STUDENT THINKING AND ATTITUDES WHEN WORKING WITH DATA IN AN INTEGRATED, PLACE-BASED CURRICULUM

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Developing students' data literacy skills through an integrated place-based curriculum is important for creating informed citizenry as well as building student confidence around mathematical and statistical thinking. Initial results from attitude and assessment surveys from 74 sixth-grade students in a rural, coastal school district in the Northeastern United States reveal that students entered the school year with positive attitudes towards mathematics. While students hold more novice conceptualizations of what constitutes "data," their confidence in their math skills and performance offer an opportunity to sustain these positive attitudes as they encounter more challenging statistical thinking tasks across math and science classrooms.

Keywords: Middle School Education, Integrated STEM, Data Analysis & Statistics

Purpose of the Study

The oceans define our planet and are central to many challenges human populations face; addressing these challenges requires citizens who are ocean literate **and** data literate. We established a research-practice partnership (RPP) with teachers and community members from rural coastal communities in the Northeastern U.S. to promote integration of ocean science, data, and technology-related competencies into science curricula. This study reports initial findings regarding middle school students' conceptualizations of data, and characterizes their attitudes towards STEM (Science, Technology, Engineering, Math) subjects at the start of the school year.

Theoretical Framework

While many research studies indicate that integrated STEM instruction can benefit students and teachers alike, educators face significant challenges in implementing integrated instruction (Mayes, 2019; Ríordáin et al., 2016). Considerable research also supports the idea that STEM subjects should be taught in an integrated, authentic way that reflects the day-to-day practices and competencies of experts and scientists (Kelley & Knowles, 2016; NGSS Lead States, 2013; Roehrig et al., 2021). We draw upon the data science framework proposed by Lee and colleagues (2022) and the positioning of data literacy at the intersection of data science, authentic context, and quantitative reasoning proposed by Kjelvik & Schultheis (2019). These frameworks guide our investigation of students' reasoning when working with data and their conceptualizations about data, specifically regarding variability, measures of central tendency, and interpretation of data visualizations, aligning with the GAISE report principles (Bargagliotti, 2020).

Furthermore, we position our project within a marine context to make it relatable and accessible for students in a state with a substantial "blue economy." Linking learning to initiatives such as Powering the Blue Economy (PBE; Office of Energy Efficiency & Renewable Energy, n.d.) helps ground students' data literacy development in real-world applications that can focus on the innovative yet sustainable use of ocean resources to boost economic growth while preserving ocean ecosystems, which has direct impacts on their local communities.

Methods

This study took place in the context of a large grant-funded RPP exploring ways to integrate authentic research and technology into grade 6-12 classrooms, with a particular focus on marine science and data literacy. Key objectives include (a) providing professional learning for teachers to support the development of community-relevant, authentic student research, (b) studying the impacts of authentic research infused with technology on diverse students' knowledge of and engagement with the material, and (c) expanding students' career knowledge and awareness by establishing local community partnerships. Following the first series of professional learning sessions in Summer 2023, teachers developed lessons based on existing classroom instruction that incorporated these elements into instruction for the 2023 - 2024 academic year.

Participants

Student participants were recruited from grade 6-12 classrooms enrolled in the project; Institutional Review Board approval was obtained prior to any recruitment and data collection activities. This study focuses on pre-instruction data from participating 6th graders. Pre-instruction survey responses were collected from 74 6th grade students enrolled in Earth Science; post-instruction surveys will be deployed by the end of the 2023-2024 school year. Respondents include 38 females, 21 males, and 15 students who left the gender question blank or preferred not to answer.

Data Collection and Analysis

Data was collected using two pre-post surveys targeting both student reasoning about data and their attitudes towards STEM. Student attitudes were assessed using the Student Attitudes Towards STEM (S-STEM) survey (Friday Institute, 2012). The S-STEM survey conceptualizes student attitudes as representing both student self-efficacy and expectancy-value beliefs (Unfried et al., 2015). The research team created a Data Assessment survey that included a mix of Likert items and multiple-choice items drawn from previously published instruments (*e.g.*, Gormally et al., 2012; Zoellick et al., 2016) aimed at understanding students' views on what "counts" as data (Bargagliotti et al., 2020) and how they think about data in their lives.

