Quantitative and Qualitative Indicators of Student Interest in STEM Careers

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Abstract: This paper reports on research on middle-schoolers attitudes towards STEM learning and careers. A questionnaire investigated 41 middle-schoolers' understanding of STEM topics related to space science and their intentions to pursue a career in this field, following two days of technology-infused eighth grade space science learning engagement activities. The methodology of this research was to identify and describe potential relationships of participants' qualitative responses and associate these with participants' quantitative responses to established right or wrong answers. The analysis method also incorporated how participants' responses to future career aspirations may be connected to the level of participants' interest and insightfulness on the open-ended question *Why are solar wind and space weather something we should think about on Earth*? Epistemic Network Analysis (Shaffer, 2017) revealed that the collective 'centers of gravity' (centroids) of these multiple sources of information were significantly ($p < .05$) different for students who planned to pursue a career in STEM versus those who did not. Implications for teacher education are discussed.

Keywords: STEM career interest, quantitative indicators, qualitative indicators

Introduction

The intention of this study was to identify if there was an interrelationship between middle school participants' attitudes towards their career plans, their responses to content knowledge (right/wrong) questions, and how they responded to a specific open-ended question within the questionnaire (*Why are solar wind and space weather something we should think about on Earth?*) – after they participated in two days of technology-infused, space science engagement activities. Students participated in an activity implemented in an eighth-grade classroom focusing on space science and then responded to a survey about space science and future career paths. The National Aeronautics and Space Administration (NASA) grant sponsoring the project seeks to inspire students to select a Science, Technology, Engineering, and Mathematics (STEM) career. A positive attitude and interest in STEM topics create a higher likelihood of student engagement (Jolly, Campbell, & Perlman, 2004). Furthermore, both proficiency and an interest in STEM fields is influential in choosing a STEM career (Bouvier, 2011; Neathery, 1997).

The primary approach of this research was to investigate whether a connection existed between qualitative data (open-ended questions) and quantitative data (pre-determined right and wrong answer choices). The aim was to go beyond the justification for a mixed-methods approach (as far as a conceptual framework). Instead, the goal was to better understand how participants' interests in space science related to their understanding of space science and vice-versa. This approach was chosen to also enable a deeper investigation of the relationship between qualitative and quantitative data. This type of analysis is done through a joint analysis of quantitative and qualitative data. While using mixed methods is often advocated for its strength in depth and variety, it is not often achieved (Gallivan, 1997). The authors intended to determine if participants' overall understanding of space science was aligned with their responses regarding their reported future career plans. Within this context, the primary research question guiding this study was:

- To what extent is there a connection between middle schoolers' interest in space science (qualitative data), their proficiency in space science content (quantitative data), and their intentions for a career in STEM (quantitative data)?

Research Methodology

Forty-one eighth-graders from a public school in a suburb of a large metropolitan area in the southern USA participated in a space science classroom activity and were subsequently given a survey regarding their understanding and attitudes/perceptions of space science. Eight quantitative items (multiple choice questions) were related to solar winds and space weather. These were topics that had been addressed during the two-days of classroom activities led by their science teacher, based on technologies and training (smartphones, drones, virtual reality) provided to the teacher by the NASA-funded project team. These items were scored *1= correct; 0= incorrect.*

An open-ended qualitative question was asked to gain insight into participant assimilation of the activity content. The item read: *Why are solar wind and space weather something we should think about on Earth?* Three researchers independently coded the open-ended item considering 1 = relevant; 0 = irrelevant. A second round of coding considered, among the answers determined relevant, a rating of: 1 = insightful; 0 = not insightful. Inter-rater reliability was confirmed by the three researchers subsequent to independent coding. Finally, participants were asked about their interest to pursue a career in STEM, which was a multiple-choice item. Three researchers independently coded participant responses to careers in STEM, considering: *1 = STEM, 0 = not STEM*). Inter-rater reliability was confirmed by three researchers subsequent to independent coding.

