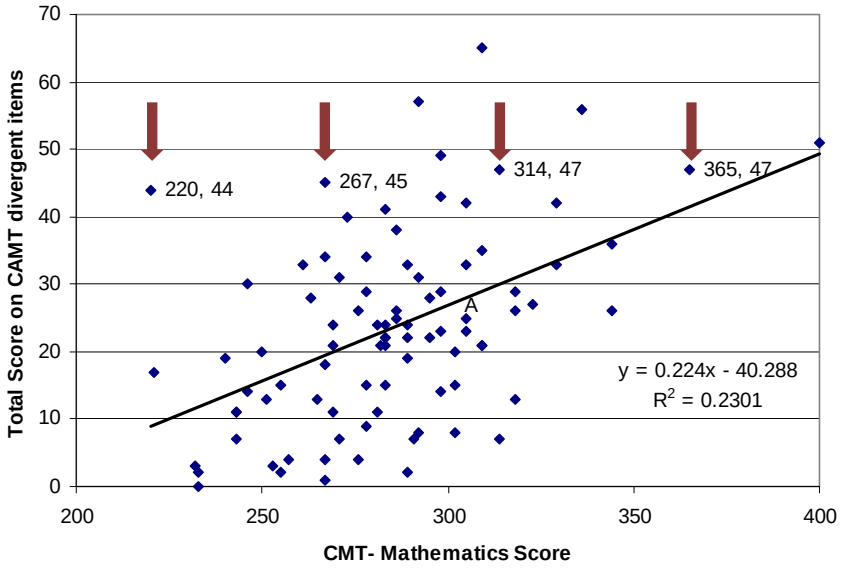
The ability to

1. Formulate mathematical hypotheses
2. Determine patterns
3. Break from established mind sets to obtain solutions in a mathematical situation
4. Sense what is missing and ask questions
5. Consider and evaluate unusual mathematical ideas, to think through the consequences from a mathematical situation
6. Split general mathematical problems into specific sub-problems

Balka, D. S. (1974). Creative ability in mathematics. Arithmetic Teacher, 21, 633–636.

Creativity in School Mathematics?

- An individual's knowledge base is the fundamental source of their creative thought. (Feldhusen and Westby, 2003)
- Students with equal mathematical achievement may have significant differences in performance on measures of mathematical creativity (Haylock, 1997)



Post Hoc Regression Analysis found that Achievement scores were a significant predictor of performance for those who scored below the mean creativity score but not above.

Dan Meyer's: Math Class Needs A Makeover

Five symptoms that you're developing math reasoning skills wrong. Your students…

1. Lack initiative
2. Lack perseverance
3. Lack retention
4. Are adverse to word problems
5. Are eager for a formula

Two and Half Men approach to learning math:

- Teaching in small, "sitcom sized problems that wrap up is 22 minutes, 3 commercial breaks and a laugh track" resulting in **Impatient Problem Solvers**

Dan's Recommendation

1. Use multimedia to bring the real world into the classroom
   - Dan often posts ideas and samples on his blog http://blog.mrmeyer.com/
2. Encourage student intuition
3. Ask the shortest question you can
4. Let students build the problem
5. Be less helpful

Doing What Mathematicians Do

- **Mathematics** when it is finished, complete, all done, then it consists of proofs. But, when it is discovered, it **always starts with a guess**. . .

  George Pólya (1966)

- Mathematics - this may surprise you or shock you some - is never deductive in its creation. **The mathematician at work makes vague guesses, visualizes broad generalizations, and jumps to unwarranted conclusions**. He arranges and rearranges his ideas, and he becomes convinced of their truth long before he can write down a logical proof. **The conviction is not likely to come early - it usually comes after many attempts, many failures, many discouragements, many false starts.**

  Paul Halmos (1968)

DISCOVERING THE ART OF MATHEMATICS
MATHEMATICAL INQUIRY IN THE LIBERAL ARTS

- The **Discovering the Art of Mathematics**[1] project provides a wealth of resources to support college faculty in teaching Mathematics for Liberal Arts, including a library of 11 inquiry-based learning books, professional development opportunities, and extensive teacher resources.

