How Do Students Experience Mathematics?
Designing and Testing a Lesson-Specific Tool to Measure Student Perceptions

Meghan Riling
Boston University
mriling@bu.edu

Leslie Dietiker
Boston University
dietiker@bu.edu

Miriam Gates
Boston College
gatesmd@bc.edu

How can secondary mathematics teachers enact learning experiences that are *mathematically captivating* (i.e., lessons that draw students in, spur student curiosity, and motivate students to engage and anticipate how the lesson will end)? Unfortunately, evidence suggests that captivating experiences for high school mathematics students are not common. For example, the 2015 National Assessment of Educational Progress (NAEP) survey shows that a majority of 8th graders (55%) describe mathematics learning as typically not engaging or interesting and that this problem is increasingly worsening over time (National Center for Education Statistics, 2015).

Fortunately, there are efforts to shift the student experience in secondary mathematical lessons so that students are motivated to ask and answer mathematical questions (e.g., 3-Act Plays). Connecting the designs of lessons that are mathematically captivating with student perceptions of these lessons (i.e., learning why and how they captivate students) could support the development of curriculum and instructional strategies that shift long-term student attitudes. However, existing tools that measure mathematics students' perceptions focus on general dispositions, but not lesson-specific attitudes; even when a mathematical lesson spurs positive student emotions, we do not yet have a tool designed to measure it.

This paper describes our efforts to design and test a survey that can enable us to reliably measure students' perceptions (i.e., interesting, boring) of a mathematics lesson. As part of a larger study, this survey was developed to enable researchers to connect how students describe their experiences (i.e., "exciting") with the designs of mathematical lessons. This tool will enable researchers to identify and study lessons that secondary students indicate are *mathematically captivating learning experiences* (what we will refer to as *MCLEs*).

Theoretical Framework

Typically, when students report "I like math," they are describing an enduring, long-term interest in mathematics (Hidi & Renninger, 2006). In contrast, we are interested in learning about students' momentary attraction toward the content (e.g., during a lesson), which is more reflective of *situated interest* (Hidi & Renninger, 2006). Although characteristics of lesson experiences that relate to situated interest are relatively unknown, some evidence has shown that incongruity, surprise, and novelty are particularly influential (Matarazzo, Durik, & Delaney, 2010).

Situated interest is only one dimension of the potential emotional effects a particular experience can offer. The way in which a mathematical lesson moves an individual also involves reactions to beauty, exciting action, and suspense—aspects of an experience that we refer to as *aesthetic dimensions* (Dewey, 1934; Dietiker, 2016; Sinclair, 2001). Researchers are beginning to explore how to design and enact what Sinclair (2001) calls "aesthetically-rich" mathematical experiences, which are those that "enable children to wonder, to notice, to imagine alternatives, to appreciate contingencies and to experience pleasure and pride" (p. 26).

Methods

As part of a larger study, an online *Lesson Experience Survey* ("LES") was designed to capture students' aesthetic reactions and situated interest in a lesson by enabling students to indicate their level of interest, basic descriptions of aesthetic experience, and other qualities that may or may not be related to situated interest, such as challenge and relevance. To test and refine the LES, we administered it to 200 students, from grades 9 to 12, at the end of 19 lessons. These lessons represented a diverse span of topics (i.e., algebra, geometry, probability) and came from 8 different classes located in three high schools in three districts in New England. Though not randomly chosen, this sample allowed us to examine student attitudes across a variety of school contexts, as it included both urban and suburban public and charter schools with student populations representing different racial groups and SES-identifiers. The lessons, selected by the teachers, were observed, video-recorded, and audio-recorded by researchers. Two or more students were interviewed after each lesson to elaborate on their LES responses. In addition, in Fall 2017, students were given a *Mathematical Disposition Survey* (MDS; Riling et al., 2018), based on the TRIPOD survey (Ferguson & Danielson, 2015) and TIMSS survey (Mullis et al., 2016), to measure students' tendency to be captivated by the subject ("Captivation") and their long-term interest in mathematics ("TIMSS Composite").