Survey data was analyzed using SPSS statistical software (IBM, version 28.0.0.0). S-STEM analysis focused on the Math subscale and associated career/course question items. Likert answer choices to subscale items were scored from 1-5, with 5 representing the most positive views; averages and standard deviations from subscales are reported based on the recommendations by the survey developers (Friday Institute, 2012). For the survey item predicting class performance, simple contrast coding was used to run linear regression with categorical predictors to determine if responses were associated with Math subscale scores. Responses to the Data Assessment were summarized using descriptive statistics. Further analysis examining both classroom observation notes and artifacts for evidence of student thinking and reasoning is currently underway and will be complete by July 2024.

Results

Student Attitudes: Middle School S-STEM Results

Middle school students' attitudes were the most positive on the 21st Century Skills subscale, with a pre-instruction mean of 3.82 ($SD = 0.50$), followed by Math (3.47, $SD = 0.69$), Engineering (3.25, $SD = 0.65$), and then Science subscales (3.17, $SD = 0.65$). A one-way ANOVA revealed there was no significant difference between scores by gender ($F_{2,71} = 0.762$, $p = 0.514$). Subscale items around future plans for pursuing careers in math and/or doing advanced math had less positive student views than those about students' current mathematical self-efficacy. For example, only about 30% of students Agreed/Strongly Agreed with the statement "I would consider choosing a career that uses math," whereas "I am good at math" had over 70% of students Agreeing/Strongly Agreeing.

Students also predicted how well they expected to do in the current school year in their math, science, and ELA classes. Math had the highest percentage of students predicting they would do very well (31%), followed by ELA (28%), and Science (20%). Only 8% of students predicted "Not at all well" for both math and science; ELA only had 4% of students predicting such. Categorical linear regression analysis revealed that students' expectations for performance in math class was a significant predictor of their attitude score on the Math subscale (Adjusted $R^2 = 0.513$; $p < 0.001$). Students in the "Not at all well" prediction category scored an average of 1.75 points lower on the Math subscale than those who thought they would do "Very well," while those in the "OK/Pretty well" category scored an average of 0.84 points lower ($p < 0.001$).

Student Thinking: Middle School Data Assessment Results

Data Assessment responses ($n = 70$) to Likert statements indicated 70% of students agreed with statements characterizing data as useful for understanding the environment; 67% acknowledged descriptions/observations and 63% said stories from people with local/historical knowledge as useful data. Only 34% agreed data were part of their everyday life, and the remaining statements regarding data collection and analysis had large percentages (36–53%) of students selecting the neutral answer choice.