Epistemic Network Analysis (ENA) was chosen as a strategy to investigate possible connections between open-ended and multiple-choice items. ENA is a quantitative ethnographic technique for modeling the structure of connections in data assuming: (1) that it is possible to systematically identify a set of meaningful features in the data (items/factors); and (2) that an important feature of the data is the way that items/factors are connected to one another within epistemic events (Shaffer, 2017). By considering the frequency and co-occurrences of items/factors, ENA produces a weighted network of the participants' responses. In order to compare the networks visually and statistically, ENA analyzes all of the networks simultaneously. Table 1 summarizes the data coding procedures for the analysis of binary questions, the open-ended item, and the career choice question included in the ENA model.

Table 1
Coding system for open ended and multiple choice questions.

Question	Coded
Why are solar wind and space weather something we should think about on Earth?	1 = Relevant (e.g. *"So that we can protect Astronauts; "It can help us survive")* 0 = Not Relevant (e.g. *"The movement or shiftment"; "idk")*
Why are solar wind and space weather something we should think about on Earth?	(Second round, among the Relevant answers) 1 = Insightful (e.g. *"They can affect many important aspects of our lives such as electronics. They can also create cool auroras.")*

	0 = Not insightful (e.g. *"It could kill us"; "Storms")*
I plan to have a career in: • Science • Technology • Engineering • Mathematics • Other	1 = STEM (e.g. *"Science"; "Technology"; "Engineering"; "Mathematics"; "Other: Aeronautics"; "Other: Medical Field")* 0 = Not STEM (e.g. *"Other: Sports"; "Other: Marketing"; "Other: Hospitality as a cruise director")*

Results

ENA used the participants' career choices as a unit, comparing career choices against each other over the groups' weighted network of items (i.e. multiple-choice items and an open-ended question). Figure 1 shows the weighted network for participants who indicated their intent to have a future career in a STEM field, while Figure 2 shows the weighted network for the students who did not intend to pursue a future career in STEM.

