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Grades 4-8 Students' Reported STEM Interest, Self-Efficacy, and Instruction

A proceedings paper for a Brief Report at the 2016 Annual NCTM Research Conference

Abstract

Preliminary results from a longitudinal investigation of *N* = 1164 Grades 4-8 students' self-efficacy, interest, and perceptions of instruction in STEM. Findings suggest that students in a low performing middle school in a low income urban setting report generally low self-efficacy, interest, and performance in mathematics and science, while also reporting a moderate amount of direct instruction, individual work time, and small group/team learning during their mathematics classes. The students' responses were weakly correlated to their performance on an annual standardized state mathematics assessment. The results include tentative indications that students' beliefs about STEM and perceptions of mathematics instruction may be useful in designing interventions to increase interest and participation in STEM.

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Background & Introduction

Many of the recommendations in *Principles to Actions* are linked to three persistent challenges facing schools as we support all students to achieve in mathematics: (1) eliminating racial, ethnic, and income achievement gaps, (2) increasing the level of mathematics learning for all students, and (3) increasing the "number of high school graduates, especially those from traditionally underrepresented groups, who are interested in, and prepared for, STEM careers" (NCTM, 2014, p. 2). These persistent challenges are now widely understood as both important and remarkably difficult to address in K-12 schools. For example, despite decades of strong demand and coordinated efforts to promote STEM occupations, together with private and public support to prepare students for STEM fields starting as early as elementary school, only about one in six U.S. high school seniors is both proficient in mathematics and interested in a career in a STEM (U.S. Department of Education, 2014).

One of the reasons why the three challenges have been so difficult to overcome has been the ways in which they are profoundly intertwined, both with one another and with myriad socio-cultural, political, and personal factors. *Principles to Actions* (and related publications) offers research-supported "best practice" guidelines to promote essential strategies and components for effective and inclusive K-12 mathematics programs. However, educators acknowledge the contexts of student learning often have profound effects on "what works", and, particularly when it comes to ways in which challenges facing mathematics achievement are interrelated, there remain a number of important unanswered questions, including about how relationships among achievement in mathematics and interest in STEM careers manifest themselves in educational settings serving young people from traditionally underrepresented groups.

This brief report, meant to accompany a presentation at the 2016 NCTM Research Conference, provides a summary of initial findings pertaining to the complex relationships among middle levels students' achievement in mathematics and science over time, the students' confidence in STEM domains, and the students' reported interests in pursuing STEM occupations. The quantitative study, which employs a three-year longitudinal research design, is built on a theoretical framework informed by social cognitive learning (Bandura, 1997), especially the construct of *self-efficacy*, or one's belief in their ability to achieve a particular outcome under a specific set of circumstances.

Findings center around two research questions:

Among Grades 4-8 in an ethnically diverse, large urban school district in the U.S. South,

1. *are students' reported self-efficacy to achieve and interest in STEM disciplines statistically associated with their reported instructional practices in mathematics classes?*
2. *can students' reported STEM self-efficacy, interest, and instructional practices, be used to improve statistical models of future achievement in mathematics?*

Conceptual Framework

Social cognitive theory views learners as agents who actively work to shape their destiny based on *outcome expectancies* (i.e., perceptions of what will happen) and self-efficacy. In modeling of academic performance, self-efficacy is one of only a few variables that have ever been identified as a better statistical predictor of performance than prior performance and ability (e.g., Bandura & Locke, 2003). Some quantitative research has suggested *calibration* (the outcome-based accuracy of self-efficacy beliefs) has important mediating effects on the relationship between self-efficacy and performance in middle levels mathematics (Chen & Zimmerman, 2007).

Self-efficacy is especially relevant to student learning and interest in STEM domains because it influences the decisions students make, the goals they set, the effort they are willing to exert on reaching those goals, and the persistence they display when faced with obstacles (Pajares, 2005). Students with high self-efficacy in science and mathematics are more likely to set challenging goals and work harder to accomplish those goals, and are more likely to express interest in STEM-related professions (Eccles, 1994; Lent, Brown, & Hackett, 1994). The relative strengths of these effects and the particular mechanisms of self-efficacy development appear to be strongly connected to contextual and cultural factors, such as ethnicity (Pajares & Kranzler, 1995) and gender beliefs. For example, one study found high self-efficacy had a stronger predictive role in the vocational choices of girls than those of boys (Larose, Ratelle, Guay, Senécal, & Harvey, 2006).

Despite thousands of studies on self-efficacy in educational contexts (Lightsey, 1999), research on interventions to improve self-efficacy in middle levels STEM learning are exceedingly rare (Beier & Rittmayer, 2008). STEM education research (e.g., Zeldin, 2000) has, however, supported Bandura's (1997) claims that four sources of self-efficacy beliefs, including mastery experience (related prior experience and performance), vicarious experience (observations of

others performing similar tasks), social persuasion (feedback from others on performance and ability), and physiological reaction (emotional and physical states). In their review of research on the sources of self-efficacy in school settings, Usher and Pajares (2008) specifically recommended research on interventions aimed at increasing mathematics and science self-efficacy in middle levels schools.

Methods

The reported study's research design features the first of three years of longitudinal self-reported survey data and state mathematics and science assessment results for N = 1,049 participating students at five schools in a large urban school district in the U.S. South with a primarily Hispanic student population. This student data represents just one facet of a larger research program surrounding the effects of a prototype mathematics and science teacher preparation project between the partner school district and a mid-sized public university in the same city. Having recently completed the first two years of a three year project sponsored by a $1.5 million grant from a federal agency, ETEAMS investigates an unconventional strategy for increasing the quantity, quality, and diversity of mathematics and science teachers in high-need schools. The project supports generalist elementary preservice teachers to engage with middle levels STEM teaching through a fellowship at three participating schools (two elementary, one middle). In addition, students at two nearby schools (one elementary, one middle) are participating in the study as a statistically matched control group. In addition to data reported in this report, the research plan includes forthcoming analysis of data on preservice teachers and inservice teachers' STEM self-efficacy, interest, and content knowledge, as well as qualitative indicators of students and teachers' views on the nature of science, changes in the quantity, quality, and diversity of local grades 4-8 mathematics and science teachers.