To learn whether the LES measures student aesthetic experience and situated interest, we examined whether (a) students would vary in their descriptions of aesthetic experiences and interest levels after the lesson (i.e., will different students select different adjectives for the same lessons? Will students report boredom?), (b) these measures collectively would vary across lessons (i.e., Are some lessons measurably different than others when class measures are aggregated?), and (c) the tool enabled us to reliably separate or connect student interest from other conditions (e.g., is the reported interest related to the degree to which the student felt they understood the content of the lesson?). To answer these questions, we calculated the average situated interest associated with each lesson and aesthetic descriptor, identified frequently selected descriptors for each lesson, conducted t-tests to compare survey results across lessons, and ran linear regressions to test relationships between questions designed to measure similar experiences, and between responses regarding situated and long-term interest, in order to determine whether or not the LES, in conjunction with the MDS, is able to identify these relationships.

Design of the Lesson Experience Survey

To develop the LES (see Figure 1), we piloted several ways for students to report their lesson experience. Students described lesson experiences in their own words, providing vocabulary appropriate for high school students. Additionally, students defined given aesthetic descriptors in the context of a lesson (e.g., "If your friend used the word "intriguing" to describe a math lesson, what do you think they would have meant?"). Words that students described in meaningfully different ways were excluded from the survey.

The resulting LES has four parts. First, students select three aesthetic descriptors (from 16, ranging from negative to positive and presented in a random order) that best describe their lesson experience. Next, students indicate whether they felt they understood the lesson content to determine if reports of lesson interest are indicators of level of understanding. Then, students indicate their level of interest during the lesson with a Likert-scale question. Finally, students respond to a series of Likert-scale items to support researcher conclusions regarding the first three parts of the survey and to test potential relationships.

Findings

The LES is able to distinguish between student experiences and lessons. In addition, the LES measures situated interest and aesthetic experiences. In what follows, we elaborate and justify these claims.

The LES can discriminate between different kinds of experiences across students. Students reported a range of experiences, positive and negative, through the survey. Each possible lesson interest level (see Table 1) and aesthetic descriptor (see Table 2) was selected by some students. While, as we would anticipate, students reported fairly uniform lesson interest levels for some lessons, a wider range of responses and higher standard deviations suggest that student experiences differed in other lessons (see Table 3).

Interview data further supports the conclusion that differing student responses reflect different experiences. For example, a student who expressed a lack of enthusiasm during a one-on-one interview ("It wasn't anything, like, super exciting… I was just chugging along") chose the aesthetic descriptors "dull," "just OK," and "boring," and reported feeling *uninterested*. Alternatively, a student who said, "It was great. I like to do activities that are fun" in their interview selected "fun," "enjoyable," and "fascinating," and reported feeling *very interested*.

The LES can discriminate between different kinds of experiences across lessons. The average lesson interest level ranged from 2.50 (between *uninterested* and *interested*) to 3.14 (higher than *interested*). The verbal descriptors selected most frequently by students also varied by lesson, in some cases corresponding to lesson interest levels (see Table 4). Lesson F3, for which 43% of students selected "amazing," had the highest average lesson interest (3.14), which was statistically significantly different from interest reported for other lessons ($p = 0.004$). Lesson E4, which had an unusually high frequency of "not special," had one of the lowest average lesson interest levels, though its difference does not reach statistical significance ($p=0.061$).

We also found evidence that verbal descriptors can distinguish between lessons that are perceived as interesting for different reasons. In one lesson, students worked in groups to discover a new theorem, which was typical for their class. These students described the lesson as "fine," "just OK," and "not special," perhaps because it was similar to other lessons in their class, but also as "thought-provoking" and "intriguing." In another classroom, students worked as a class to find the numerical answer to a contextualized problem. These students were more likely to use the descriptors "fun," "amazing," "funny," and "fascinating." These two sets of descriptors are positive, but qualitatively different from each other.

