NLP4Science: Designing a Platform for Integrating Natural Language Processing in Middle School Science Classrooms

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***Abstract*—Artificial Intelligence (AI) and Natural Language Processing (NLP) have become increasingly relevant across multiple fields, creating a necessity for young learners to understand these concepts. However, resources enabling learners to apply AI and NLP, particularly in middle school science, remain limited. To address this gap, we present the early development of NLP4Science, an interactive visualization application facilitating the integration of NLP concepts such as sentiment analysis and keyword extraction into middle school science. We adopted an iterative co-design process starting with a professional development workshop with four teachers, followed by a 2-day pilot study with 48 eighth graders, and concluding with a 5-day study involving 50 sixth graders. This poster presents an overview of NLP4Science, highlighting its key features, and sharing insights gained from the iterative design process, demonstrating the potential of NLP4Science to transform AI and NLP learning within middle school science classrooms.**

***Index Terms*—AI Education, Natural Language Processing, Middle School, Visualization**

I. Introduction

Artificial Intelligence (AI), particularly the sub-field of Natural Language Processing (NLP), is increasingly embedded into everyday life, fundamentally changing the way people interact with technology [3]. While NLP is predominantly associated with computer science, linguistics, and AI, there is a growing interest in applying NLP to other disciplines. In K-12 education, researchers have been exploring effective ways to integrate NLP into other subjects like social studies, as a way of providing the necessary knowledge and skills for young learners to better understand the application of NLP techniques in analyzing textual data [1] [2] [4]. However, due to the complexity and challenges involved in understanding and analyzing textual data, there is a need to design and develop easy-to-use educational resources and tools to attract young learners to NLP in an engaging and approachable way.

This poster describes the design and development of *NLP4Science*, a unique AI learning platform for middle school students. Through an iterative co-design process involving teachers and students, we built NLP4Science to combine AI, NLP, and middle school science education, providing an interactive experience that promotes understanding of NLP principles and supports science learning outcomes. By bridging these domains, NLP4Science aims to enhance students' knowledge of AI and NLP and foster their interest in STEM fields. The poster presents the development process, key features, classroom usability study, and the contribution of our work to integrating AI and NLP into middle school science.

II. Iterative Design and Development

A. Exploration and Initial Design Process

The design process for the NLP4Science platform followed an iterative development approach, closely collaborating with middle school teachers and students. We partnered with the teachers for weekly professional development sessions, six of which took place in the Fall of 2022 and three in the Spring of 2023. The goal was to provide science teachers with the opportunity to deepen their understanding of NLP and AI and to learn how they can incorporate these concepts into their teaching. The sessions included introduction to AI, ML and NLP and hands-on activities on fundamental NLP topics, including sentiment analysis and keyword extraction.

We conducted an extensive search to find a suitable platform for teachers to engage in hands-on NLP learning tasks during the workshops. The most promising tool we found was MonkeyLearn, an NLP platform for businesses to evaluate textual data and generate visualizations [5]. However, MonkeyLearn was primarily developed mainly for commercial use, and we were able to acquire only temporary free user accounts for the duration of the teacher workshops and it also lacked the interactive elements needed to engage young learners. Inspired by their experiences with MonkeyLearn, the teachers were able to provide insightful design ideas for a more student-friendly version that would be suitable for their classrooms.

B. NLP4Science Components

Based on the recommendations from the teachers, we designed the first prototype of the NLP4Science platform with the following key components:

1. Data Input: Users can import a new text dataset into the system in a variety of formats, such as CSV or TXT, use a previously uploaded dataset or use a direct text input to analyze text. The interface is split to accommodate both data uploading for batch classification and direct text input, providing users with flexibility in their analysis approach (Figure 2).

2. Text Preprocessing: Once the dataset is uploaded, the system automatically performs initial preprocessing to clean

and prepare the text for analysis. This might include removing duplicates, stop words, punctuation, and special characters.

3. Keyword Extraction: The platform incorporates one of the fundamental NLP techniques, keywords extraction (Figure 3), to enable users to analyze text data. It extracts the most relevant keywords from each document and presents the top keywords for each document, which can provide insights into the main topics or themes of the text. The result of the keyword extraction is displayed with a histogram, frequency table and a word cloud (Figure 4).