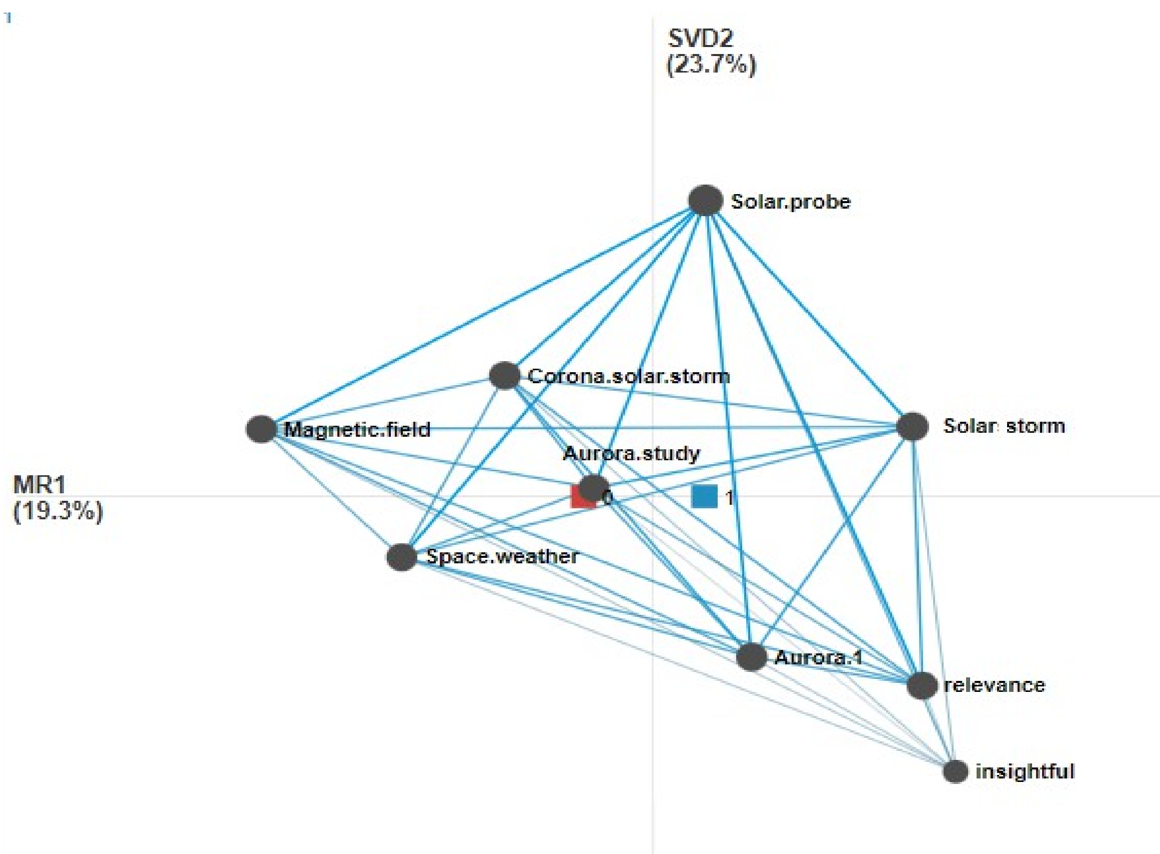

Figure 1. Weighted network for participants indicating a choice of STEM career.