Data Sources

The primary data sources for the reported student data include students' individual scores on state mathematics and science assessments (including scores of assessment subscales) during the 2013 and 2014 administrations, along with students' self-reported self-efficacy and interest in STEM domains from the published *Student Attitudes toward STEM (S-STEM): Upper Elementary Survey* (MISO, 2012) and students' responses to modified student versions of the *Survey of Instructional Practices: Grades K-8 Mathematics and Science* (Council of Chief State School Officers & Wisconsin Center for Education Research, 2013). Background variables include students' grade level, age, school, mathematics and science instructors, ethnicity, and sex. The completeness of data ranges by data source from the 38% of students who completed the state science assessment in 2013 (the exam is only administered in some grades) to the 90% of students who completed the mathematics assessment in 2014 (average completeness rate of all variables = 64%). In all, there are approximately 122,000 unique data values represented in the processed data, including approximately 240 statistical variables grouped according to data source. The final sample of students for which we have all data regarding their mathematics performance, perceptions of instruction, and beliefs about STEM is n = 1164, including 338 students in Grade 6 and 776 students in Grade 7.

Following the subscales built into the survey instruments, we combined students' responses to the multiple survey items indicating their self-efficacy, performance, and interest in STEM, as

well as perceptions of mathematics instruction to form composite scales. The internal consistency of responses within composite scales was evaluated in each case, with a cronbach alpha of 0.7 used as the criterion for acceptable single-factor reliability of these subscales.

Results

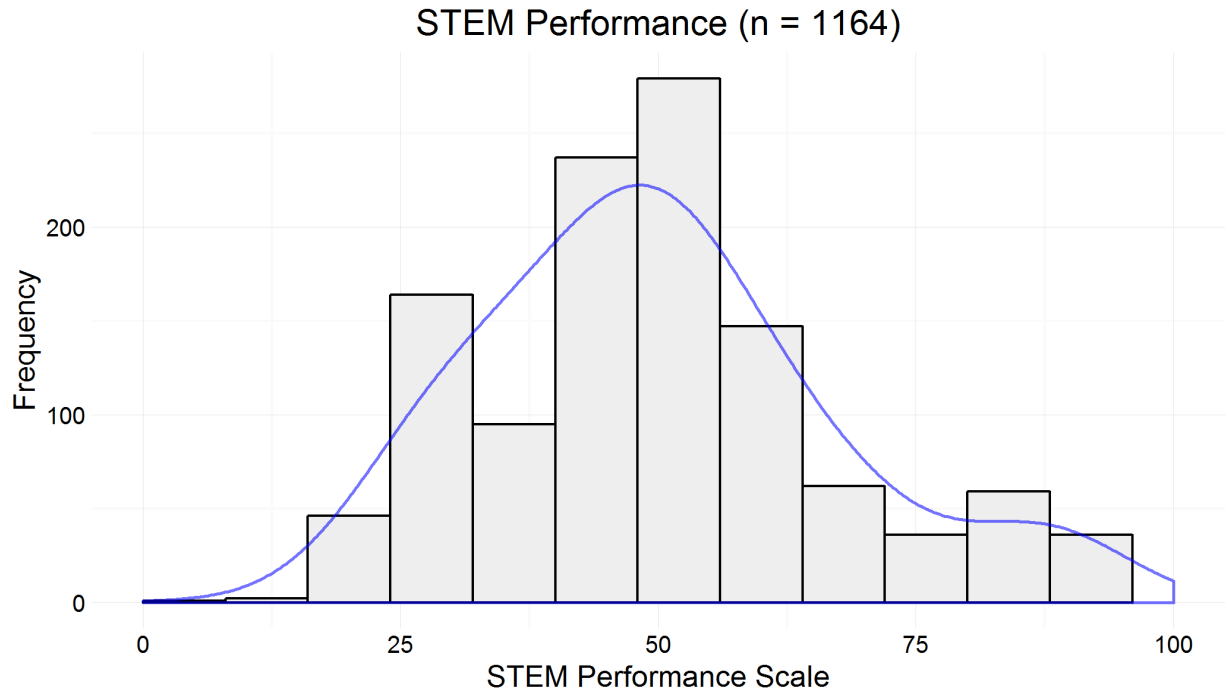
We structure the presentation of our findings according to the two research questions.

Among Grades 4-8 in an ethnically diverse, large urban school district in the U.S. South,

1. *are students' reported self-efficacy to achieve and interest in STEM disciplines statistically associated with their reported instructional practices in mathematics classes?*

Descriptive Statistics

As indicated in Figure 1, the sample of *N* = 1164 sixth and seventh grade students' self-reported STEM performance, STEM self-efficacy, and STEM interest each varied substantially as a percentile of the maximum possible response, with respective means and standard deviations of *M* = 49.9 (*SD* = 16.9), *M* = 43.0 (*SD* = 19.0), and *M* = 45.2 (*SD* = 15.0).