The LES measures lesson interest and aesthetic dimensions as distinct from other qualities. The aesthetic descriptors enabled students to describe differences between lessons. Examining the lesson interest of students who selected each descriptor furthered our qualitative understanding of these terms (see Table 2). For example, students who selected the words "dull," "just ok," "not special," and "boring" also had the lowest lesson interest levels, on average, while students who selected the words "amazing," "fascinating," "enjoyable," and "fun" had the highest. However, students who selected "stressful" had a fairly low lesson interest level on average. Its high standard deviation (0.8) suggests that stress is selected by students with both positive and negative experiences (perhaps because of other factors, such as an exam). The lesson interest levels of students who selected "not special" also had a fairly high standard deviation (0.7), which may indicate a quality of the lesson (i.e., typical) rather than an emotional reaction.

In addition, student lesson interest was correlated positively with the potential to be captivated by mathematics and degree of agreement with the statement "time flew by" (see Table 5). Treating each

lesson as one unit, with each measure calculated as the mean of the students in that class, we found that a significant proportion of variation in "time flew by" can be predicted by lesson interest ($p < 0.001$). Since having time pass unnoticed is a characteristic of experiences that are fulling engaging and absorbing (e.g., Nakamura & Csikszentmihalyi, 2014), this predictive relationship supports the validity of the interest measure. Although we expected students to be less interested when more challenged, we found no relationship.

Although a class's average overall long-term interest in math did not predict the class's average level of interest in a lesson, this disposition was somewhat correlated with ($r^2=0.206$) and statistically significantly ($p=0.005$) predictive of interest for one teacher and statistically significantly predictive for two others (see Table 6). This means that for some teachers, students who have a more positive disposition toward mathematics were more interested in the lessons that we observed. Since our goal is to disrupt students' negative dispositions towards mathematics, this correlation is something we aim to impact with future lesson designs.

Significance

While this instrument will continue to be revised and improved, it currently offers an important snapshot of the situated interest and aesthetic dimensions experienced by students in secondary mathematics classrooms. The LES can be used to connect the particular perceptions of students with their experiences. Further, it can be used to compare experiences in different classrooms, within or between teachers, in relation to the MDS. This information could provide both teachers and students with important information about learner profiles. Ultimately, results from applications of this instrument could provide a set of recommendations for targeting aesthetic responses and associated activities. It will allow us to test relationships through the design of new MCLEs. For example, can increased challenge lead to heightened lesson interest? Can new MCLEs change the existing relationship between long-term interest in mathematics and lesson-level interest? We anticipate that this instrument is not just useful in our context, but will also provide other researchers important information to evaluate mathematical lessons. Moreover, it could provide a way to identify possible pathways for improving student dispositions toward mathematics.