4. Sentiment Analysis: Sentiment analysis is an important component of NLP4Science, allowing users to identify and analyze sentiments within text data. To present the sentiment analysis results, we utilized various visualizations, including gauge chart, pie charts, and bar graphs (Figure 2).

5. Interactive Data Visualization: The results from sentiment analysis and keyword extraction are dynamically represented through various interactive visualizations like pie charts, word clouds, bar charts, and tables. For instance, clicking on a section of the pie or bar chart applies filters to all the charts accordingly, providing a cohesive data analysis experience. The word cloud provides an animated visualization, changing in response to the change in input data, which enhances the engagement factor for students.

6. Workflows (Using multiple NLP models together): Workflows enable users to apply multiple NLP approaches, such as sentiment analysis and keyword extraction, simultaneously on the same dataset. Users can identify positive sentiment tweets and apply keyword extraction to identify the main words within the tweet in a single display.

After developing the initial prototype, we asked teachers to interact with it. We conducted focus group interviews with teachers to collect their feedback on the application, which influenced subsequent designs. The teachers particularly liked the interactive features, such as workflows and data visualizations. They reported that the platform would complement their classroom instruction, providing an innovative approach to teaching challenging science concepts.

C. User Studies in Middle School Science Classrooms

In Spring 2023, we conducted a 2-day study in Indiana with 48 eighth grade middle school students and a 5-day study in Florida with 50 sixth grade middle school students to test our platform's classroom usability. To better understand the students' experience and thoughts on ways to improve the platform, we conducted semi-structured interviews with 19 students during the study in Florida. We listened to the interview recordings and extracted the most common themes from the interviews. We present a summary of the students' feedback as follows:

1. Textual Data Visualizations: The students were notably receptive to the word cloud and pie chart visualizations for keyword extraction and sentiment analysis, respectively. Approximately 83% of the students preferred the word cloud visualization for keyword extraction. They found it straightforward to discern the most frequently used words due to the proportional representation of word frequency by size. Moreover, around 95% of students favored the pie chart for sentiment analysis over histogram visualization. This visualization enabled the students to easily segregate positive, negative, and neutral statements.

2. Interface Feedback: Most students reported that navigating around the website was intuitive. However, they recommended making the user interface more accessible by enlarging the text size and eliminating collapsible menu elements.

3. Cross-disciplinary Applications: When asked about the potential use of visualizations in other subjects, five students expressed that they would utilize the word cloud in other topics like chemistry for visualizing element occurrences in various compounds. Similarly, they would utilize the pie chart in history to represent different demographic segments during a specific historical era. This showcases the potential versatility of these visualizations and their capacity to facilitate comprehension across diverse academic fields.

4. Using Real-world Data: Students used real-world data comprising of tweets about plastics in the ocean extracted from Twitter to enhance their understanding of NLP and its application in science. These practical applications of AI and NLP concepts provides students a novel way to explore topics related to science such as environmental conservation.

III. Conclusion

This poster presents NLP4Science, an interactive and educational tool for integrating NLP in science classrooms. Key features of NLP4Science, such as sentiment analysis, keyword extraction, interactive data visualizations, and workflow creation, are implemented to foster deeper understanding and interest in AI and NLP for middle school students. By synergizing the fields of AI, NLP, and middle school science education, it strives to endow students with fundamental AI and NLP knowledge, thereby boosting their interest and proficiency in STEM disciplines. The findings from the user studies with teachers and students affirm the potential of NLP4Science as a practical, engaging platform for teaching AI and NLP concepts in middle school science classrooms.

Future work will include the implementation of a data cleaning module for enhanced transparency during pre-processing, the development of a comparative feature for evaluating the performance of various NLP models, and the introduction of an interactive supervised learning module where students can engage in hands-on data tagging. The NLP4Science platform offers a promising opportunity for integrating NLP into middle school science classrooms, thereby promoting students' interest in AI and STEM fields.