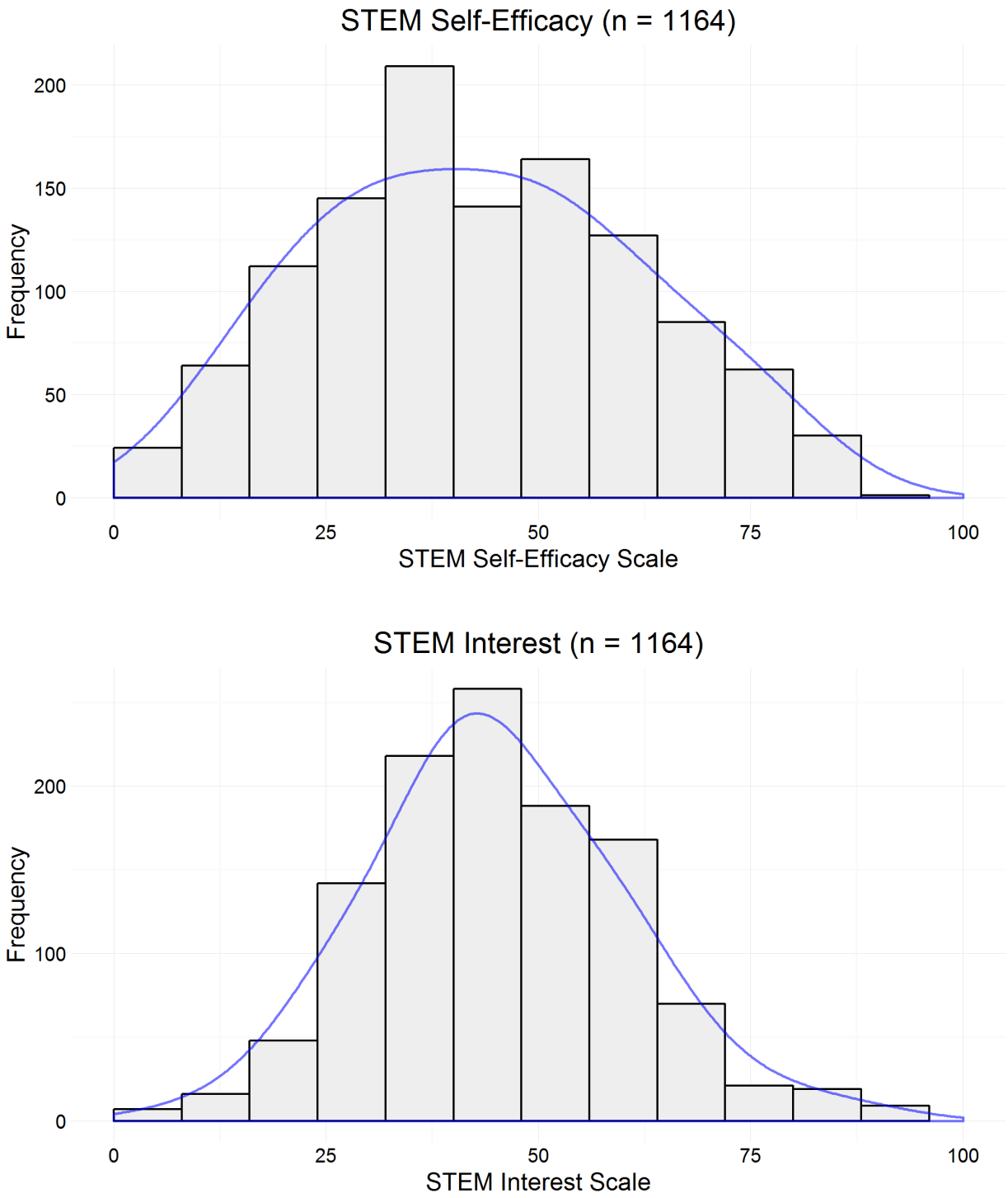
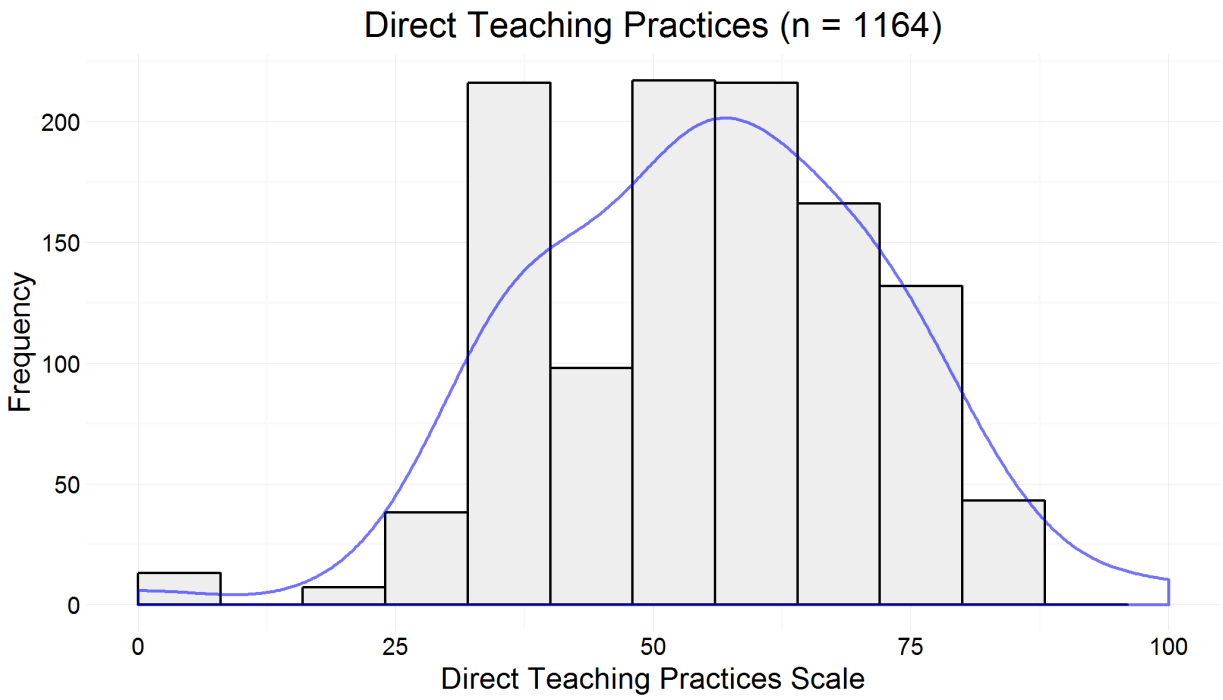
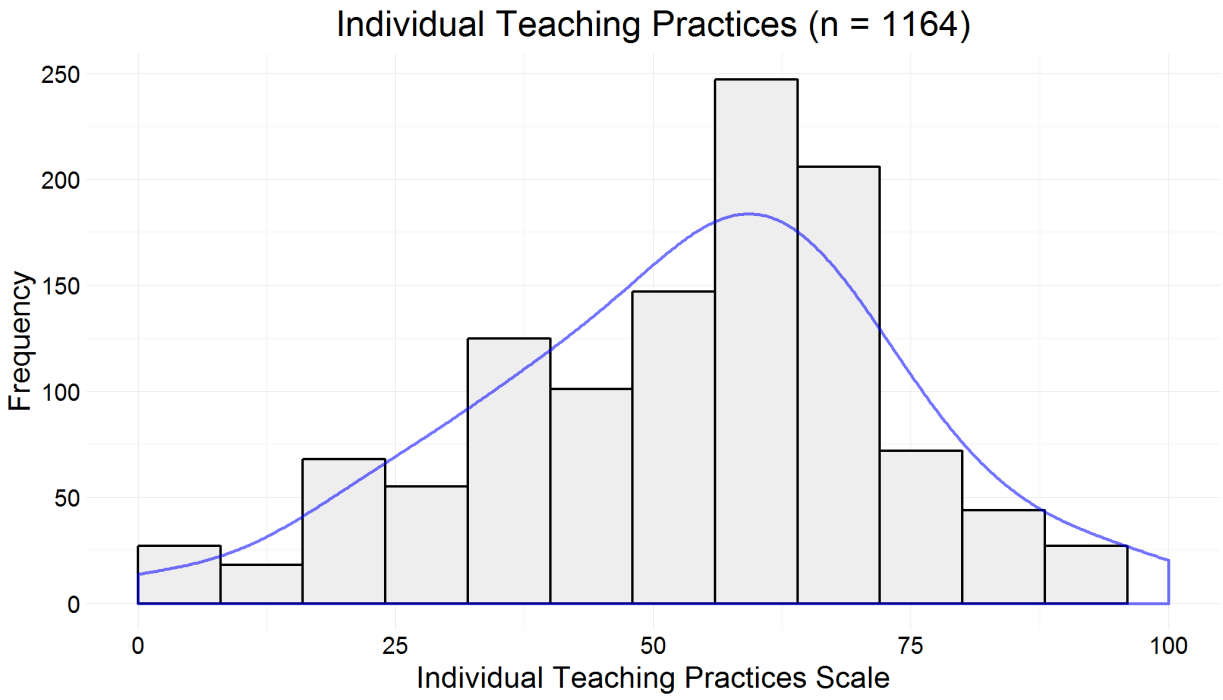