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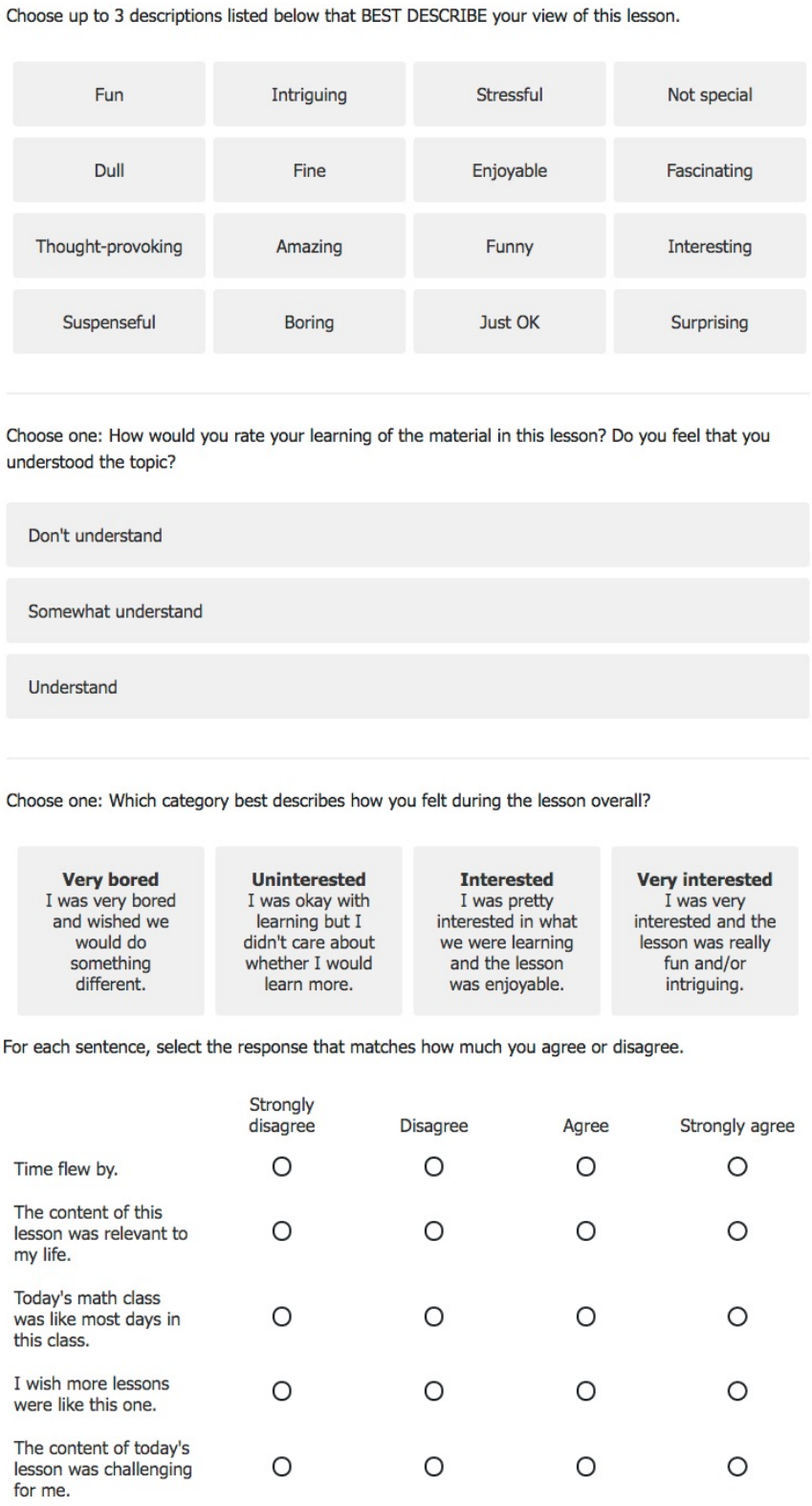

Figure 1. Lesson Experience Survey (LES), given to secondary students at the end of a lesson.

Table 1
Student interest level across the 19 lessons

Interest level	Very bored	Uninterested	Interested	Very interested	Total
Number of responses	12	66	207	42	327
Percentage of responses	4%	20%	63%	13%	100%

Table 2
Degree of student interest (mean value between 1-4) by aesthetic verbal descriptors

Verbal Descriptor	Mean interest by lesson	S.D. of interest by lesson	Number of responses
Amazing	3.5*	0.5	6
Fascinating	3.5*	0.6	22
Fun	3.3*	0.5	42
Enjoyable	3.3*	0.5	63
Intriguing	3.2*	0.5	39
Surprising	3.1*	0.4	20
Thought-provoking	3.0*	0.6	60
Funny	3.0*	0.5	21
Interesting	3.0*	0.5	104
Suspenseful	2.8	0.4	6
Fine	2.7	0.5	115
Stressful	2.7	0.8	19
Just OK	2.5	0.6	90
Not special	2.3	0.7	39
Dull	2.0	0.6	15
Boring	1.7	0.6	17

*Indicates a score that is reflective of students, on average, feeling “Interested” or higher in the corresponding lesson.

