CAREER: Mathematically Captivating Learning Experiences (MCLE) Project

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Project Goals

Our goal is to explore how the design of mathematical content of high school lessons can inspire student curiosity, wonder, and excitement, and overall shift student attitudes toward mathematics.

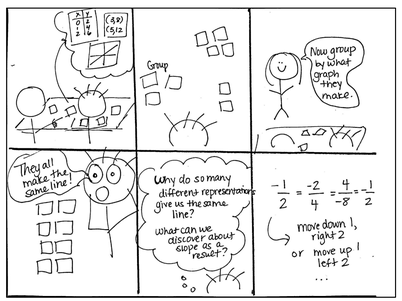
Working with six experienced teachers, at 3 high schools in the Boston area, we have designed and tested 17 *mathematically captivating lesson experiences* (MCLEs).

Design Approach

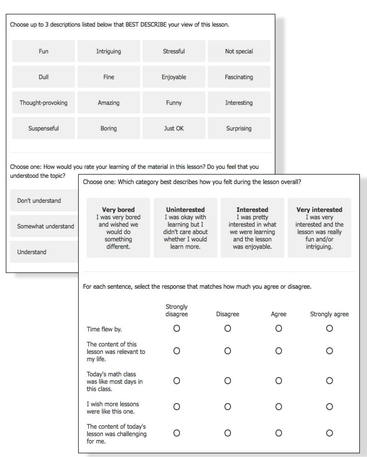
The MCLEs were designed using the mathematical story framework: an approach that interprets mathematical sequences (i.e., lessons) as a form of narrative for how it captures attention, inspires questions, and offers surprises (Dietiker, 2013, 2015).

So far, the MCLEs went through two design-and-test cycles in which we observe and film the lesson enactments. To test the MCLEs, we give students a post-lesson survey. We also interview between 2-5 students about their experiences in the lesson.

We use the same protocols for non-MCLEs (non-special lessons selected throughout the school year with the same students and teacher), and then compare and contrast student reported experiences in MCLEs with non-MCLEs.



Data Collection Tool - The Lesson Experience Survey



Comparison Group of Lessons: Captivating vs. Non-Captivating

Lesson Topics and Interest Measures for Captivating and Non-captivating Lessons per Teacher

			Captivating Lessons			Non-Captivating Lessons		
Teacher	Course	Grades	Topic	Avg. Interest	Avg. Positive Descriptor	Topic	Avg. Interest	Avg. Positive Descriptor
Ms. Cherry	Alg 2H	10	Extraneous solutions	2.89	1.61	Systems of ineqs	2.71	1.12
Mr. Palm	AP Calc	12	Deriv. of exp. functions	2.82	2.00	Product rule	2.60	1.33
Ms. Elm	Math 3H	10, 11	Rational root theorem	3.19	2.05	Percent change	2.65	0.96
Ms. Spruce	Math 1	9	Equivalent linear functions	3.69	2.62	Graphing lin ineqs	2.86	1.79
Mr. Ash	Alg 2	11	Intro to imaginary numbers	2.80	1.50	Properties of logs	2.69	1.38
Ms. Willow	Alg 2	10	Logarithm identities	2.90	1.27	Inverse functions	2.36	1.09

	Weighted Average Positive Descriptors			Weighted Average Student Lesson Interest Measure		
Class	Non-MCLE	MCLE	Δ	Non-MCLE	MCLE	Δ
A1	1.87	2.10	+0.23	3.04	3.33	+0.29
B1	1.42	1.40	- 0.02	2.67	2.80	+0.13
B2	0.73	1.29	+0.56	2.33	2.62	+0.29
C1	1.13	1.45	+0.32	2.64	2.89	+0.25
C2	2.00	2.17	+0.17	2.81	2.94	+0.13
D1	1.55	1.50	- 0.05	2.74	2.77	+0.03
E1	1.34	1.74	+0.40	2.85	2.98	+0.21
F1	1.33	1.90	+0.57	2.60	2.92	+0.32

Proportion of Descriptors Selected by Students after Each Lesson, with Dominant Aesthetic Qualities for Each Lesson Highlighted

For MCLE Lessons, the dominant aesthetic qualities were **more positive and less negative overall** when compared with lessons that were not designed with the Mathematical Story Framework.