Figure 1. Distributions of Students' Reported Self-efficacy, Interest and Performance in STEM.

Moreover, Figure 2 shows the distributions of the measures of the sampled students' self-reported perceptions of mathematics instruction. The students' responses indicate similar overall distributions of instructional emphasis on direct instruction (M = 55.4, SD = 17.9), individual work (M = 52.2, SD = 17.9), and small-group work (M = 51.6, SD = 19.5).


Direct Teaching Practices (n = 1164)
Frequency
200
150
100
50
0
0
25
50
75
100
Direct Teaching Practices Scale


Individual Teaching Practices (n = 1164)
Frequency
250
200
150
100
50
0
0
25
50
75
100
Individual Teaching Practices Scale

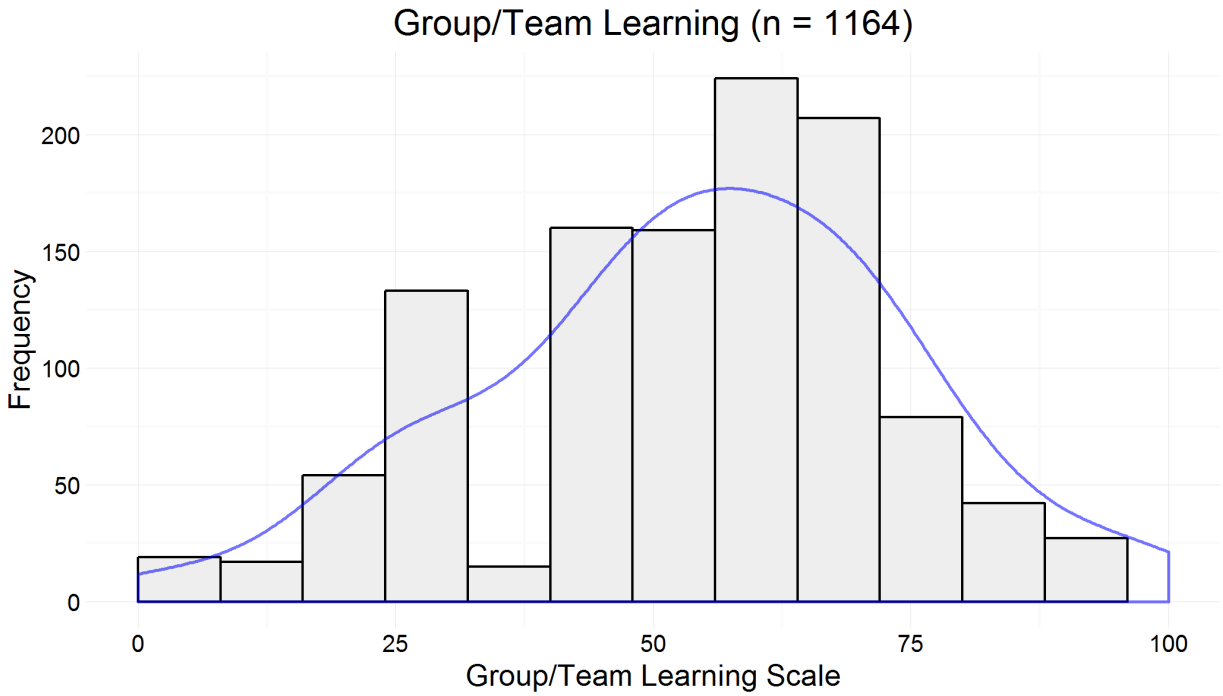


Figure 2. Distributions of Students' Perceptions of Mathematics Instruction.

Bivariate Associations

We identified a number of bivariate associations among students' self-reported beliefs about their mathematics instruction and STEM performance, self-efficacy, and interest. As indicated in Table 1, the five subscales of perceived mathematics instruction were moderately to highly correlated, with particularly strong positive correlation between reported emphasis on small group work and emphasis on individual work (r = .89). The three measures of STEM beliefs were also intercorrelated, with moderate positive associations. There was also a weak positive correlation between instructional emphasis on group/team learning and STEM interest (r = 0.12)

Table 1. Intercorrelations of Survey Scales

	Direct Instruction	Individual Learning	Group Learning	STEM Performance	STEM Interest
Direct Instruction	_				
Individual Learning	0.72	_			
Group Learning	0.68	0.88	_		
STEM Performance	0.01	0.02	0.03	_	
STEM Interest	-0.01	-0.05	0.12	0.37	_
STEM Self-Efficacy	-0.02	0.02	0.01	0.49	0.53

Figure 3 illustrates the observed correlation between perceptions of Direct Instruction and Group/Team Learning through a proportionally sized scatter plot.

