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# Working with Real-World Data: A Pilot Study of Pre-Service Elementary Teachers

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***Abstract:*** *The purpose of this pilot study was to engage pre-service elementary teachers in a semester-long project to deepen their quantitative reasoning skills when working with real-world data. Over three semesters, all pre-service elementary teachers enrolled in mathematics content courses focusing on K-8 mathematics topics had to collect, analyze, visualize, and interpret data. The data collected for this pilot study included all presentation slides, fieldnotes from observing their presentations, and the final papers. The analysis was two-fold: (1) Function language analysis, and (2) a grounded theory-inspired open coding. Results indicate that verb choice seems to make a difference in the tone and confidence of the written language and increased ownership seems to lead to stronger reasoning. The open coding and constant comparison of the data as an aggregate led to four potential challenges: (1) Avoidance of quantities, (2) only offering qualitative accounts, (3) graph choice purely based on preference, and (4) a lack of quantitative language.*

***Key Words:*** quantitative reasoning, real-world data, pre-service elementary teachers, function language analysis

In today's society, navigating and understanding all the different kinds of quantitative information that we are presented with is challenging—it is difficult to analyze vast, complicated data and develop an informed opinion, so people often rely on the interpretations of others. We rely on quantitative information summarized in many ways, such as graphs, charts, or tables to name a few, in order to make informed decisions. A timely and applicable example is the current COVID-19 pandemic, where we see daily, even hourly, data updates related to the state of public health, and the media provides multiple interpretations and predictions that may or may not be personally relevant, depending on the data and representation used. Pre-service elementary teachers will be tasked with introducing many of these representations and approaches for working with real-world data in their future classrooms. To successfully navigate these topics, they will need to help their future students develop quantitative reasoning skills in context (QRC). These QRC skills are currently underemphasized in their teacher preparation program. At a time when doubts about science are rampant, understanding what supports pre-service teachers need to be prepared to teach QRC will advance the curriculum development of their teacher preparation program.

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## RELEVANT LITERATURE

Quantitative reasoning skills help students navigate quantitative information and think critically about data and graphical representations across various contexts. The definition of QRC used for this research has been derived from the work of Steen (The National Council on Education and the Disciplines, 2001), Shavelson (2008), Madison (2006), the Mathematical Association of America (MAA, 1998), the National Numeracy Network (NNN, 2011), and Thompson (2011), and from a quantitative reasoning research team (Mayes et al., 2014):

> Quantitative Reasoning in Context (QRC) is mathematics and statistics applied in real- life, authentic situations that impact an individual's life as a constructive, concerned, and reflective citizen. QRC problems are context dependent, interdisciplinary, open-ended tasks that require critical thinking and the capacity to communicate a course of action. (Mayes et al., 2013, p.6)

Organizations, such as the MAA (1998) the Association of American Colleges and Universities (AAC&U, 2010), and recent research studies suggesting a lack of quantitative reasoning skills in STEM and non-STEM undergraduates (Elrod & Young Park, 2020) call for a greater presence of and emphasis on quantitative reasoning throughout K-16.

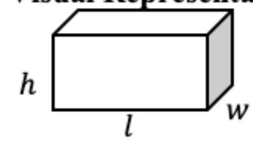
Quantitative reasoning is interdisciplinary, as students often have to work with, interpret, and model real-world data across all STEM disciplines, especially in science. According to the National Research Council (2012), the key goal of science is to construct evidence-based explanations and models of real-world phenomena that can also detect trends and allow for predictions. A learning strategy that promotes QRC is a scaffolded written argumentation assignment called Data Story. Data Stories were developed by the *Maine Data Literacy Project* as part of their work in a five-year project (2010-2015) funded by the USDOE Title II Math-Science Partnership Grant Program, Data Literacy and the Davis Family Foundation. Data Stories are designed to help bridge the gap between data and the real world by using a hybrid of mathematical and visual representations, scientific arguments, and literacy skills which together, allow students to talk about real data comfortably and confidently.

When constructing a Data Story, students work with real-world authentic data sets. They begin by formulating a statistical question that builds the foundation of their claim. Next, they decide what evidence to create in order to answer their question and make decisions about meaningful calculations and selecting appropriate graphs. Finally, in their reasoning they need to link their evidence to their question and claim and discuss their story within the bigger picture of the phenomenon under investigation. The use of real-world data can enhance interdisciplinary connections and increase relevancy for students, which in turn can increase student engagement (Garfield & Ben-Zvi, 2009; McNeill, 2009; Neumann, Hood & Neumann, 2013).