IV. Acknowledgement

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APPENDIX

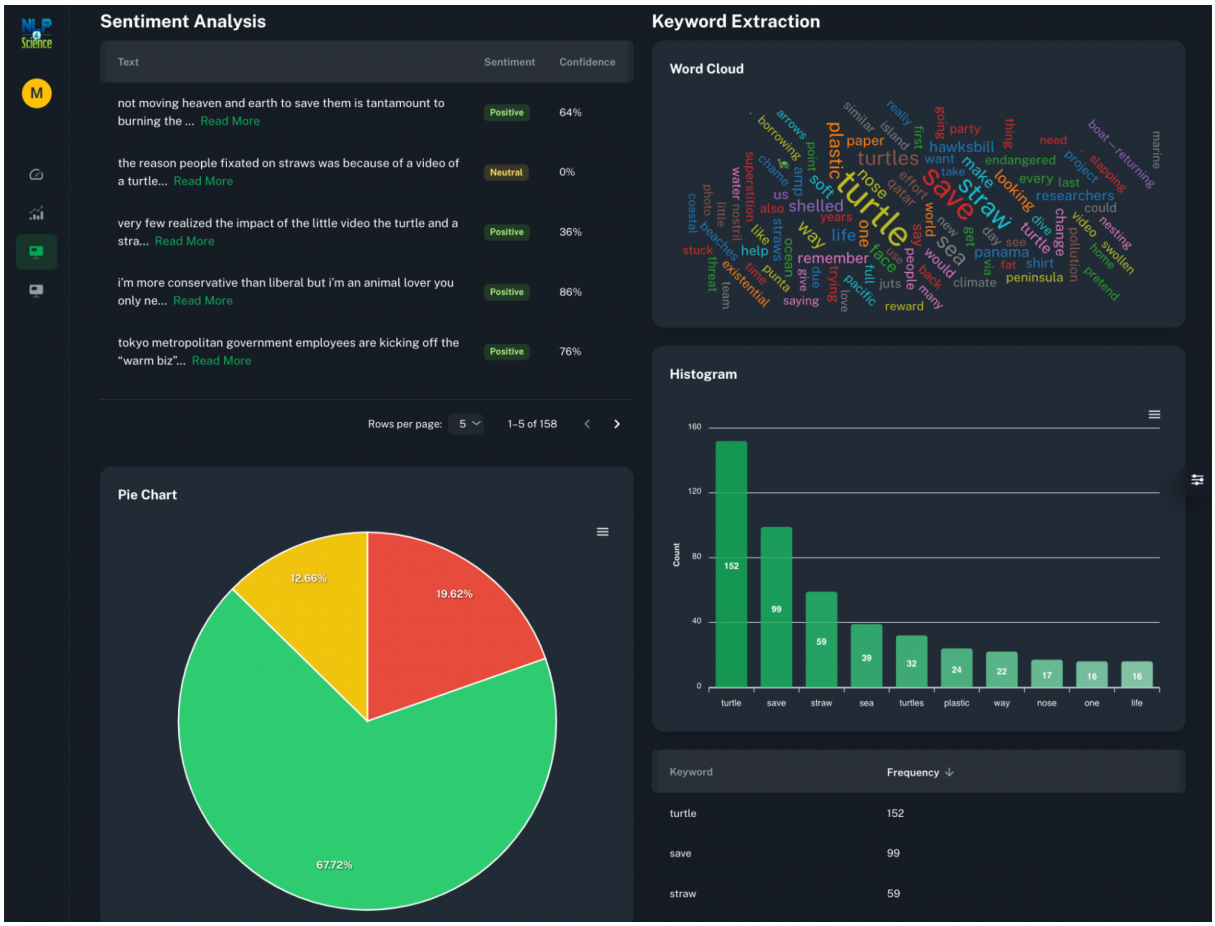

Fig. 1. **Workflow:** This figure demonstrates the interactive workflow view, which shows a combination of keyword extraction and sentiment analysis