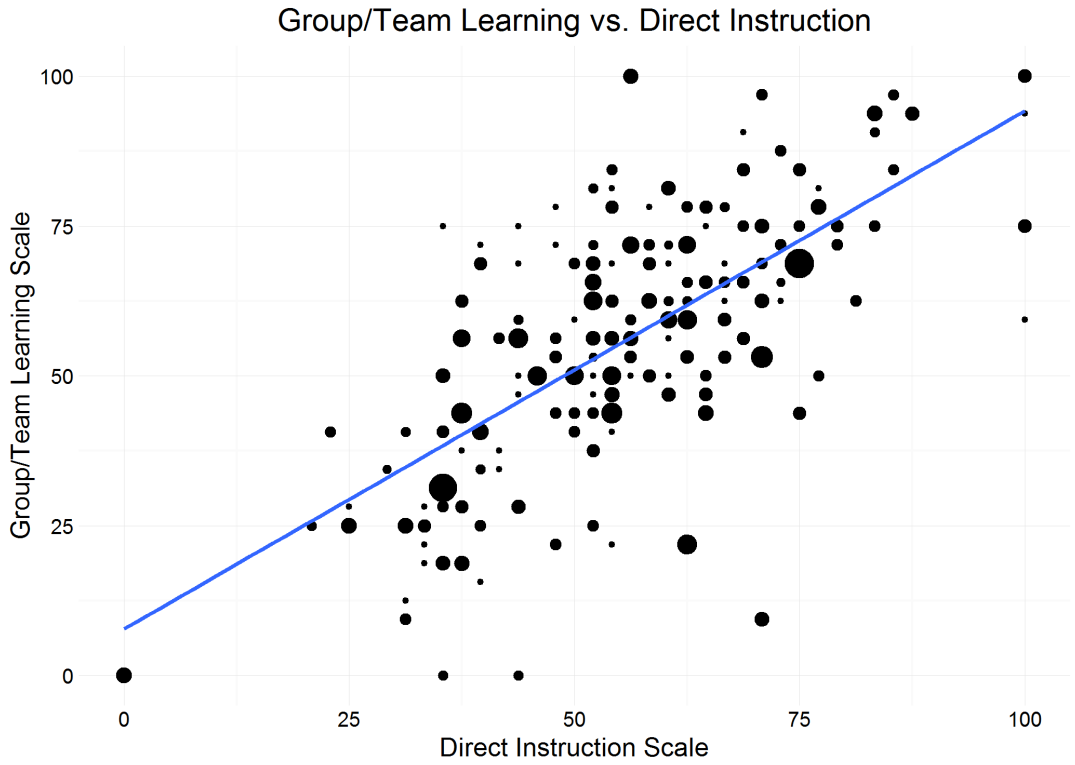
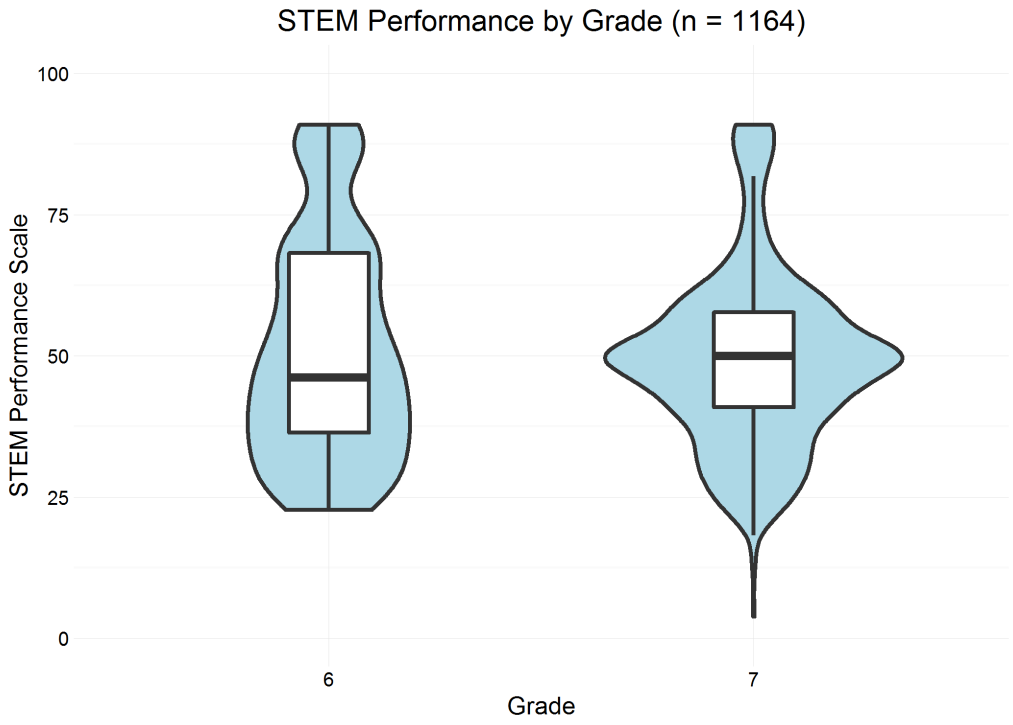