When presenting and writing Data Stories, pre-service teachers need to communicate their mathematical reasoning, which can be challenging due to the linguistic challenges of mathematical language (Fang & Schleppegrell, 2010; Schleppegrell, 2007).

**Figure 1**

*An example of the three semiotic resources of mathematical language*

| Generic Print | Symbols | Visual Representation |
|---|---|---|
| The volume of a rectangular prism can be calculated by multiplying the length, width, and height or the prim. | $V = l \cdot w \cdot h$ |  |



Full comprehension of mathematical texts includes the simultaneous interaction and understanding of all three semiotic resources (Figure 1). Additionally, mathematical language includes unique technical vocabulary along with every day English words that can take on a different meaning when used in a mathematics classroom (Fang, 2012; O'Halloran, 2015). Thus, focusing on pre-service teachers' use of language can provide insights in how they are making meaning of the data.

## MATERIALS AND METHODS

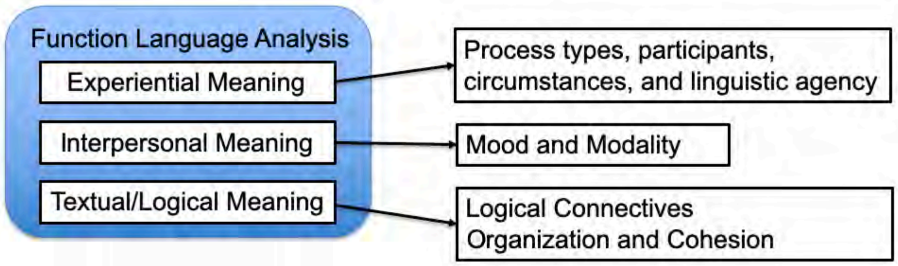
Data collection took place over three semesters in four mathematics content courses for pre-service elementary teachers. A total of 109 pre-service teachers participated and worked in groups of three to four, totaling 84 Data Stories; three per group. The semester-long group project asked each group of pre-service teachers to collect gas price data from two different gas stations three times a week (beginning, middle, and end). Each group monitored one gas station in their hometown and one located in a different region of the state. All pre-service teachers used Google Maps to monitor and collect the price changes and entered their data into a spreadsheet shared with the whole class. After ten weeks of collecting gas price data, each group had to create three Data Stories using the shared data spreadsheet including their choice of claim/question, evidence/graph, and provide reasoning/conclusions. The data collected for this pilot study included pre-service teachers' final presentation slides, observation fieldnotes from their presentations, and their final papers where they had to formally write up their Data Stories. The guiding research questions were:

(1) What affordances and challenges do pre-service elementary teachers face when reasoning quantitatively with real-world data?
(2) How does their use of language convey meaning in their developed Data Stories?

The analysis was two-fold: (1) Using function language analysis to examine the language use, and (2) coding for common themes following a grounded theory approach. For the grounded theory approach, the researcher coded the data using open coding and the constant comparison method to identify emerging themes (Corbin & Strauss, 2008). Function language analysis focuses on the language used by participants to convey meaning (Fang & Schleppegrell, 2010; Halliday & Matthiessen, 2014; Schleppegrell, 2007). It distinguishes between three types of meaning: (1) Experiential meaning, (2) interpersonal meaning, and (3) textual/logical meaning (Figure 2). Experiential meaning analysis focuses on the choice of verbs (process types), which can be action verbs or verbs that indicate relations, for example. It also examines the participants and circumstances and to whom the authors assigned linguistic agency (often the subject in a sentence). Interpersonal meaning focuses on mood and modality and what attitudes and feelings the presenters and authors convey. Finally, the third type of meaning analysis examines the organization and cohesiveness of the presentation/written account.

**Figure 2**

*The three types of meaning in function language analysis*




## RESULTS

The most interesting result regarding the function language analysis came from examining and comparing the use of process types in the final written papers. All papers seemed to fall into one of two categories: (1) Action or (2) Balance. I chose these terms since the *Action* group predominantly used action verbs and the *Balance* group included a more balanced amount of action and being/relating verbs (Table 1).

**Table 1**

*Frequencies of process types in percent*

| Process Type (Verbs) | Action Group | Balance Group |
|---|---|---|
| Action verbs | 52.6% | 42.6% |
| Being/Relating verbs | 25.6% | 40.2% |
| Auxiliary verb combined with verbs indicating sensing | 10.3% | 0% |
| Auxiliary verb combined with verbs indicating doing | 3.8% | 10.3% |
| Other | 7.7% | 6.9% |

Being and relating verbs are all forms of 'to be' and 'to have'. These are the most common ones used in formal definitions in textbooks. It provides a tone of certainty and confidence in the content. By using a balanced mix of action and being/relating verbs the *Balance* group was able to strengthen their reasoning, whereas the *Action* group missed opportunities to do so.