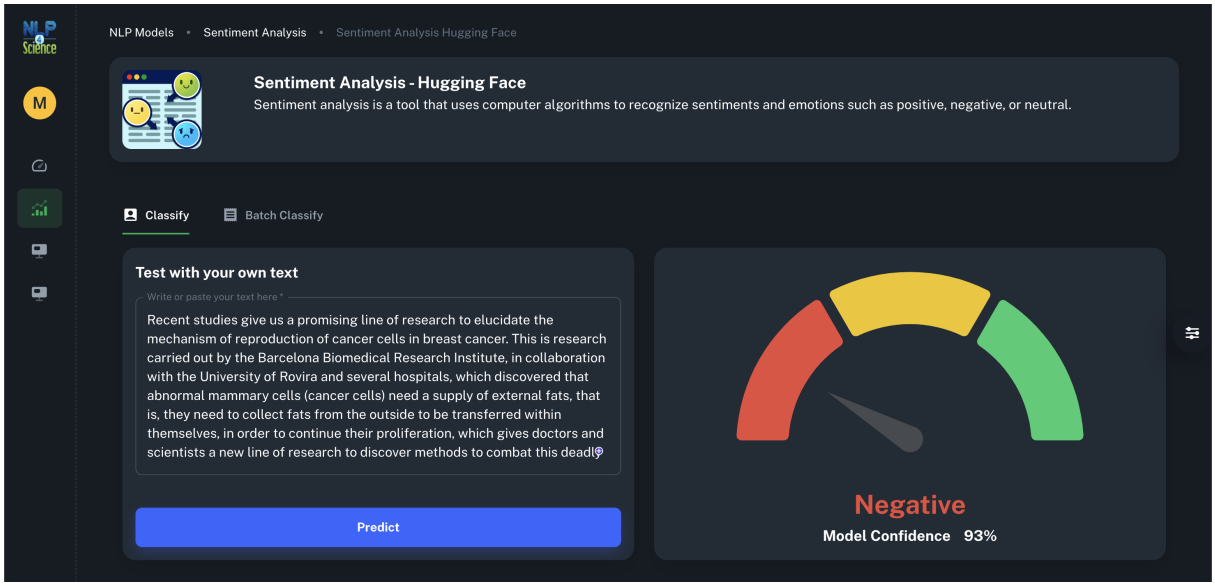

Fig. 2. **Sentiment Analysis Visualization:** This gauge-style visualization illustrates the sentiment analysis results of a given text. The gauges represent the degrees of negative, positive, and neutral sentiments detected in a given text.

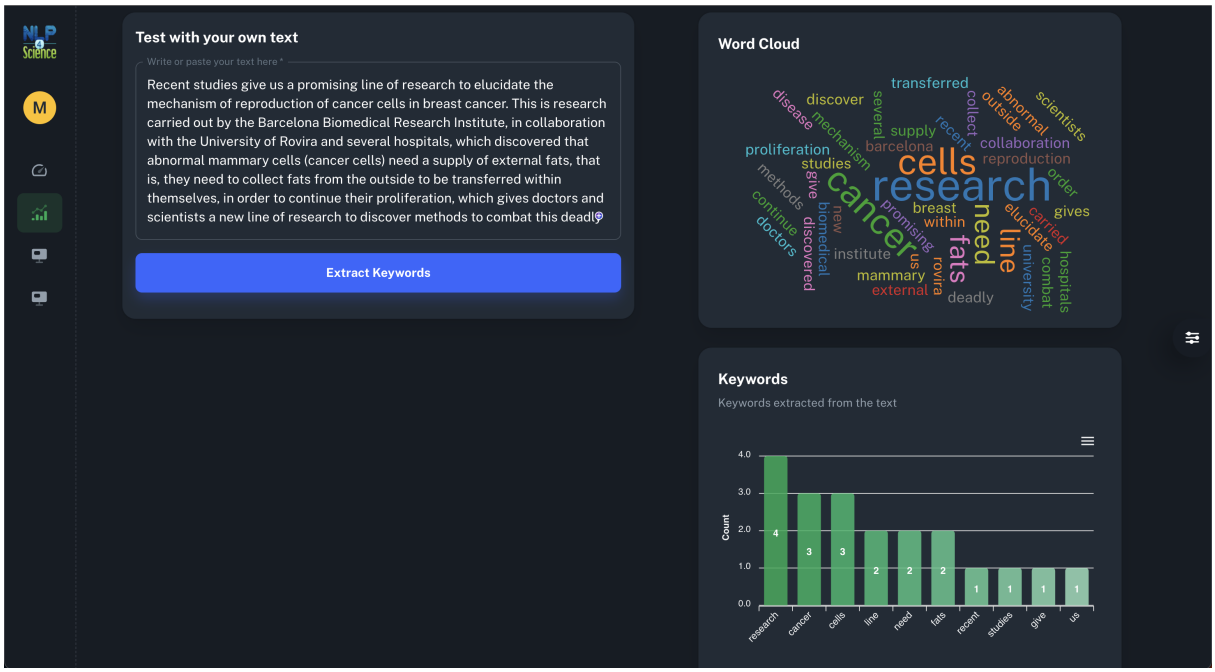

Fig. 3. **Keyword Extraction (using a raw text input) Visualization:** This figure presents the results of a keyword extraction. In the word cloud visualization, the size of each word corresponds to its frequency within the text. The histogram shows the top 10 most frequent words, and frequency table displays the counts for each keyword