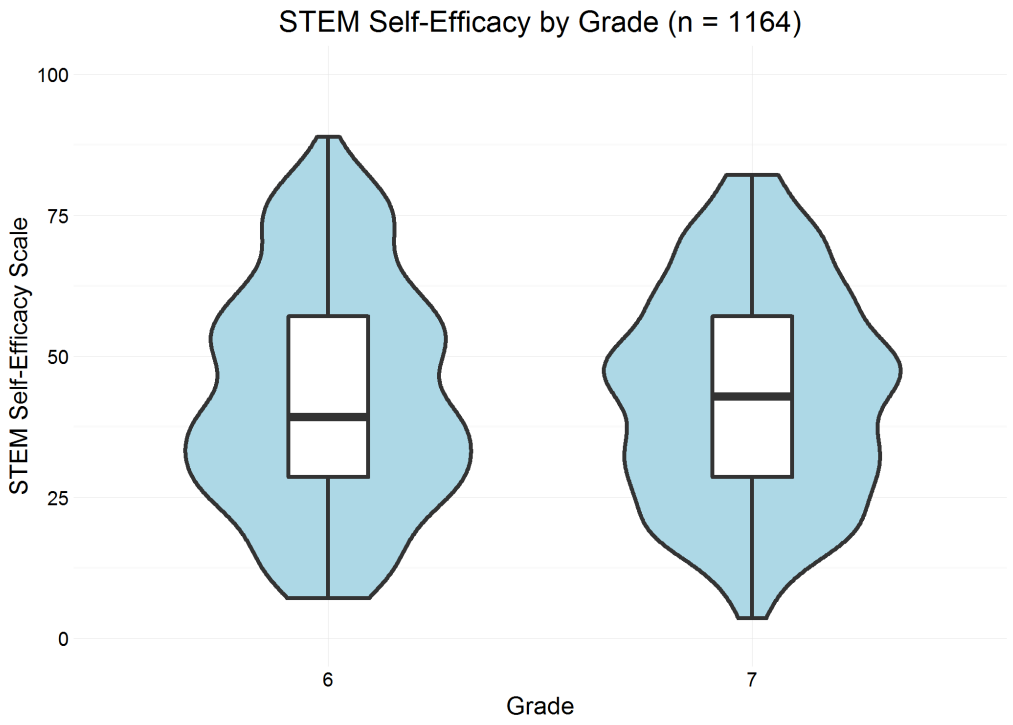
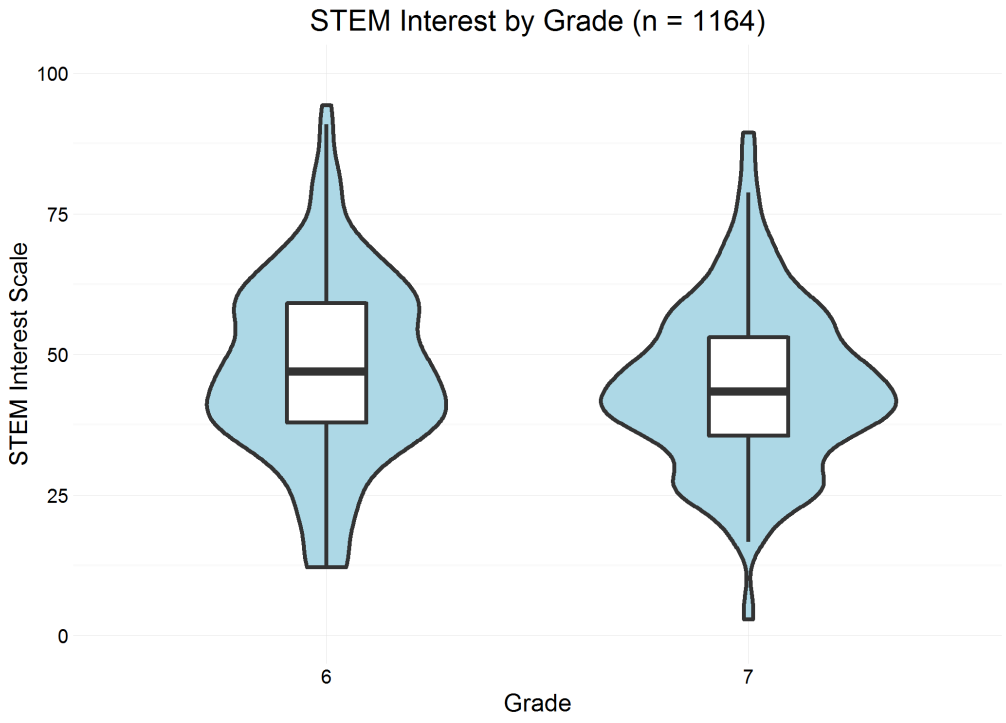


