Measuring and Visualizing Metadiscursive Markers in Student Writing

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Abstract

Metadiscourse markers (MDM) are words or phrases that help connect and organize ideas or attitudes in genre-specific written discourse. Using rule-based or dictionary-based techniques, the presence of MDM may be confirmed and their distribution measured to help deconstruct genre-specific discourse. Such a deconstruction may help identify "something" about knowledge sharing, learning, topic or authorship attribution, and knowledge symmetries (or asymmetries) in cross-sectional or longitudinal analyses of writing.

In this paper, we introduce a methodology consisting of data processing and visualization that is at the intersection of genre analysis, statistics, dimensionality reduction, and natural language processing. We apply this methodology to publicly available newsgroup data which is pre-labeled by topic to demonstrate that MDM distribution may be used to extract a visual dichotomy in the text structure belonging to different topics. In other words, text data pertaining to a specific topic have similar MDM distribution characteristics. In the future we will apply this methodology to labeled reflections authored by n students in an Engineering mechanics classroom that is infused with activities that involve an Entrepreneurial mindset (EM) to identify if MDM distribution and clustering indicates the presence of EM.

Future work will also include exploring the confluence of MDM and rhetorical moves, since we believe this will support identifying EM, metacognition, and/or the achievement of a threshold skill. As part of this broader goal, we will create web-based digital tools to assess student writing and statistical regression models that would automatically classify the presence of an Entrepreneurial mindset in student writing.

Introduction

Metadiscourse markers (MDM) are words or phrases that signal the structure or organization of the text to help forge a relationship with the reader and "offer a framework [1, 2] for understanding communication as a social engagement." They signal the writer's views through hedges (almost, believed/believed to be, doubt, generally . . .), attitude markers (surprisingly, interestingly, disappointing . . .), emphatics (amazingly, appropriately, correctly . . .), etc. Metadiscourse can be an indicator of the relative strength of affective elements of reflection: awareness and control of feelings that accompany certain situations.

Hardy et al. [3] argue that undergraduate writing has not been a focal point for discourse communities because undergraduates have yet to 'learn to play the game'. Pennebaker et al. [4, 5] suggest that metadiscourse markers, which account for a small percentage of our vocabulary but are used quite often, may be used as a signature of *personality* and *affect*. Based on this and the contention of Hyland et al. [1] ("metadiscourse is a key dimension of genre analysis to show how language choices reflect different purposes of writers, and their psychological state"), we speculate that metadiscourse analysis could be a valuable tool for understanding the development of undergraduate writing skills.

To the authors' knowledge, there are no metadiscourse analyses that focus on identifying metacognition, the achievement of threshold skills, or identifying an Entrepreneurial Mindset (EM), in engineering education. As per the Kern Entrepreneurial Engineering Network, EM is a curious, connected, and value-creation way of thinking to solve problems. We believe that metadiscourse analysis may be used to identify the presence of metacognition by looking for explicit statements or behaviors that suggest the degree to which the speaker or writer is reflecting on their own cognition, skills, or mindset, such as:

1. "I [Person Marker] applied the equations to solve this problem": In this statement, the speaker or writer uses the Person Marker, "I" in their reflection.
2. "I now know [Emphatic] that the important difference between the two scenarios is that one [Frame Marker] needs a simple equation while the other clearly [Emphatic] requires a modified equation.": In this statement, the speaker or writer uses the Person Marker, "I," and the Emphatics, "know" and "clearly" while using a Frame Marker "one" to structure their reflection.

Further, we believe that metadiscourse analysis-driven feedback to students would allow them to make more effective arguments and to gain an appreciation of the importance of context when communicating.

Research question

We developed this research question as part of the ASEE Archival Publications Authors workshop (2022): "What is the distribution of rhetorical moves (RM) and metadiscourse markers (MDM) in student reflections in an engineering course infused with EM activities?" Our multi-year, broader research question is composed of two tasks: 1. to

determine the rhetorical moves and metadiscourse markers in student writing associated with EM and 2. to create a computational tool to identify, count, and visualize the distribution of metadiscourse markers. These tasks can evolve independently.