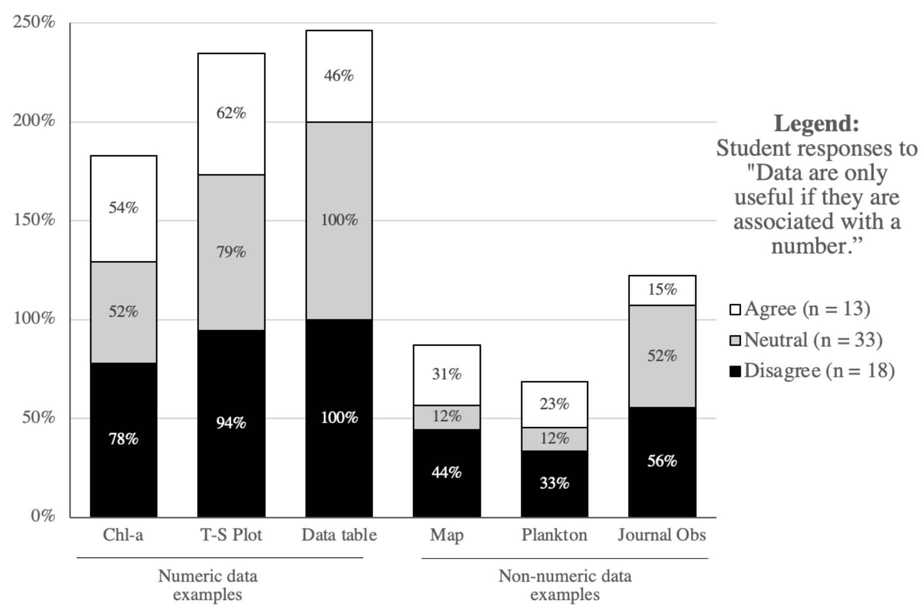

Figure 1: Percent of Students Within Each Response Category Who Identified Numeric vs. Non-Numeric Examples as "Data"

Students were shown six different images containing both numerical and non-numerical marine data sources and asked to choose all images they would classify as "data." Numerical examples included a satellite image of sea surface chlorophyll-a concentrations (Chl-*a*), a time-series plot of sea surface temperature and salinity (T-S Plot), and a table of temperature and salinity data at three locations (Data Table). Non-numerical examples included a map of a local bay (Map), a photo of a phytoplankton cell (Plankton), and a journal entry detailing intertidal observations (Journal Obs). The most popular images selected by students were the numerical sources: Data Table (81.4%), T-S Plot (72.9%), and Chl-*a* (55.7%). Less than half of the students (41.4%) chose Journal Obs as a kind of data; few chose Map (24.3%) or Plankton (18.6%).

Because of the small number of students who classified the non-numerical examples as representing types of data, we investigated their responses to this item in light of how they answered the Likert statement "Data are only useful if they are associated with a number" (Figure 1). 64 students responded to this survey question; 18 disagreed, 33 were neutral, and 13 agreed. Students who disagreed (i.e. held a more expert-like view of what "counts" as data) were more likely to choose non-numeric data examples over those who were neutral or agreed. For example, 44% of the Disagree students (black bars) identified the Map as a type of data, as compared to only 12% of Neutral students (gray bars) and 31% of Agree students (white bars). Because students could choose multiple options, percentages add up to more than 100%. In the final series of questions around handling hypothetical data dealing with outliers and variability, 54.3% of students correctly answered how to handle outlier data in a dot plot, but only 28.6% chose the correct description of variability in non-technical terms. 32.9% of students chose the distractor choice "The number of different values in the data set" for describing variability.

Discussion & Conclusions

We conclude that the average Math subscale score of 3.47 indicated more positive views towards math than science, when considering both subscale averages and prediction of performance in both classes in the coming year. Since participants were enrolled in their first standalone science class of their academic careers, uncertainty about what this course looks like could contribute to less confident attitudes towards science. The overwhelmingly positive responses to self-efficacy-type Math items were encouraging and suggest that younger middle school students may hold a more positive mathematical mindset than expected.

With the regression analysis indicating significant differences observed in overall math attitudes between the performance prediction groups, our results reinforce recommendations from previous work (e.g., Boaler, 2015) that building confidence and self-efficacy amongst the students who have negative performance predictions is critical to future success, especially as studies continue to demonstrate math anxiety having negative impacts on performance (Barroso et al., 2021). Efforts to build positive, growth-mindset oriented mathematical attitudes need to happen beyond math classrooms. More explicit opportunities for students to engage with mathematical thinking and reasoning in other subjects (like Earth Science) may help break down stigmas students have towards math and allow these practices to be more accessible.

Students' responses to the Data Assessment Likert questions had several statements with which students neither agreed nor disagreed; these may reflect more uncertainty than a true neutral stance. Modifying the survey to eliminate the neutral option and/or following up with an open response question or individual student interviews could be a way to better understand these responses. Despite students' agreement that data did not have to be numeric, Figure 1 shows that the majority of students still gravitated to data examples that had quantities attached to them, which may be a result of their familiarity with these types of representations.

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