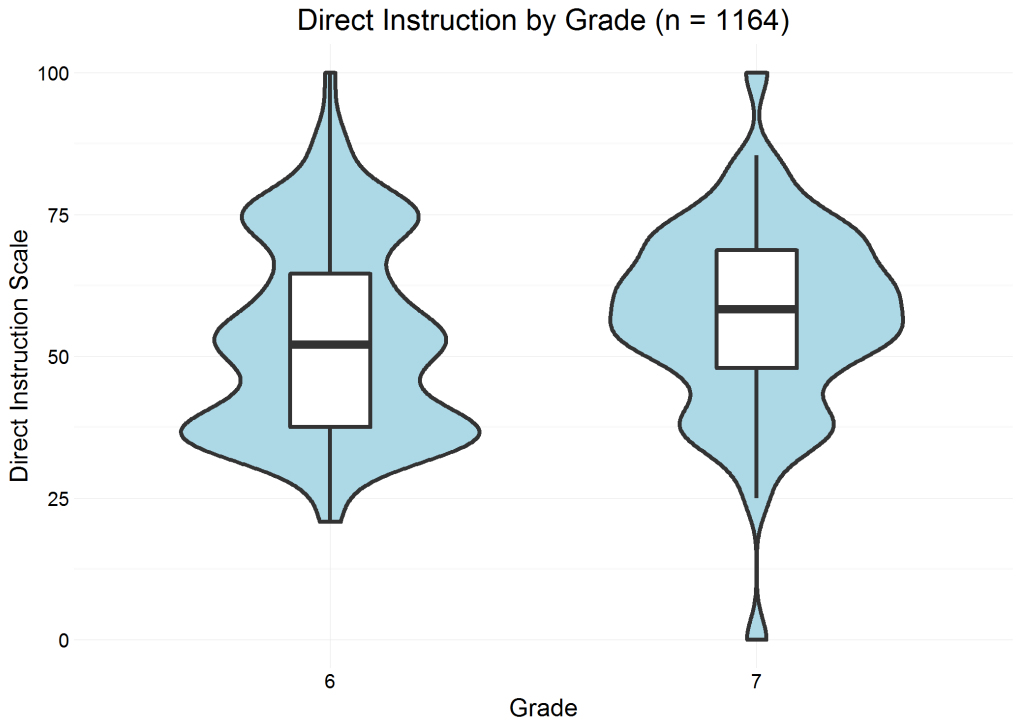
Figure 3. Scatter Plot Relationship between Perception of Direct Instruction and Group/Team Learning. *Note*: Sizes of points are proportional to their respective frequency of occurrence.

In addition to the associations among students' self-beliefs and among their perceptions of instruction, there did appear to be differences in the distributions of STEM interest and self-efficacy between the 6th and 7th grade students, especially a potential decrease in both the tendency to express strong interest and self-efficacy, and a decrease in variation across students. See Figure 4 for details.


STEM Performance by Grade (n = 1164)
STEM Performance Scale
100
75
50
25
0
6
7
Grade


STEM Self-Efficacy by Grade (n = 1164)
STEM Self-Efficacy Scale
100
75
50
25
0
6
7
Grade


STEM Interest by Grade (n = 1164)
STEM Interest Scale
100
75
50
25
0
6
7
Grade


Direct Instruction by Grade (n = 1164)
Direct Instruction Scale
100
75
50
25
0
6
7
Grade

