Investigating Patterns of Tone and Sentiment in Teacher Written Feedback Messages

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Abstract. Feedback is a crucial factor in mathematics learning and instruction. Whether expressed as indicators of correctness or textual comments, feedback can help guide students' understanding of content. Beyond this, however, teacher-written messages and comments can provide motivational and affective benefits for students. The question emerges as to what constitutes effective feedback to promote not only student learning but also motivation and engagement. Teachers may have different perceptions of what constitutes effective feedback utilizing different tones in their writing to communicate their sentiment while assessing student work. This study aims to investigate trends in teacher sentiment and tone when providing feedback to students in a middle school mathematics class context. Toward this, we examine the applicability of state-of-the-art sentiment analysis methods in a mathematics context and explore the use of punctuation marks in teacher feedback messages as a measure of tone.

Keywords: Online learning platforms · Feedback Messages · Mathematics Learning · Sentiment Analysis · Tone Analysis.

1 Introduction

Feedback is an essential part of student learning. Whether in the form of simple indicators of correctness or more descriptive textual comments, feedback can help guide students' understanding of instructional content, offer solutions to fix errors in their work, and provide motivational and affective/emotional benefits to the students, improving their overall learning experience. Some teachers may prefer to use a more directive approach when giving feedback, while others may take a more supportive approach. Additionally, the approach used by teachers may differ based on different groups of students, such as the students who are struggling versus those who are exceeding in their given task.

Researchers in the past have reported on meta-analyses exploring the effects of Feedback Interventions (FI) on performance, with mixed results suggesting that the context, content, and structure of feedback impact its effectiveness [7,

9, 13, 11, 12, 1, 14]. Feedback can often impact students' reactions and behavior when working on activities[16, 6, 3, 2]. Student perception plays a crucial role in the effectiveness of the feedback; as reported by Weaver and colleagues [15], students who perceived feedback as vague or lacking content exhibited little benefit as compared to students who recognized feedback as detailed and constructive. Studies, such as [10], discuss that providing feedback in an online setting is an art and that there are various best practices, including generating positive and/or balanced feedback (positive, negative, then positive).

In designing tools to support the provision of feedback for teachers in the context of online learning platforms, it is important to understand not only how to structure feedback so that it is effective in improving student learning, but that feedback also needs to match the teacher's voice so that they want to utilize it. Teachers may have different communication styles, and they tailor their approach of feedback to meet the needs of their students. Toward this, understanding the sentiment and tone carried by teachers' feedback to students is necessary. While prior works have examined the analysis of sentiment in various domains (e.g. [5]), this work observes a subtle distinction between this concept and that of tone. While sentiment refers to the emotional valence of the text itself, we define tone as the intended emotional response to the feedback. Consider, for example, a teacher who provides the feedback of "Come on, I know you can do this!" to a student who responded to a problem with an answer such as "I don't know". While, without context, the sentiment of the text itself is arguably positive, in reality, the tone is more critical in nature.

The study aims to investigate trends in teacher-written feedback messages in a middle school mathematics context through the sentiment and tone of these comments. Through examination of the applicability of state-of-the-art sentiment analysis methods and exploration of the use of punctuation in teacher feedback messages, this study aims to gain a deeper understanding of how teachers choose to structure their feedback. By examining the trends in teacher-written feedback messages, we hope to gain a better understanding of the impact of feedback on student learning in mathematics and inform recommendations for best practices in the delivery of feedback.

2 Dataset

The study uses a teacher feedback dataset taken from ASSISTments[8], consisting of student answers to open-ended math problems and teacher-authored textual feedback messages. The data includes 8,307 open-ended mathematics problems and 1,93,187 total responses given by 23,853 distinct students and the corresponding feedback message given by 1,296 different teachers. The dataset also consists of numeric scores on a 5-point integer scale ranging from 0 to 4 provided by teachers through a manual scoring process as part of normal classroom instructional practices.

Table 1: Most common mathematical words selected from the top 100 frequent words in the teacher feedback dataset, categorized by sentiment.

Sentiment	**Mathematical Words**
Positive	value, side, multiply, explanation, ratio, equal, enter, label, length, solve, congruent, scale
Neutral	answer, number, line, point, +, -, equation, explain, angle, graph, question, divide, rotate, unit, slope, degree, reflect, factor, area, solution, first, segment
Negative	triangle, mean, reason, measure, problem

3 Sentiment Analysis in Mathematics

Toward understanding the sentiment of teacher-written feedback messages in mathematics, we conduct a sentiment analysis to infer whether a given feedback is 'Positive', 'Negative', or 'Neutral' using a fine-tuned downstream version of the *'bert-base-uncased'* model [4]. This is a transformer-based model trained over a generic dataset of classified text. As most of the commonly-used sentiment analysis methods are based on social media data, we hypothesized that this model being trained on a generic dataset had a higher likelihood of generalizing to our application domain (a hypothesis that will be tested).