		Positive												Neutral		Negative	
Topic	Interest	Suspenseful	Amazing	Fascinating	Fun	Funny	Enjoyable	Satisfying	Intriguing	Surprising	Thought-provoking	Fine	Just OK	Frustrating	Not special	Dull	Boring
MCLEs																	
Equivalent linear functions	3.69	23%	8%	8%	62%	38%	62%			31%	31%	15%		23%			
Geometric transformations	3.43	14%	21%	14%	29%		64%	21%	36%	7%	36%	43%	14%				
Rational Root Theorem	3.19	5%	5%	24%	24%	5%	38%	19%	24%	14%	48%	57%	29%		10%		
Volume of solids	3.14	7%			64%	21%	57%	21%	21%	21%	21%	29%	21%	14%			
Polynomial division	2.94		22%	33%	50%	6%	33%	11%	17%	6%	39%	44%	22%	6%	6%		6%
Exploring tile patterns	2.93		7%	13%	13%		27%		27%	13%	33%	47%	60%	40%	13%	7%	
Logarithmic identities	2.90	20%		10%	20%	10%		10%	40%		40%	50%	40%	10%	20%	10%	20%
Extraneous solutions	2.89		6%	6%	11%		28%	6%	39%	6%	61%	61%	33%	17%	11%	6%	11%
Function horizontal translation	2.88			6%	24%		24%	29%	35%		12%	76%	35%	18%	18%	12%	12%
Derivatives of exponential fns.	2.82			9%	9%		27%	27%	64%		64%	45%	27%			9%	18%
Imaginary number introduction	2.80			20%	7%	7%	20%	7%	20%	33%	60%	47%	27%	20%	13%	13%	7%
Area of trapezoids	2.80		10%		10%		30%	20%	20%	10%	40%	60%	10%	20%	30%	10%	30%
Riemann sums and integrals intro	2.79				7%		21%	14%	29%	14%	50%	50%	36%	29%	21%	7%	21%
Introduction to the unit circle	2.77		5%		18%		27%	18%	27%	9%	41%	45%	50%	9%	14%	18%	18%
Logarithmic identities	2.73						27%	7%	33%	13%	47%	87%	40%		27%	7%	13%
Introduction to inverses	2.36		9%	18%	9%	18%	9%	9%	9%	9%	18%	55%	55%		45%	18%	18%
Non-MCLEs																	
Scatter plots and trend lines	3.18		12%	6%	53%	6%	59%		12%	29%	18%	59%	35%			6%	6%
Logarithm basics	3.04	4%	4%	8%	20%		44%	28%	16%	12%	32%	60%	44%		20%		8%
Graphing linear inequalities	2.86		14%	21%	29%	7%	64%	7%	7%		29%	64%	29%	7%	7%	7%	7%
Rational expressions (test prep)	2.81		25%	13%	19%	13%	50%	6%	25%	6%	44%	13%	31%	31%	6%	6%	13%
Exponential decay (with dice)	2.80	7%			27%		60%	20%	27%	7%	27%	73%	20%		20%	7%	7%
Systems of inequalities	2.71			6%			24%	24%	18%		41%	82%	59%	18%	12%	12%	6%
Props. of logs, solving exp. eqns.	2.69	13%		6%		6%	25%	6%	38%	6%	38%	63%	31%	13%	25%	19%	13%
Surface area of cones	2.67				25%		42%	25%	25%	8%	17%	42%	33%		25%	25%	33%
Percent change (review)	2.65				17%	4%	22%	13%	4%	9%	30%	65%	30%	13%	48%	43%	
Differentiating with Product Rule	2.60			7%	13%	7%	20%	7%	27%		53%	67%	53%	13%	20%	7%	7%
The unit circle	2.54			8%	8%	8%	15%	15%	15%	15%	31%	69%	62%		23%	15%	15%
Inverse functions	2.36			9%	18%			18%		9%	9%	45%	45%	27%	36%	27%	55%
Logarithm change of base rule	2.18				8%			8%		17%	25%	33%	50%	33%	42%	25%	33%

Characteristics of Captivating vs. Non-Captivating

	Captivating mean (sd)	Non-Captivating mean (sd)
Overall Structure of the Mathematical Plot		
Number of acts	13.67 (4.37)	13.00 (2.90)
Number of formulated questions	52.17 (6.65)	46.83 (10.76)
Characteristics of the Formulated Questions		
Mean arc length (in acts) *	**3.35 (0.56)**	**2.05 (0.83)**
Mean arc length as proportion of story*	**0.26 (0.05)**	**0.16 (0.03)**
Max arc length as proportion of story*	**0.89 (0.13)**	**0.57 (0.24)**
Proportion of extended story arcs*	**0.52 (0.09)**	**0.35 (0.09)**
Percent of story arcs with uncoded acts*	**0.34 (0.10)**	**0.16 (0.10)**
Percent of formulated question disclosed	0.70 (0.16)	0.69 (0.13)
Characteristics of the Acts		
Mean number of questions open per act*	**13.33 (3.46)**	**7.12 (1.51)**
Mean degree of inquiry per act*	**9.73 (2.92)**	**3.50 (1.62)**
Percent of acts in story arcs with codes	0.85 (0.05)	0.92 (0.06)
Mean number of coded questions per act*	**9.24 (2.63)**	**5.53 (1.28)**