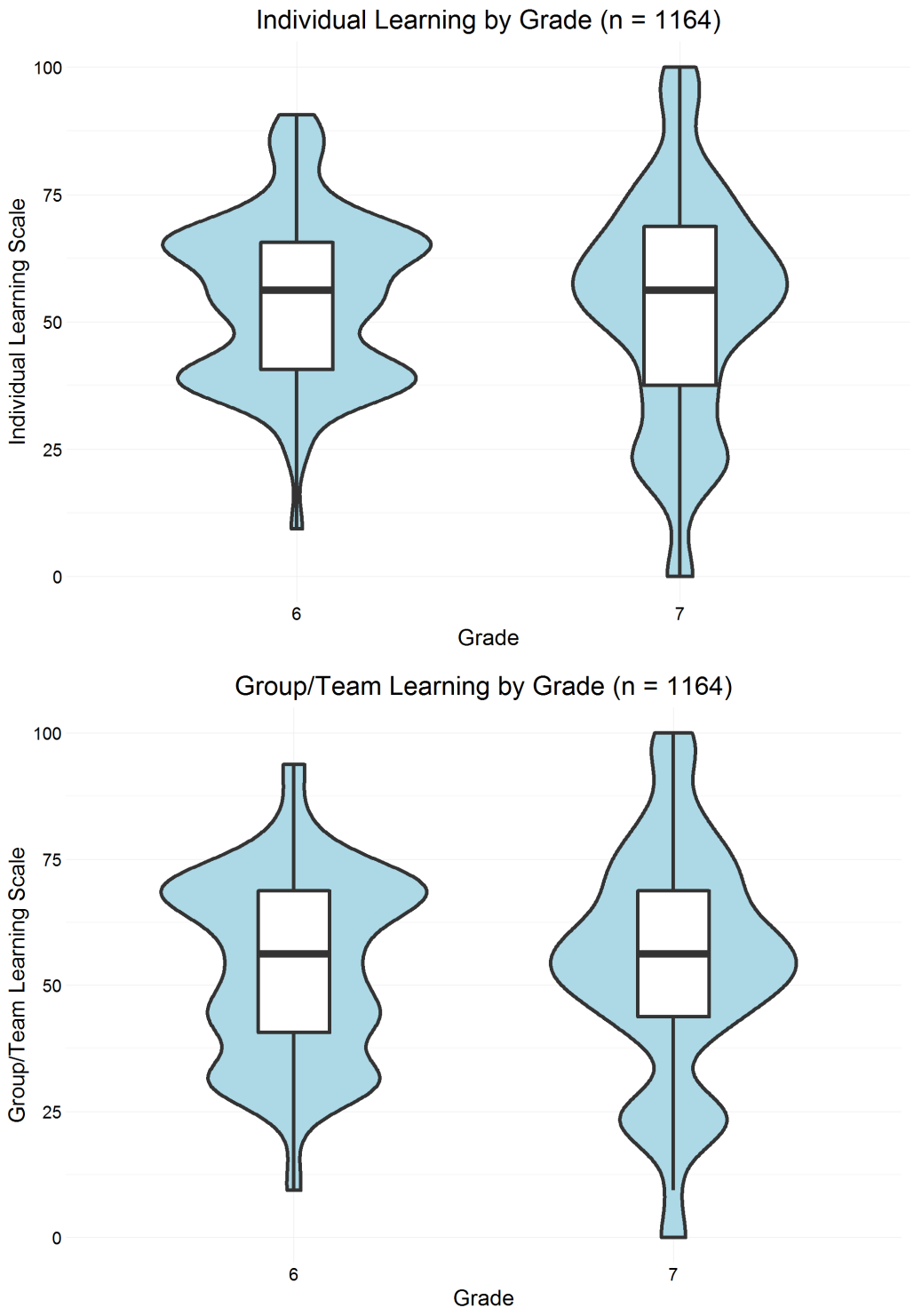


Figure 4. Scale Scores of Students' Reported STEM Beliefs and Math Instruction by Grade

2. *can students' reported STEM self-efficacy, interest, and instructional practices, be used to improve statistical models of future achievement in mathematics?*

There are some tentative indications that student's reported beliefs about STEM and perceptions of their mathematics instruction are associated with their subsequent mathematics performance. With the exception of students' reports of direct instruction, each of the variables was weakly positively correlated with the students' scores on the end-of-year annual state standardized mathematics assessment, with the largest associations between their test scores and students' reports of individual work time and self-beliefs about STEM performance. A linear regression model incorporating these variables along with students' grade level explained a statistically significant portion of the variance in students' standardized test scores (F (3, 1160) = 5.7), with estimated standardized effect sizes of 0.07 and 0.08, respectively.

For example, the modeling results suggests that students in the sample whose reports of individual work time were 1 standard deviation above the mean response, on average, would be projected to score 0.07 standard deviations higher than the mean on the state annual assessments (approximately the 53rd percentile). This may seem to be a small overall effect, but may be quite significant given context at the research site (the participating middle school is currently under formal "Improvement Required" status within a school district with heavy emphasis on state assessment performance).

Conclusion & Discussion

This report contains a brief preliminary summary of 1164 students in Grades 6 and 7 in terms of their beliefs about STEM and their perceptions of mathematics instruction. The most notable findings are that this group of students typically reported generally low interest, self-efficacy, and performance in STEM (on average, less than 50% of the maximum possible responses to likert-type survey questions), with distributions that indicate considerable variation among students and by grade. In addition, when surveyed about the instructional practices in their mathematics classes, the students reported moderate amounts for each of direct instruction, small group/team learning, and individual learning, with high intercorrelations among those variables. Though the internal consistency of the subscales indicated reliable scales, the correlations among the scales, together with students' relatively young ages, suggests two (not mutually exclusive) possibilities: (1) students may not accurately distinguish between the three types of instruction identified in the survey (so that responses tend to reflect a single perception of instruction, rather than multiple perceptions), and/or (2) teachers at the research site may tend to use the three types of instruction together. Both of these hypotheses have implications for future research, and we plan to address them in future research.

Given the nationwide emphasis on preparing students to pursue STEM careers, the findings regarding students' self-efficacy, interest, and perceived performance in STEM are sobering. To the extent the survey findings may reflect students' views at other schools in low income, high need communities of underrepresented students, the results indicate students' may already have considerably "checked out" of STEM subjects as early as 6th grade, with decreasing interest and self-efficacy by seventh grade. These cognitive beliefs may not have strong correlations to performance and achievement on standardized tests, but they are quite likely to influence students' choices as they pursue mathematics and science curriculum in high school,

which in turn has strong determinant effects on the opportunities to pursue STEM careers down the road.

Further, we suggest future research dig deeper into the complex factors affecting middle grades students' self-efficacy and interest in STEM subjects. SES will likely emerge as an important factor, but there are some indications in our sample (which includes a very high percentage of underrepresented students of low SES), that self-efficacy and interest in STEM can be affected by instruction in mathematics. Social cognitive learning literature has emphasized mastery experiences and social comparisons as important causal links to self-efficacy, persistence, and interest in a domain, and we recommend additional study into specific instructional strategies that emphasize providing underrepresented students opportunities to experience meaningful success in mathematics learning in ways that are likely to increase their self-efficacy and interest in STEM.

Disclaimer

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