In this paper, we present the latter part, viz., a computational tool for identifying and visualizing the distribution of metadiscourse markers. This tool is first demonstrated by visualizing metadiscourse markers or ratios of MDM or counts of MDM for a large corpus (11,000+ documents) in a matter of seconds. After this, the tool is applied to student reflection data for preliminary visualization. This tool can be expanded to allow statistical fits and machine learning models in the future. Once we have completed labeling student writing (or other forms of discourse) for the presence of EM, our tool can be trained as a machine learning classifier. Publicly available newsgroup data was chosen as a test case because it has significant data density of over 11,000 conversations across 20 different topics thereby allowing us to test our code. While we do not yet have sufficient student reflection data to draw definitive conclusions, our preliminary results suggest that this framework has the potential to be valuable for metadiscourse analysis. Specifically, our analysis suggests that the framework can be used to identify different types of metadiscourse, track their use over time to identify the emergence of EM or other state, and compare the use of metadiscourse across different groups of students.

The relevance of student reflection for teaching and learning

Reflections are commonly used as a tool for students to communicate their learning to instructors. Investigations on the utility of reflections in engineering education are firmly grounded in the theory of metacognition. Additionally, reflections provide opportunities for students to express their emotional responses to situations. Similar to metacognition, grappling with these affective elements can raise self-awareness and lead to better control of emotions [6].

Reflections solicited from engineering students have been well regarded as an important element in student learning, and their professional development. The prominent main reasons for soliciting reflections are: To support outcome-based assessment consistent with ABET accreditation [7–9], an instrument to promote metacognition by allowing students to reflect on their progress [10–19], promote professional values and skills [20–23], boost academic achievement [20], encourage making meaning out of experiences [20, 21].

MDM Identification in newsgroup data and student reflections

In this preliminary work, a dictionary-based MDM identification program is developed in Python. The nine classes of MDM are tabulated in Table 1. Using a home-grown Python program, we applied the MDM dictionary to two datasets: openly available newsgroup data and student reflections submitted to an engineering mechanics course. Our objective for this preliminary study was to visualize MDM distribution in these datasets. These two chosen datasets are described in the following paragraphs.

The newsgroup dataset provided by the Python package scikit-learn [24] is used for this

preliminary analysis. Newsgroups are an aggregation of discussions of participants in certain topics of self-selected interest. They are a rich source of metadiscourse data because they are public, and they involve a large number of participants. This makes them ideal for studying how people interact with each other and how they use metadiscourse to communicate their ideas (reflections, responses, arguments, rebuttals, expositions, etc.). This dataset contains 11,314 total conversations distributed unequally under the following twenty different topics categorized as: alt.atheism, alt.atheism, comp.graphics, comp.os.ms-windows.misc, comp.sys.ibm.pc.hardware, comp.sys.mac.hardware, comp.windows.x, misc.forsale, rec.autos, rec.motorcycles, rec.sport.baseball, rec.sport.hockey, sci.crypt, sci.electronics, sci.med, sci.space, soc.religion.christian, talk.politics.guns, talk.politics.mideast, talk.politics.misc, talk.religion.misc.

In the mechanics course, students were asked to respond to reflection questions prompting them to consider their experiences in course material. The reflection prompts are:

1. In 250 words or less, reflect on this week's content (lecture videos, in-class discourse). Clearly state (1) what part challenged you (what was a roadblock), (2) how you overcame this challenge, (3) how overcoming this challenge has reinforced your understanding,
2. In 250 words or less, reflect on this week's homework assignment or practice quizzes. Clearly state (1) what part challenged you (what was a roadblock), (2) how you overcame this challenge, and (3) how overcoming this challenge has reinforced your understanding, and (4) how this content relates to you personally, and
3. What is something that is not directly related to this week's content that you hope you will learn during this course? Be as concise as possible. This is not a place for feedback about the course.

Our metadiscourse analysis is limited to the second question as it generated the greatest reflection data-density.

Choice of metadiscourse markers for this preliminary study

We performed two preliminary analyses: first we compute and visualize the ratios of select metadiscourse markers and next we count and visualize a single metadiscourse marker:

1. Newsgroup dataset:
   (a) Ratio of Emphatics to Evidentials: We performed metadiscourse analysis of the newsgroup data by visualizing the ratio of "Emphatics to Evidentials." Our initial hypothesis is that scientific discourse would have a stronger dependence on Evidentials rather than Emphatics while discourse on recreational sport may have a stronger emotional response with a stronger dependence of Emphatics to Evidentials.
   (b) Person Markers: Since our target analysis (although preliminary in this paper) are reflective essays, we chose to illuminate the nature in which these reflective