Note: *Reflects a statistically significant difference (alpha < .05)

Relationship of Story Characteristics with Student Interest

Independent Variable	Intercept	Slope	Standardized slope	R^2
Characteristics of the Formulated Question				
Mean story arc length (in acts)	2.35	0.19	0.18	0.28
Mean arc length as proportion of story	**2.02**	**4.04**	**0.27**	**0.66**
Max arc length as proportion of story	2.35	0.68	0.17	0.26
Proportion of extended story arcs	2.23	1.41	0.17	0.27
Percent of story arcs with uncoded acts	2.48	1.45	0.19	0.34
Characteristics of the Acts				
Mean number of questions open per act	**2.18**	**0.07**	**0.29**	**0.66**
Mean inquiry per act	**2.38**	**0.07**	**0.28**	**0.72**
Mean number of coded questions per act	2.22	0.09	0.25	0.50

MCLEs Shifted the Quality of Questions

	MCLE mean (SD)	non-MCLE mean (SD)
Average Number of Questions per Lesson		
Number of teacher questions per lesson	39.2 (5)	30.3 (8.5)
Number of student questions per lesson	12.8 (7.3)	16.5 (6.8)
Proportion of Teacher Questions by Type		
EMMR *	23.8 (10.4)	1.3 (2.1)
GIPF*	27.2 (12.7)	50.7 (16)
SIPF*	0.4 (0.97)	5.9 (5.8)
PET	18.7 (16.2)	6.4 (5.2)
PSWP	29.6 (15.7)	35.6 (19.2)
IT	0.38 (0.9)	0.0 (0.0)
Proportion of Student Questions by Type		
EMMR *	25.8 (24.1)	0.06 (1.6)
GIPF	19.4 (13.5)	38.9 (17.8)
SIPF	6.2 (13.4)	11.6 (18)
PET	18.5 (14.1)	23.5 (15.8)
PSWP	23.4 (14.4)	22.4 (14.8)
IT	6.7 (10.3)	3.02 (5.7)

Note: *Reflects a statistically significant difference (alpha < .05)

EMMR (Exploring mathematical meanings and/or relationships); GIPF (Gathering information, Procedural and Factual); SIPF (Struggling with information, Procedural and Factual); PET (Probing for an explanation of thinking); PSWP (Problem Solving Without known Procedure); IT (Inserting Terminology)

Read more

Dietiker, L., Singh, R., Riling, M., & Nieves, H. I. (2020). What makes a mathematics lesson interesting to students? Mathematics Education Across Cultures: Proceedings of the 42nd Meeting of the North American Chapter of the International Group for the Psychology of Mathematics Education, 391–399. https://doi.org/https://doi.org/10.51272/pmena.42.2020

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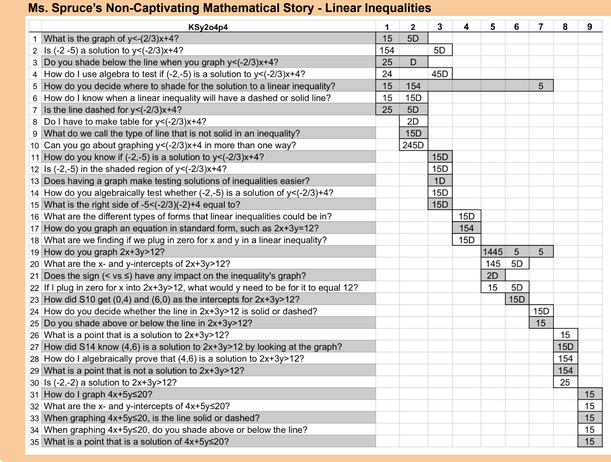
Sample Comparison of Mathematical Plots

Ms. Spruce's Captivating Mathematical Story - Linear Functions

Ms. Spruce's Non-Captivating Mathematical Story - Linear Inequalities