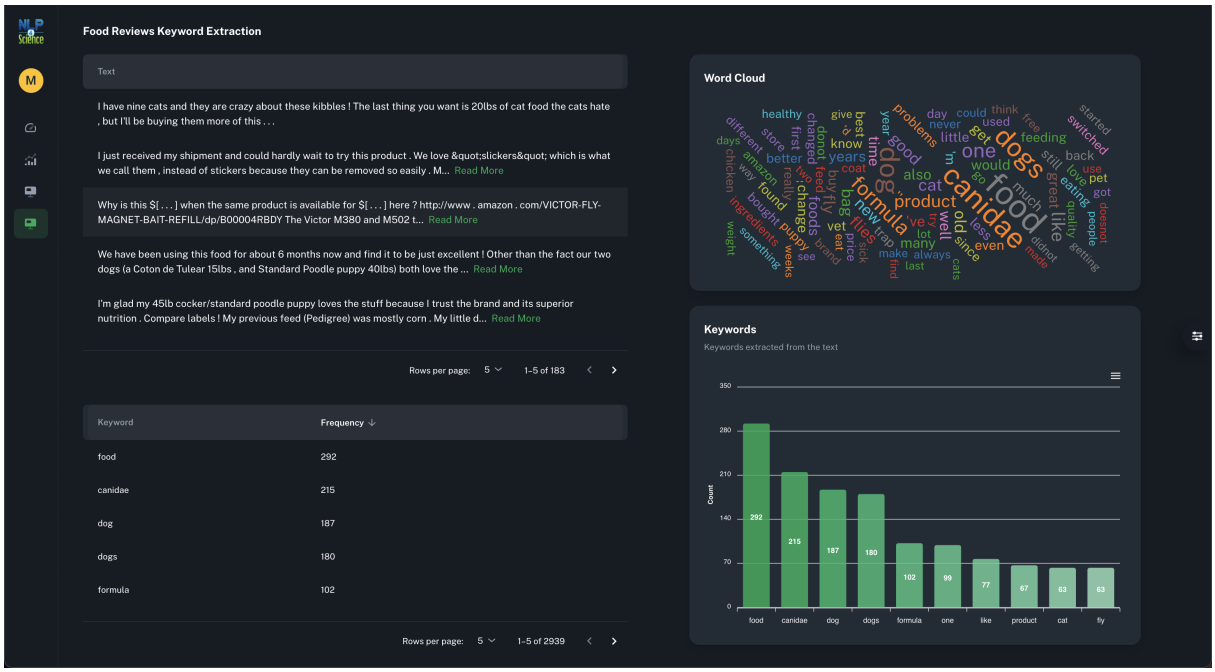

Fig. 4. **Keyword Extraction (using a text file) Visualization:** In this sample project, the student uploaded a CSV file. The actual text data is shown on the top left.

REFERENCES

[1] Jonathan Grudin and Richard Jacques. Demystifying ai: A comprehensive guide to understandable artificial intelligence. *Computer*, 52(3):68–78, 2019.

[2] Arthur Hjorth. NaturalLanguageProcesing4All: -A Constructionist NLP tool for Scaffolding Students' Exploration of Text. In *Proceedings of the 17th ACM Conference on International Computing Education Research*, pages 347–354, 2021.

[3] Michael I Jordan. Artificial intelligence — the revolution hasn't happened yet. *Harvard Business Review*, 2018.

[4] Irene Lee, Safinah Ali, Helen Zhang, Daniella DiPaola, and Cynthia Breazeal. Developing middle school students' ai literacy. In *Proceedings of the 52nd ACM Technical Symposium on Computer Science Education*, SIGCSE '21, page 191–197, New York, NY, USA, 2021. Association for Computing Machinery.

[5] MonkeyLearn Team. MonkeyLearn: Text Analysis with Machine Learning, 2022.