[1] This project is based upon work currently supported by the National Science Foundation under NSF1225915 and previously supported by NSF0836943 and a gift from Mr. Harry Lucas.

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- Student Comments
  - Instead of falling asleep listening to lectures I was able to solve problems and make conjectures.
  - This course is a breath of fresh air. It helps me understand why math professors enjoy math so much. I see the fun in math now and how beautiful it can be.
  - This class taught me how to think independently about not only math but other subjects and everyday problem solving.
  - The fact that it was never easy to find an answer to the problem made me want to find it so much more.
  - …Math is no longer a student-engagement subject. Students are not give the time or encouraged to experiment with a math problem and find patterns for solving it.…[In this course] I was encouraged and guided to engage in making the discoveries and understandings for myself.

Building a Foundation

The Mathematical Education of Teachers II (2012) Conference Board of the Mathematical Sciences

- Programs designed **to prepare elementary teachers** should include **12 semester hours focused on a careful study of mathematics associated with the CCSS** (K–5 and related aspects of 6–8 domains) from a teacher's perspective. … Number and operations, treated algebraically with attention to properties of operations, should occupy about 6 of those hours, with the remaining 6 hours devoted to additional ideas of algebra (e.g., expressions, equations, sequences, proportional relationships, and linear relationships), and to measurement and data, and to geometry. (p. 31)
- It bears emphasizing that familiar mathematics courses such as college algebra, mathematical modeling, liberal arts mathematics, and even calculus or higher level courses *are not an appropriate substitute for the study of mathematics for elementary teachers*, although they might make reasonable additions. (p. 32)

Building a Foundation

Table 4. Empirical requirements and electives identified from the international top performing primary programs

Requirements	Electives
University Mathematics	**University Mathematics**
Number Theory	Analytic Geometry
Probability	Axiomatic Geometry
Math Education	**Math Education**
Math Instruction	Math Standards
	Observing Math Teaching
School Mathematics	**School Mathematics**
Measurement	Functions
Numbers	Geometry

Schmidt, W., Burroughs, N., Cogan, L. (2013) World class standards for preparing teachers of mathematics (Working Paper), Center for the Study of Curriculum at Michigan State University.

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Research in the attitude of preservice elementary teachers has generally found that they have negative attitudes towards mathematics. MacNab and Payne (2003) reported that among preservice elementary teachers in their first undergraduate year, 46% listed the word “worried” when discussing working on mathematical tasks. Kolstad and Hughes (1994) found that 34% of the K-4 teachers in their study had strong negative attitudes toward mathematics, a significantly higher percentage than other educators.

Matthews, M.E, & Seaman, W. I, (2007) The effects of different undergraduate mathematics courses on the content knowledge and attitude towards mathematics of preservice elementary teachers. IUMPST: The Journal, Vol 1, p. 2.

Implementing Change

- Teacher Preparation
  - Education, licensure, professional development
  - Elementary Math Specialists
- Breaking stereotypes / Qualitative Literacy
  - SIGMAA-QL
  - Association of American Colleges & University's Special Issue of *peer Review* (Summer 2014) on Quantitative Reasoning
- Education
  - School boards, parents, communities
  - Quality curriculum materials
    - Education Week March 4, 2015, Most Math Curricula Found to Be Out of Sync with Common Core. Updated, March 17 as Review of Math Programs Comes Under Fire
      - See the report @ EdReports.org

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Changing Mathematics Education in Michigan

Conversations among Colleagues

Designed in 2003-2004 to engage mathematicians, mathematics educators and leaders in mathematics education in conversations to share learning related to mathematics education and the development of mathematics teachers in the state of Michigan.

Michigan Association of Mathematics Teacher Educators

Promote excellence in the preparation and continuing development of all teachers of mathematics by providing quality leadership among mathematics teacher educators in the broad mathematics education community.

Michigan Council of Teachers of Mathematics

Provides public voice and leadership to support and advance high quality teaching and learning of mathematics for all students.

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