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Learning about NLP in Middle School Science

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Abstract: In this paper, we examine an inquiry-based learning approach in which students employed NLP techniques such as sentiment analysis and keyword extraction to investigate an environmental conservation issue. They used a digital platform to analyze public opinions about single-use plastic straws. The pre-test/post-test study showed significant gains across all subconstructs.

Introduction

With advances in artificial intelligence (AI), introducing K-12 students to Natural Language Processing (NLP) is necessary for preparation to interact with and possibly develop AI technologies. To prepare students to understand how this innovative technology works, our project was initiated as a participatory co-design experience between researchers and experienced teachers with a central goal to design, develop, and implement learning experiences aimed to teach middle-school students about NLP concepts integrated within science learning in an inquiry-based learning. The paper focuses on a curriculum designed to create learning experiences that introduce middle-school students to NLP while they investigate a science problem.

Theoretical Framework

Inquiry-Based Learning (IBL) is a student-centered pedagogy that puts students in control of their learning. Grounded in a social constructivist approach, IBL results in more engaged and deeper learning when compared to didactic instructional practices (Furtak et al., 2012). An IBL curriculum is organized around solving problems that are authentic and relevant to the discipline. In IBL children conduct systematic scientific investigations that involve gathering, analyzing, and interpreting data which can be addressed using technology (Duncan & Chinn, 2021) and would otherwise be challenging. Our curriculum addresses these challenges by including use of a digital platform to explore datasets and learn different NLP concepts while investigating a science problem). The following research question framed our study: How does a co-designed and enacted NLP curriculum affect student learning outcomes? More specifically, as part of the co-design process, our teacher partner wanted the students to learn and use the NLP techniques to "understand people's willingness to transition away from plastic straw use and tell a convincing story to support this transition."

Curriculum Description

Our curriculum focused on teaching NLP techniques like Keyword Extraction (KE) and Sentiment Analysis (SA) through a combination of unplugged activities and the use of a digital platform (Figure 1; Katuka et al., 2024) to explore datasets and investigate peoples' opinion on—and their willingness to—move away from using plastic straws. The curriculum did not just focus on the "what" of these techniques, but more specifically on the "how" and "why" of applying these techniques to investigate a problem. In total, the curriculum encompassed five days of instruction, which included foundations of AI, keyword extraction, sentiment analysis, and the ethical matrix. Learners completed a pre- and post- test on the first and last day respectively.

Methods

In this paper we present findings from the intervention that took place across five eighth-grade classes and included 48 consented students (60% female, 36% male, 4% non-binary) all taught by the same teacher in a school located in rural Midwestern US. Pre- and post- tests and surveys were administered at the beginning and the end of the study to measure student learning outcomes. The primary data source was the pre- and post-test instruments which were collected online using our assessment instrument. The aim was to analyze the pre- and post-test items and responses to check for the reliability of the assessment instrument and to measure student performance. We used classroom video to triangulate with the assessment results.

Figure 1
Digital Platform Results Screens

Results

Students' pre and post test results are shown in Table 1. Paired *t*-test for the overall construct of NLP showed a pre-test to post-test gain and yielded a statistically significant and a large effect size (Cohen, 1988). Statistically significant results were observed for the three subconstructs: 1) Overall Concepts of NLP, 2) Keyword Extraction and 3) Sentiment Analysis. The *p*-value for general concepts was the highest and can be attributed to the lesser number of questions in comparison to the other two subconstructs. The highest gains were observed for the second subconstruct, Keyword Extraction.

Table 1
Pre-Post Test Results

Construct (Score) *(N=48)*	**Pre-test**		**Post-test**		***p-value***	**Cohen's d**
	M	**SD**	**M**	**SD**		
Overall Concepts of NLP (2 items)	1.44	0.68	1.69	0.55	0.02	0.40
Keyword Extraction (5 items)	1.60	1.19	3.96	1.07	<0.001	2.07
Sentiment Analysis (3 items)	1.27	0.94	2.25	1.04	<0.001	0.99
Total (10 items)	4.31	1.90	7.90	2.10	<0.001	1.79

Discussion

The results indicate that the students performed well on all items and the highest gains were observed for Keyword Extraction. We conjecture that our student-centered, inquiry-based curriculum set the ground for students to learn and use different NLP techniques to investigate science problems. This was our first implementation and analysis in progress examining in detail how students engaged in inquiry-based learning, and how the digital platform may have mediated that learning and related to the observed learning outcomes.

References

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