We first seek to validate the use of a pre-trained sentiment model for use on our dataset by examining the impact that mathematical terminology may have on model estimates. A potential shortcoming of automated sentiment analysis methods is that such models may be confused by domain-specific language; this poses a potential risk in misinterpreting results. For example, words such as "power", "addition", and "multiply" may be associated with positive valence in certain contexts, but likely represent neutral mathematics concepts when used in the context of teachers' feedback messages.

Considering the potential effect of some of these mathematical terms on the sentiment, in our next step we remove these common math words before predicting the sentiment of the feedback messages. For this, we first identify the top 100 most-frequent words from all the teacher feedback dataset, and from this list, we extract only the mathematical terms. Table 1 lists the common math terms extracted as a part of this step and categorizes them based on their predicted sentiment from the pre-trained model. We stem each of the extracted words to their base form (eg. multiply, multiplied, etc would be stemmed to multipli) and then exclude these terms from the feedback before finally applying the sentiment prediction model. Table 2 presents some examples of teacher feedback messages and their resulting sentiment with and without the mathematical words.

Table 2: Some examples of teacher-written feedback messages, predicted sentiment with and without math terms, and the corresponding scores from teachers.

Teacher-written Feedback	**Sentiment w Math**	**Sentiment w/o Math**	**Score**
[REDACTED] - you were doing a great job. Please don't enter nonsense responses.	Positive	Positive	0
I like that you labeled your angles with 3 letters. Angle CDM is 90 degrees. Angle DMC is 63 degrees. Together they make 153 degrees. Remember that complementary refers to 2 angles whose sum is 90. Can you find 2 angles that would add up to 90?	Positive	Positive	2
congruent	Positive	**Neutral**	3
Labels!	Positive	**Neutral**	4
Perfect Answer!!	Positive	Positive	4
-2; lack of effort in completing cool down.	Negative	Negative	0
This will cost you 2 points for Unit 5, lesson 8.	Negative	Negative	0
No - x would have to be negative.	Negative	**Neutral**	2
When we ignore the 5 or 6, we reduce the number outcomes down to 4 instead of 6. That way P(score)=1/4 and P(not score)=3/4.	Negative	**Neutral**	2
Label your units please	Negative	Negative	3
Sorry this was not working for you!	Negative	Negative	4

4 Exploring Tone using Punctuation Marks

The use of punctuation marks within a text of writing can reveal important cues about the tone and sentiment expressed in the text. For example, exclamation '!' marks are used within a piece of writing to indicate the writer's excitement, happiness, and sometimes, conversely, anger. Use of question '?' marks, in the direct sense, indicate a question, but can also be a rhetorical approach to inspire thought or convey discontent (e.g. "???").

For this, we explore the commonly used punctuation marks within the teacher written feedback messages. The top 5 commonly used punctuation marks are: '.', ',', '?', '!' and ')' respectively. Out of these, we are interested in the use of question marks and exclamation marks as these punctuation marks can tell us more about the tone of a feedback message. Also, we understand that the use of ')', may be used by some teachers to express a smiling emotion, and in some other cases may be used in the form of mathematical expression. Question marks and exclamation marks are seen in about 12% and 15% of the feedback data respectively. Table 3 shows the use of some of these common punctuation marks across the feedback messages. Based on this, question marks are more common within the feedback that is given to students who received a score of 0 to 3, and

Table 3: Percentage distribution of common punctuation marks in feedback messages across score categories

Score	**?**	**!**	**:) :-)**
0	11.61%	3.36%	0.29%
1	16.38%	2.59%	0.54%
2	18.43%	3.48%	0.45%
3	17.19%	5.69%	1.10%
4	2.97%	41.12%	4.55%

is less common among students who received a full score of 4. On the contrary, exclamation marks are used both to express positive emotions like happiness and sometimes negative emotions like anger, we hypothesize that teachers use them differently based on correctness. Based on Table 3, we see that exclamation marks are most common in feedback given to students who received a full score on the problem. Although smiley emoticons are not seen frequently within the feedback dataset, it is used more frequently to express happiness when a students get a full score.

5 Conclusion

This paper aims to explore trends in teacher sentiment and tone when writing feedback messages to students in a mathematics class. We use a generic sentiment analysis method and explore how such methods can be applied to a mathematical context. Through conducted analyses, we find that sentiment and student performance metrics are correlated, but also find potential risks in utilizing pre-trained sentiment models without considering validity within the context of application; in this regard, the use of punctuation actually offers a simpler means of interpreting the valence of teacher feedback when considered in conjunction with provided scores. The study however has several limitations which should be noted. First, we addressed the issue of generalization of the pre-trained sentiment model by omitting mathematics terms, while future work could focus on retraining or fine-tuning such models for application within mathematics domains. Also in the next steps, we could explore using other ways to measure tone in feedback, through the use of various natural language processing techniques. This work may be further expanded by exploring the use and effectiveness of different feedback writing styles based on tone and sentiment across various students in a mathematics classroom.

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