Another difference between these groups was evident in the combination of verbs with a leading auxiliary verb. The *Action* group mostly used auxiliary verbs, such as 'would' and could', in combination with sensing verbs, such as 'look', 'seem', or 'feel'. The *Balance* group, however, chose most combinations to be between auxiliary verbs and action verbs. By doing so, the *Balance* group's reasoning was stronger and the *Action* group's language sounded more speculative and in places doubtful due to the use of sensing verbs. This was also supported by the fact that the *Action* group used passive voice 25% of the time, compared to 4.7% in the *Balance* group's language. There was no noticeable difference regarding the linguistic agency and its participants, except for a sense of ownership. The *Balance* group's language indicated more ownership in their reasoning and their Data Stories versus more neutrality in the *Action* group's language use. Organization and cohesion were similar, most likely due to how the assignment was structured. I did not expect the papers and presentations to differ much regarding their organization. In comparing the beginnings of each paragraph, the ownership in the language of the *Balance* group was evident again (Table 2).

**Table 2**

| *Group Action* | *Group Balance* |
| --- | --- |
| Paragraph 1: "Our group…" | "A collection of data…" |
| Paragraph 2: "The ***first*** question…" | "The ***first*** question…" |
| Paragraph 3: "After forming the question…" | "To answer **our** first question…" |
| Paragraph 4: "After seeing the data…" | "To answer **our *second*** question…" |
| Paragraph 5: "We concluded from this data…" | "Answering **our *third*** question…" |
| Paragraph 6: "The ***second*** question…" | |
| Paragraph 7: "As shown in Figure 1.3…" | |
| Paragraph 8: "The ***third*** and final question…" | |

In their presentations it became quickly clear that most linguistic agency was indicated through pointing words, such as 'this', 'that', 'here', or 'there'. None of the pre-service teachers used much of the statistical terms. Some mentioned the type of graph they created, for example 'bar graph' or 'pie chart', but some just said 'graph' for all their representations.

The open coding and constant comparison of the data as an aggregate led to four potential challenges: (1) Avoidance of quantities, (2) qualitative accounts, (3) graph choice, and (4) quantitative language. All pre-service teachers avoided the use of quantities unless prompted. When prompted, most would refer to single case accounts, meaning they would, for example, simply read the quantity where the price was highest and lowest. It seemed challenging for most to reason about the data's variability and graphs as a whole. If they did try to describe the data as a whole, they used predominantly qualitative accounts. This means they would say things, like "The graph goes up and then down again" without providing quantities of range, difference, slope, or trends. How they chose their graphs seems to be guided by which ones they think are easiest to read and not which ones are best used to answer their statistical questions. Bar graphs, line graphs, and pie charts were the most used graphs. In verbal and in written language all students struggled to use quantitative language. Even though the *Balance* group's language displayed stronger reasoning skills, there is still room for improvement regarding the use of quantitative language.

## Discussion and Conclusion

The results of the pilot study align with previous work done on quantitative reasoning in 6$^{th}$ through 12$^{th}$ grade within the context of environmental literacy by the NSF MSP Targeted Partnership project: Culturally relevant ecology, learning progressions and environmental literacy (DUE-0832173). The interaction of the QRC processes was complex and the most common problem was student avoidance of quantitative information. They initially chose to give strictly qualitative accounts, more so when the information was in an equation or complicated science box model than when given in tables or graphs. The pre-service teachers also tended to avoid using quantities and would rather use pointer words, such as 'here', 'this', or 'that'.

Similar results were found by a recent Master's graduate working with the author in her research thesis project. Keenhold (2019) analyzed three sets of Data Stories created by 9$^{th}$ graders throughout one school year as part of their normal classwork in a life science classroom. To create their Data Stories students used TuvaLabs, an interactive commercial online data visualization platform. It allows students to easily explore and manipulate data by dragging and dropping variables on axes and selecting any kind of graph or statistical calculation. The follow-up qualitative interviews with purposefully selected students revealed that they also avoided using quantities unless prompted and they had difficulty explaining their reasoning. Students who were less successful in creating cohesive Data Stories tended to randomly drag and drop variables onto the axes until they liked the way the graph looked. Then they attempted to make a claim or ask a question, which often led to confusing statements.

This pilot study aimed to identify potential affordances and challenges pre-service teachers face when working with real-world data. The results were used to design a research project currently under way focusing on getting a deeper insight into their thinking. We will collect data in form of follow-up interviews and will record pre-service teachers creating a Data Story and talking us through their decision making. We hope to gain more insights into the supports pre-service teachers need to in turn help their future students become quantitative literate citizens to make informed decisions. Future generations will rely more and more on making decisions based on data and it is vital that we help them succeed.