Table 1: Nine classes of MDM

Marker	Dictionary
PersonMarkers	"i", "we", "me", "mine", "our", "my", "us", "we", "you", "your", "yours", "your's", "ones", "one's", "their"
AnnounceGoals	"purpose", "aim", "intend", "seek", "wish", "argue", "propose", "suggest", "discuss", "like", "focus", "emphasize", "goal", "this", "do", "will"
CodeGloss	"example", "instance", "e.g", "e.g.", "i.e", "i.e.", "namely", "other", "means", "specifically", "known", "such", "define", "call"
AttitudeMarkers	"admittedly", "agree", "amazingly", "correctly", "curiously", "disappointing", "disagree", "even", "fortunate", "hope", "hopeful", "hopefully", "important", "interest", "prefer", "must", "ought", "remarkable", "surprise", "surprisingly", "unfortunate", "unfortunately", "unusual", "unusually", "understandably"
Endophorics	"see", "note", "noted", "above", "below", "section", "chapter", "discuss", "e.g.", "e.g", "example", "chapter", "figure", "fig", "plot", "chart"
Hedges	"almost", "think", "apparent", "apparently", "assume", "assumed", "believe", "believed", "certain", "extent", "level", "amount", "could", "couldnt", "couldn't", "doubt", "essentially", "estimate" "frequent", "frequently", "general", "generally", "indicate", "largely", "likely", "mainly", "may", "maybe", "mostly", "might", "often", "perhaps", "possible", "probable", "probably", "relative" "seem", "seems", "sometime", "sometimes", "somewhat", "suggest", "suspect", "unlikely", "uncertain", "unclear", "usual", "usually", "would", "wouldnt", "wouldn't", "little", "bit"
Emphatics	"actually", "always", "certainly", "certainty", "clear", "clearly", "conclusively", "decidedly", "demonstrate", "determine", "doubtless", "essential", "establish", "indeed", "know", "must", "never", "obvious", "obviously", "prove", "show", "sure", "true", "absolutely", "undoubtedly"
FrameMarkersStages	"start", "first", "firstly", "second", "secondly", "third", "thirdly", "fourth", "fourthly", "fifth", "fifthly", "next", "last", "begin", "lastly", "finally", "subsequently", "one", "two", "three", "four", "five"
Evidentials	"according", "cite", "cites", "quote", "establish", "established", "said", "say", "says", "argue", "argues", "claim", "claims", "believe", "believes", "suggest", "suggests", "show", "shows", "prove", "proves", "demonstrate", "demonstrates", "literature", "study", "studys", "research"

Person Markers crept into the newsgroup dataset so that similar analysis may be applied to student reflections. Person Marker distribution varied between genre.

2. Student reflections (preliminary analysis of limited data):

   (a) Ratio of Emphatics to Hedges: Since reflections were used to explore students' experience with the course content and to share insights about learning, students may use emphatic metadiscourse to emphasize their own thoughts and feelings and Hedges to identify their limitations, discomfort, or lack of comprehension of the content.

   (b) Person Markers: Since this preliminary analysis surrounded reflective essays, it made sense to track the usage of a reflective metadiscourse element, viz., the Person Marker.

Preliminary results – newsgroup data

We first applied our MDM Python program to publicly available data from newsgroups. We categorized a subset of these discussions into two broad genre: Sports (rec.sport.baseball, rec.sport.hockey) and Science (sci.crypt, sci.electronics, sci.med, sci.space). For the newsgroup data, we first focus on the ratio of Emphatics to Evidentials. Our hypothesis is that scientific discourse would have a stronger dependence of Evidentials rather than Emphatics while discourse on recreational sport may have a stronger emotional

Table 2: Newsgroup data: The median value of ratio of Emphatics to Evidentials compared by word-count across two genre of discourse: scientific and recreational sport.

	nWords between 10 - 100	nWords between 100 - 500	nWords between 500 - 1000	nWords between 1000 - 3000
sci.med	0.11	0.06	0.05	0.04
sci.electronics	0.13	0.06	0.03	0.04
sci.crypt	0.11	0.05	0.03	0.04
rec.sport.baseball	0.125	0.05	0.03	0.03
rec.sport.hockey	0.125	0.05	0.04	0.02

Table 3: Student reflection data: The median value of Emphatics to Hedges ratio for the second prompt.

