Natural Language Learning Supports to Represent STEM Graphical Materials for Students with Vision Impairments

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There are approximately 12 million people with blindness or visual impairments (BVI) in the U.S., including over 660,000 school-aged individuals.[1,2] Their success in STEM-related fields is hampered by inadequate accessible learning technologies and curricular resources, since most complex STEM information is often only available in visual format such as graphs, tables, and diagrams. As a result, teachers and BVI students are frequently left without efficient and accurate means of communicating key concepts from STEM curricula, and BVI students are thus not meeting current STEM educational standards and benchmarks. Research has shown that combinations of haptic, auditory, and language-based displays have proven effective for teaching BVI students various types of graphs and maps.[3,4.5]

My research focused on the natural language-based aspects of conveying graphical information presented in STEM graphic materials by examining how STEM instructional experts (i.e. faculty) describe mathematical diagrams using analysis techniques found in Natural Language Processing (NLP). NLP is a subfield of computer science that combines text analysis, information engineering, and artificial intelligence to help computers interpret, process, and manipulate human language (or natural language) to accomplish a variety of tasks.

In the first phase of this summer research, I learned how to utilize the Natural Language Toolkit (NLTK) in Python to perform core natural language processing, such as cleaning raw text through tokenizing, lemmatizing, stemming, normalizing, as well as classifying text, extracting information from text, building grammatical features, and analyzing sentence structure through tagging parts-of-speech (POS) of words and chunking. In the second half of my research, I designed a NLP pipeline that processed a raw description and extracted the spatial prepositional phrases used, and the most common instructional concepts embedded in the descriptions. This pipeline was used to analyze ~25 short descriptions of geometry diagrams collected from 5 experts in post-secondary STEM instruction. By looking for patterns in the spatial information and mathematical concepts communicated in those NL descriptions of geometry diagrams, we have begun to: 1) validate the most salient mathematical concepts conveyed in the graphics and images, 2) identify the specific spatial language terms and NL patterns communicated that relate to the critical conceptual information in the images, 3) investigate the similarities and differences in the expert spatial language patterns based on specific user sensory constraints (vision/non-visual modality).

Future goals of this research are to develop a controlled vocabulary to generate automated descriptions of STEM graphics and incorporate this into a remote multimodal learning support system that combines haptic, auditory, and NL supports for teaching BVI students graphical information. The broader impact of this work has the potential to pave the way for creating new learning opportunities and life-changing tools for blind or vision impaired learners, who currently have limited access to STEM graphical curriculum and are vastly underrepresented in STEM fields.

Faculty Mentor: Professor Stacy Doore
Funded by the Kibbe Science Fellowship

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