## References


Mayes, R. L., Peterson, F., & Bonilla, R. (2013). Quantitative reasoning learning progressions for environmental science: Developing a framework. *Numeracy*, *6*(1). https://doi.org/10.5038/1936-4660.6.1.4

Mayes, R. L., Forrester, J. H., Schuttlefield Christus, J. D., Peterson, F., & Walker, R. (2014). Quantitative Reasoning Learning Progression: The Matrix. *Numeracy*, *7*(2), Article 5. https://doi.org/10.5038/1936-4660.7.2.5

American Association of Colleges and Universities (AAC&U) (2010). VALUE: Valid Assessment of Learning in Undergraduate Education. http://www.aacu.org/value/rubrics/index_p.cfm

Corbin, J. M., & Strauss, A. (2008). *Basics of qualitative research: Techniques and procedures for developing grounded theory (3rd ed.)*. SAGE Publications. https://doi.org/https://doi.org/10.4135/9781452230153

Elrod, E., & Young Park, J. (2020). A comparison of students' quantitative reasoning skills in STEM and non-STEM math pathways. *Numeracy, 13*(2), 1–12. https://doi.org/10.5038/1936-4660.13.2.1309

Fang, Z., & Schleppegrell, M. J. (2010). Disciplinary literacies across content areas: Supporting secondary reading through functional language analysis. *Journal of Adolescent & Adult Literacy, 53*(7), 587–597. https://doi.org/10.1598/JAAL.53.7.6

Garfield, J., & Ben-Zvi, D. (2009). Helping students develop statistical reasoning: Implementing a statistical reasoning learning environment. *Teaching Statistics, 31*(3), 72–77. https://doi.org/10.1111/j.1467-9639.2009.00363.x

Halliday, M. A. K., & Matthiessen, M. I. M. (2014). *Halliday's introduction to functional grammar (4th ed.)*. London: Routledge.

Keenhold, B. (2019). Assessing quantitative reasoning in a ninth grade science class using interdisciplinary Data Story assignments (2019). *Electronic Theses and Dissertations*. 2963. https://digitalcommons.library.umaine.edu/etd/2963

Madison, B. (2006). Pedagogical challenges of quantitative literacy. *Proceedings of the Joint Statistical Meetings*, 2323–2328. Alexandria, VA: American Statistical Association. www.StatLit.org/pdf/2006MadisonASA.pdf.

Mathematical Association of America (MAA) (1998). Quantitative reasoning for college graduates: A complement to the standards. http://www.maa.org/past/ql/ql_toc.html

McNeill, K. L. (2009). Teachers' use of curriculum to support students in writing scientific arguments to explain phenomena. *Science Education, 93*(2), 233–268. https://doi.org/10.1002/sce.20294

National Numercy Network (NNN) (2011). What is numeracy/QL/QR?

National Research Council. (2012). *Education for life and work: Developing transferable knowledge and skills in the 21st century*. The National Academies Press. https://doi.org/10.17226/13398

Neumann, D., Hood, M., & Neumann, M. (2013). Using real-life data when teaching statistics: Student perceptions of this strategy in an introductory statistics course. *Statistics Education Research Journal*, *12*(2), 59–70. http://iase-web.org/documents/SERJ/SERJ12(2)_Neumann.pdf

O'Halloran, K. (2015). The language of learning mathematics: A multimodal perspective. *Journal of Mathematical Behaviour 40*, Part A, 63–74. https://doi.org/10.1016/j.jmathb.2014.09.002

Schleppegrell, M. J. (2007). The linguistic challenges of mathematics teaching and learning: A research review. *Reading and Writing Quarterly, 23*(2), 139–159. https://doi.org/10.1080/10573560601158461

Shavelson, R. J. (2008). Reflections on quantitative reasoning: An assessment perspective. *Calculation vs. Context*, 27–44. https://commons.hostos.cuny.edu/ctl/wp-content/uploads/sites/26/2015/11/CalcVsContext.pdf#page=35

The National Council on Education and the Disciplines (2001). *Mathematics and Democracy* (L. A. Steen (ed.)). Princeton, NJ: The Woodrow Wilson National Fellowship Foundation. https://doi.org/10.1007/3-540-35605-3

Thompson, P. W. (2011). Quantitative reasoning and mathematical modeling. In L. L. Hatfield, S. Chamberlin, & S. Belbase (Eds.), *New perspectives and directions for collaborative research in mathematics education* (pp. 33–56).