Week number	**Total number of entries**	**Median value of Emphatic to Hedge ratio for Prompt 1**	**Juncture of the semester**
1	37	0.13	First week of class.
2	35	0.09	
3	35	0.12	
4	30	0.15	After review for exam 1.
5	4	0.08	After exam 1.
6	32	0.11	
7	31	0.12	
8	4	0.11	After review for exam 2.
9	3	0.07	After exam 2.

response with a stronger dependence of Emphatics to Evidentials. Further, we bin the discussion responses by word count range: 10-100 words, 100-500 words, 500-1000 words, and 1000-3000 words. These bins have been chosen arbitrarily. The median values of the ratio of Emphatics to Evidentials are tabulated in Table 2

In addition to tabulating the ratios of metadiscourse markers, next we visualized (Figure 1) the kernel density estimate of the normalized count of Person Markers in "sports" and "science." The standardization and kernel density estimate plot numerically and visually reduces the metadiscourse marker count in different genre to the same scale thereby allowing us to perform an "Apples to Apples" comparison. Person markers were chosen since they could be considered a reflective component.

Preliminary results – Student-submitted weekly reflection

Nine weeks of data (211 responses in total) was available for the second prompt. Using the metadiscourse marker dictionary, the median values of the emphatics to hedges ratio was computed. The emphatics to hedges ratio was chosen as this was the only ratio that had non-zero values for at least 8 of the 9 weeks for either prompt. The results are tabulated in Table 3.

In addition to tabulating the ratios of metadiscourse markers, we visualized (Figure 2) the kernel density estimate of Person Markers students' reflections. Person markers were chosen since they could be considered a reflective component.

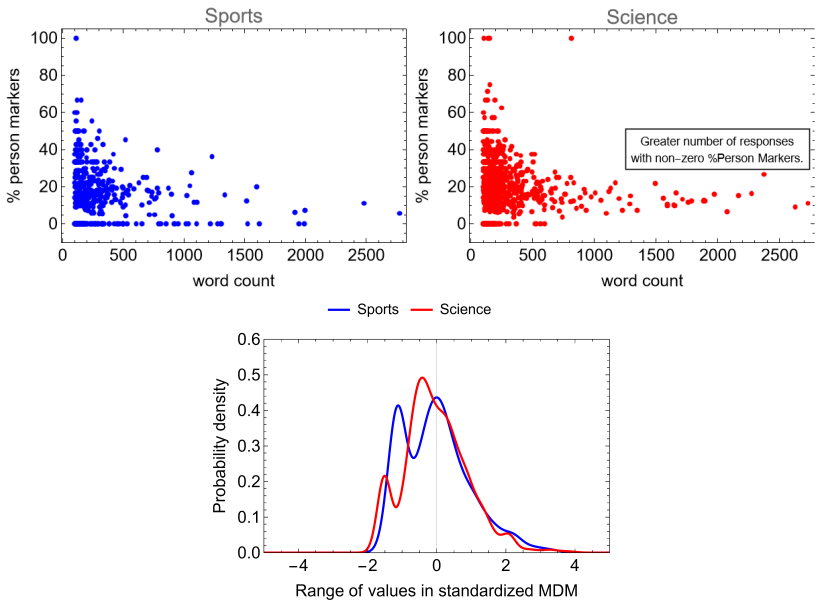

Figure 1: The percentage of of Person Markers vs. word count and a comparison of kernel density estimate (KDE) plot of standardized person markers in sports discourse versus scientific discourse.