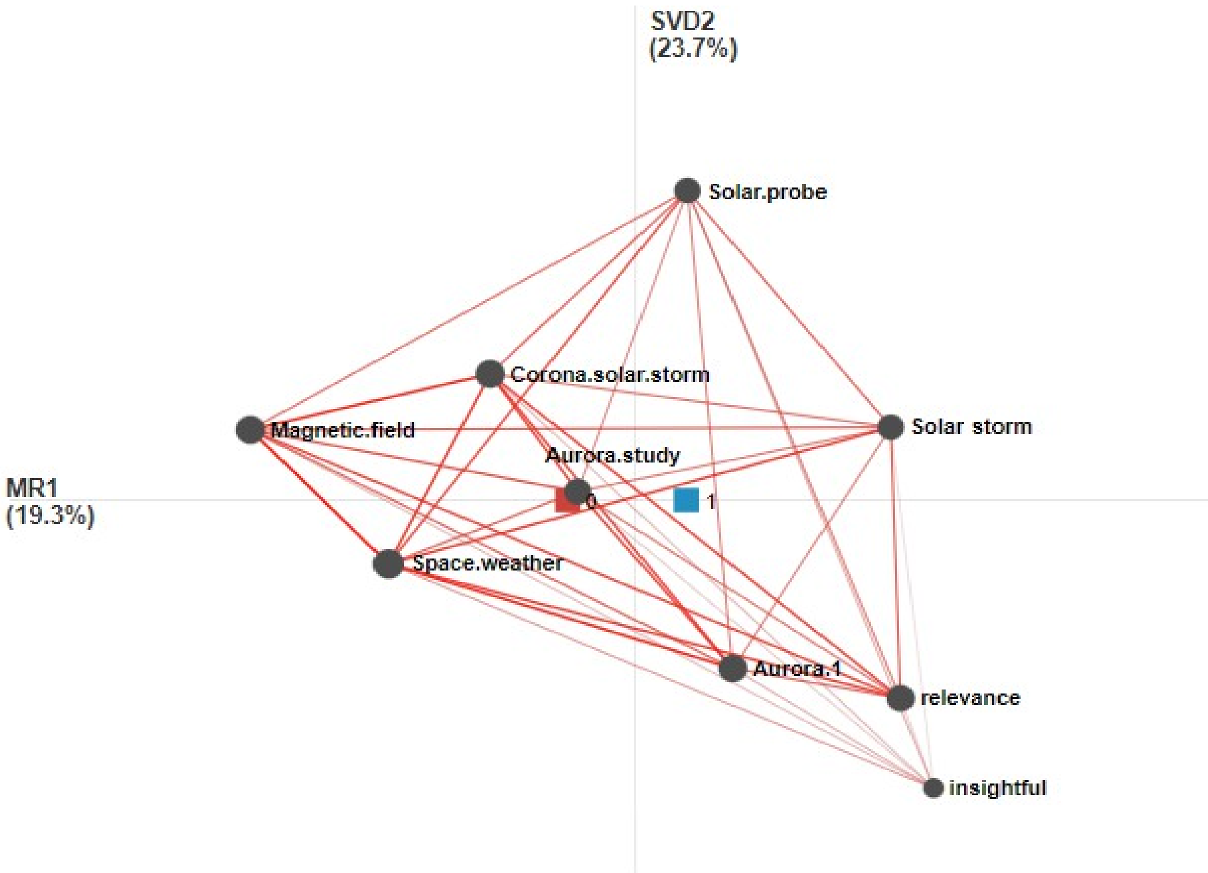

Figure 2. Weighted network for participants indicating a choice of a career not in the STEM field.

The size of the dots in Figures 1 and 2 correspond to the frequency of the answers (i.e. values of 1 in the multiple-choice items, values of 1 in the *relevant* and *insightful* ratings of the open-ended item) for each of the two groups (i.e. middle schoolers interested in STEM career, or not interested in it). Overall, the STEM-group (Figure 1) shows bigger dots, hence a higher proportion obtained a "1" on the questions than for the non-STEM group (Figure 2).

The thickness of the lines connecting the dots represents the co-occurrence of the data, implying a possible pattern between answers in the two groups. The STEM group's network (Figure1) displays thicker connections among most items, compared to non-STEM group's network (Figure 2). These findings may indicate that middle schoolers interested in a STEM career have a more sophisticated/systemic understanding of the different aspects of space science, whereas middle schoolers without a STEM interest remain unclear about connections.

Finally, the square symbol displays the centroid of each weighted network. The STEM group's centroid (Figure 1) is skewed to the right in the model. This indicates a stronger weight of nodes as the understanding of auroras, solar storms and probes; and weighted more closely aligned with relevance and insightfulness of their answers. The non-STEM group's centroid (Figure2) is skewed to the left. This indicates that in the configuration of their network, the most relevant aspects were their understanding of auroras, magnetic fields and space weather. The centroid of their core structure was also more distant from relevance/insightfulness of open-ended items.

A Mann-Whitney nonparametric test showed a significant difference in the networks of participants at their centroids, according to their choice for a STEM or non-STEM career ($p < .01$, r = 0.4). Findings suggest a significant relationship between middle schoolers' interest in space science (as investigated through the multiple-choice and open-ended items), and their possible choice of career.

Implications for Technology and Teacher Education

The integrated processing of student mastery of content knowledge, student-indicated STEM career intent, and level of richness of student responses to open-ended questions, is something that teachers do mostly automatically on a day-by-day and cumulative (across a school year) basis. Findings from this study provide confidence that teachers can trust these multi-channeled signals as indicative of a common potential path toward a trajectory for a future STEM career. As teachers pay attention to responses indicative of mastery of content, they may also be able to intricately observe an increase in interest in career paths leading to STEM careers. This prospect for combined signal processing may help reassure current and future teachers that they can be enthusiastic in their suggestions to students with early positive signs that they consider a career in STEM. It may also help guide teachers in choosing engaging activities for students possessing one or more of these attributes that appear disconnected with learning activities currently at hand.

The implications of these findings also include the use of technologies to increase student interest in subjects and encourage students to expand their knowledge and explore new STEM areas of interest. Technology integrated in the classroom activities was perceived to be engaging by students, and although the measured gain was not significant, there was a positive movement from pre to post in retrospective assessments, hinting that technologies implemented in these activities are perceived by the students to promote engaged learning. Potential further lines of research include: 1) possible causality or further interpretation of the relationship between content understanding and career choices; and 2) how a positive experience might affect their career choice after having flown a drone or completed other interactive learning activities such as exploring the solar system through virtual reality.

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