Table 3
Variation in student interest within each lesson

Lesson (Teacher, Observation Number)	Mean interest by lesson	S.D. of interest by lesson	Range of interest by lesson
A1	2.93	0.258	1
A2	2.60	0.828	2
A3	3.00	0.655	2
B1	2.84	0.765	3
B2	2.83	0.514	2
C1	2.71	0.686	3
C2	2.87	0.757	3
D1	2.64	0.505	1
D2	2.75	0.452	1
E1	2.56	0.511	1
E2	2.77	0.725	3
E3	2.50	0.519	1
E4	2.50	0.855	3
F1	3.13	0.626	2
F2	3.11	0.601	2
F3	3.14	1.215	3
Overall	2.80	0.676	3

Table 4
Most frequently chosen lesson descriptors

Verbal Descriptor	A1	A2	A3	B1	B3	C2	C3	D1	D2	E1	E2	E3	E4	F1	F2	F3	Total
Fine	*X*	*X*	*X*	*X*	*X*	*X*	*X*	*X*	*X*	*X*	*X*	*X*	*X*	*X*	*X*		*15*
Interesting	*X*	*X*	*X*	*X*	*X*	*X*	*X*	*X*	*X*	*X*	*X*	*X*		*X*	*X*	*X*	*15*
Just OK	*X*	*X*	*X*	*X*	*X*	*X*	*X*	*X*	*X*	*X*	*X*	*X*	*X*	*X*	*X*		*15*
Thought-provoking	*X*	*X*	*X*	*X*	*X*	*X*	*X*		*X*	*X*	*X*	*X*	*X*	*X*			*13*
Enjoyable	*X*	*X*			*X*	*X*	*X*		*X*	*X*	*X*			*X*	*X*	*X*	*11*
Intriguing	*X*	*X*	*X*	*X*	*X*		*X*	*X*						*X*			*8*
Not special	*X*				*X*		*X*	*X*	*X*			*X*	*X*		*X*		*8*
Fun						*X*	*X*			*X*	*X*			*X*	*X*	*X*	*7*
Boring						*X*			*X*			*X*	*X*				*4*
Stressful				*X*							*X*	*X*	*X*				*4*
Surprising	*X*	*X*						*X*									*3*
Funny										*X*	*X*					*X*	*3*
Fascinating		*X*												*X*		*X*	*3*
Dull								*X*				*X*					*2*
Amazing																*X*	*1*
Suspenseful																	*0*
N	15	15	15	19	18	17	23	11	12	18	13	14	14	24	10	7	290

Table 5
Variables related to lesson interest

Independent variable	Linear relationship between independent variable and indicated lesson interest	Correlation (r^2)	Significance
Measures of Mathematical Disposition (from MDS)			
Captivation	$y = 1.776 + 0.381x$	0.320†	0.022*
TIMSS Composite	$y = 2.123 + 0.239x$	0.130	0.170
Measures of Lesson Experience (from LES)			
Challenge	$y = 3.022 + -0.087x$	0.013	0.679
Relevance	$y = 2.106 + 0.303x$	0.149	0.139
Time Flew	$y = 1.034 + 0.597x$	0.385†	0.010*
Understanding	$y = 1.989 + 0.314x$	0.119	0.191
Wish more	$y = 1.651 + 0.424x$	0.186	0.096

† $r^2 \geq .20$
* $p < .05$

Table 6
Relationship between TIMSS Composite Score and Lesson Interest

Teacher	Average TIMSS Score	Relationship between TIMSS Composite score and interest in a lesson	Correlation (r^2)	Significance
A	3.2815	$y = 3.18 - 0.1x$	0.007	0.559
B	2.6606	$y= 1.69 + 0.45x$	0.206†	0.005**
C	2.8915	$y = 1.6 + 0.41x$	0.183	0.005**
D	2.9683	$y= 2.09 + 0.22x$	0.116	0.112
E	2.5948	$y = 1.81 + 0.3x$	0.106	0.012*
F	2.8559	$y = 2.50 + 0.23x$	0.078	0.089

† $r^2 \leq .20$
* $p < .01$
** $p < .05$