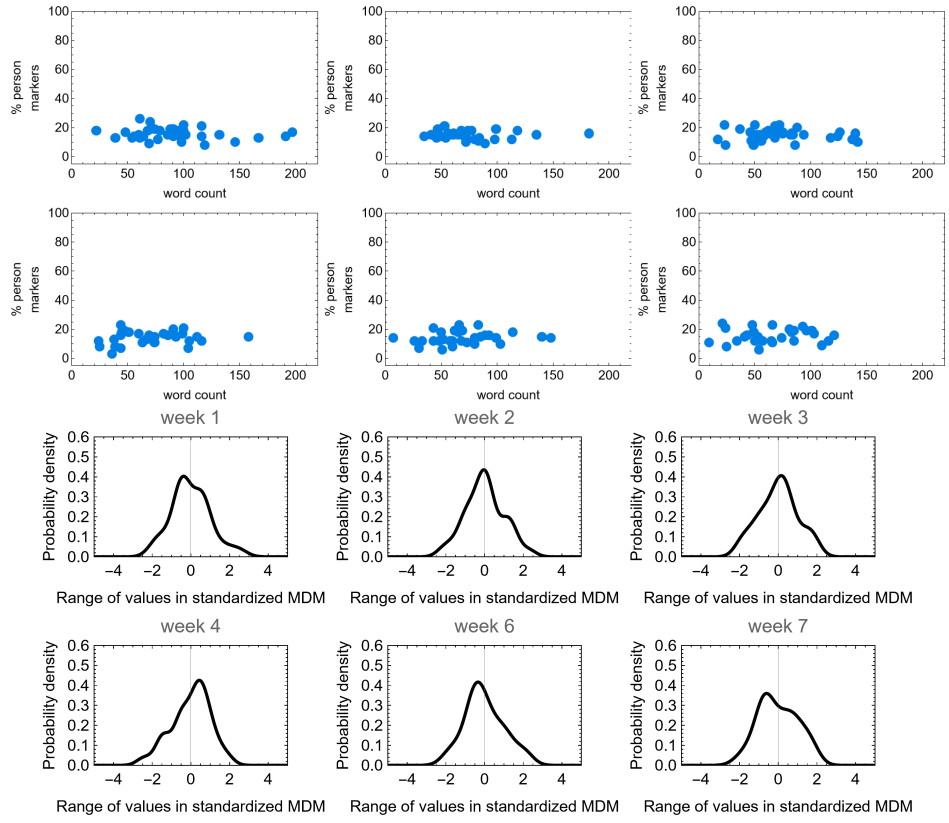

Figure 2: The weekly (weeks 1,2,3,4,6,and,7) percentage of Person Markers vs. word count and the associated weekly kernel density estimate (KDE) plot of standardized Person Markers in student reflections.

Discussion of results – What does metadiscourse analysis tell us about newsgroup discussions?

The openly available newsgroup data provided 11,314 conversations distributed into nine genre. We picked six of the genre, four of which involved scientific discourse (medicine, electronics, space, and cryptography) while two involved discourse on recreational sports (baseball and hockey). The ratio of Emphatics to Evidentials was chosen as a signature of metadiscourse for newsgroups. The discourse was binned by word-count into 10-100 words, 100-500 words, 500-1000 words, and 1000-3000 words. The following observations are made:

1. **Metadiscourse Signatures (ratios of Emphatics to Evidentials)**:
   (a) The median value of the Emphatics to Evidentials ratio was less than 1 for both sports discourse and scientific discourse. In other words, both genres had strong evidentiary metadiscourse.
   (b) For the 10-100 words bin, the median value of the ratio of Emphatics to Evidentials was higher in recreational sports discourse than in scientific discourse. In other words, for shorter communication of up to 100 words, the metadiscourse on recreational sports was more evidence-driven than the scientific metadiscourse.
   (c) For discourse that had at least 100 words but not more than 3000 words, the ratio of Emphatics to Evidentials was generally higher in scientific discourse. In other words, the scientific metadiscourse was generally more evidence-driven for longer communication of between 100 to 3000 words than the discourse on recreational sports.
2. **Person Markers**: The newsgroup data was grouped into "sports" and "science" categories and the distribution of Person Markers was visualized. The following are observed in Figure 1:
   (a) Longer scientific discussions are more reflective than longer discussions on recreational sports.
   (b) Sports discourse has a different distribution from scientific metadiscourse, as indicated by the variation of KDE plot shapes.

Discussion of results – What does metadiscourse analysis tell us about student reflections?

Student-submitted reflections from an undergraduate engineering mechanics course (enrollment of 37 students) were analyzed with our dictionary-based MDM platform. These reflections were constrained to being less than 250 words through explicit instructions to students. The three prompts focused on student-reflections on weekly course content and associated deliverables and their aspirations that this course may fulfill. We performed a metadiscourse analysis on the responses to the second prompt since this had the most data density. The ratio of Emphatics to Hedges was chosen as the signature of discourse. The following observations are made:

1. **metadiscourse signatures related to Prompt 2**:
   (a) In any entry, the minimum number of words used were 15 while the maximum number of words were 247.
   (b) It is observed the median value of ratio of Emphatics to Hedges (grouped by week) showed a 30-40% reduction after examination grades were posted. This is not definitive proof of a metadiscursive signature because of the small number of responses. Only approximately 10% of the students responded to these prompts after an examination.
2. **Person markers**: Kernel density estimate plots (Figure 2) of standardized Person Markers show a variation in the weekly distribution.

We note that there are no validated ratios of metadiscourse markers to study undergraduate student reflections. We are currently identifying and labeling "affect" in student reflections. We believe the affect labels alone will be valuable in understanding how students develop their entrepreneurial mindset. Our computational framework will enable a swift analysis and quantitative correlation of affect labels to metadiscourse marker distribution.

The limited data (due to dwindling weekly student engagement after an exam) is the main limitation of our analysis of student data. However, we have a framework that can be applied to labeled data to extract descriptive statistics on the distribution of meta-discursive markers.

Summary and Conclusions

In this paper, we described a dictionary-based MDM identification technique that when applied to a text dataset measures the presence of MDM from nine different MDM classes, and computes the ratios of Emphatics to Hedges, Evidentials to Hedges, and Emphatics to Evidentials. This dictionary was initially applied to openly available online newsgroup data (containing over 11,000 conversations distributed among twenty topics) and to some preliminary reflection data (211 responses for three prompts) from an engineering mechanics class infused with an activity that inculcates an entrepreneurial mindset.

In the newsgroup dataset we discovered that for scientific conversations that had between 100 to 3000 words, the ratios of Emphatics to Evidentials was higher than in conversations that surrounded recreational sports. However, for shorter conversations or comments (10 - 100 words), the ratio of Emphatics to Evidentials was higher in discussions surrounding recreational sports than in scientific discussions. Sports discourse has a different distribution of Person Markers than scientific discourse. More of the longer articles in scientific discourse have a greater reflective nature (more discourse pieces with a relatively higher percentage of Person Markers) than the longer articles in Sports discourse.

We do not have sufficient student reflection data to make a definitive claim on the distributions or strength of ratios of MDM. However, we have a framework in place that can be readily applied to generate MDM insight in a matter of seconds. Transferring the

methodology applied to comparing sports vs science discourse in newsgroup conversations, we can compare the metadiscursive evolution of different groups of students in any given epoch or across epochs (longitudinal) supported by rigorous parametric or non-parametric statistical analysis in the future.

We hypothesize that MDM in undergraduate (engineering) writing can indicate the presence or emergence of an entrepreneurial mindset, metacognition, or achievement of threshold skills, or entrepreneurial mindset. Therefore we are pursuing an automated MDM identification computational platform.

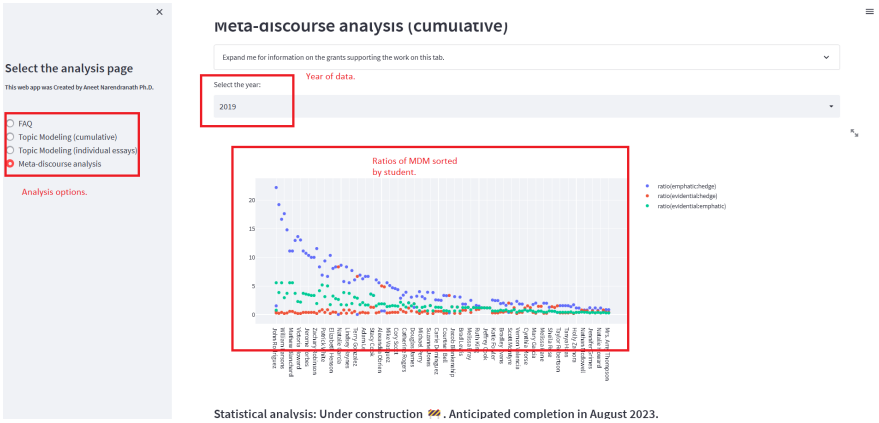

Figure 3: Discourse analysis platform with the metadiscourse analysis page active. The X-axis ticks were synthetically generated using the Python package, faker (https://github.com/joke2k/faker.)

Future direction

Our future goals are multifold:

1. Gather a larger corpus of student reflections and label them for the emergence of EM. This may be from multiple courses (much like the newsgroup data containing twenty different topics). In response to a reviewer's comment, we speculate that the following complement of metadiscourse markers are relevant to the identification of EM: Person Marker (to show closeness or distance to a concept), Emphatics and Attitude Markers (to demonstrate emotion or affect), Hedges (to demonstrate doubt and a possible risk-taking mindset), Frame Markers and Endophorics (to demonstrate a logical/analytical approach to make connections between domains and to demonstrate structured curiosity).

2. Create a rule-based (grammar-based) method for MDM identification. A dictionary-based MDM analysis establishes a framework but needs to be augmented by a rule-based technique to ensure complex linguistic patterns are identified.

3. Create, validate, and deploy a cloud-based discourse analysis platform that includes MDM identification and visualization capacity. A Python-based platform is currently

under construction. A sample screen is presented in figure 3. This visual representation of data will provide clear evidence of student development over time.

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