Automated Analysis of Aspects of Written Argumentation

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ABSTRACT
In this paper, we report on a model that uses a mathematically and cognitively augmented Latent Semantic Analysis method to automatically assess aspects of written argumentation, produced by students in a science communication course.

CCS Concepts
• **Computing methodologies → Natural language processing**

Keywords
Latent Semantics Analysis, Automated Assessment

1. INTRODUCTION
Learning argumentation through writing requires students to use complex cognitive processes, such as advancing claims, hedging, asserting, paraphrasing and taking stances [1]. While instructors make every effort to assess the major elements of scientific argumentation in student essays using rubrics, the enormous volume of material makes it impossible to code for every possible element. Furthermore, there is a risk that this amount of feedback would not be consumable by students. However, a detailed argumentation analysis could yield useful information about where students generally perform well and poorly. Instructors could then use this information to design suitable activities targeting the problem areas in argumentation. Cognizant of this potential impact on student learning, we created an automated argumentation analysis model and software. In this paper, we report on the application of a latent semantics analysis (LSA) model that automatically assesses argumentation in students' writing.

2. THEORY
2.1 Argumentation
Written language is the direct cognitive by-product that externalizes how students build arguments supported by evidence. In our context, we define argumentation as a complex cognitive act produced by a writer, and evaluated by a reader using the meaning conveyed by natural language. In short, it is a combination of a logical product and a rhetorical process [2]. Assuming that language is core to learning and that thought and language are inseparable [4], examining students' argumentation offers opportunities for gaining insights into how students engage in scientific reasoning.

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2.2 Automatic assessment of argumentation
Regardless of the architectures, frameworks, interfaces and functionalities, all computer-based systems that support some form of argumentation draw on natural language processing (NLP) methods [9]. The NLP field investigates methods for the mathematical representation of language, allowing straightforward analyses of compositionality, to enable machines to interpret aspects of human language. The core assumptions are that the elementary components of natural language within a text can be identified and their meanings, relationships and dependencies analyzed to uncover aspects of argumentation.

3. RELATED WORK
Previously developed models and systems focused on the use of argumentation to teach students hypothetical reasoning and to engage students in domain-specific problem solving [[6], [8], [5]]. More recently, Shum *et al* [7] offered a model and system integrating insights from linguistic parsing and learning analytics to assess dimensions of reflective writing to deepen learners' understanding. Our model and system builds on the insights in the studies referred to above and focuses on the analysis of written essays to assess the quality of the argumentation. The design of our model integrates insights from the fields of cognition and computation of language, learning analytics, and education theory.

4. THE STUDY
4.1 Context
Students' essays used for developing this model originate from a first-year writing intensive science course, offered at The Faculty of Science, University of British Columbia. The overarching course goals are to define and discuss the elements of a scientific approach, to teach students ways of communicating science through writing and peer reviewing.

4.2 Data
Our text corpus is unannotated and it includes 1346 term papers, 2020 essays, totaling 15.147.000 word corpus. The essays and term papers were collected over four academic terms (from 2014 to 2016), and from 673 Science students, who consented in written form. Each text is an essay assignment that is produced by the students based on writing prompts for the assignments essays and based on no writing prompts for the text of the term papers.

4.3 Method (model)
Our model uses LSA to automatically assess aspects of argumentation in written essays. LSA is an automatic statistical (probabilistic) method for representing the meaning of words, phrases and passages in text [3]. The power of the LSA model lies in its mathematical ability to use vectors to map out semantic spaces found in an essay. This contributes to the automatic interpretation of an essay through the dependencies revealed by the semantic maps. Since the NLP task in this model and system

is a natural language understanding task at its core, we adapted and added both mathematical and cognitive extensions to render LSA more context-sensitive and more cognitively plausible. From a mathematical perspective, we added the ability to use Euclidean distances to measure the length of the vectors and Cosine to measure the similarity of vectors. From a cognitive processing perspective, we augmented LSA with the use of *n*grams that encode syntax-informed inferential paths, and form a targeted semantic network of the concepts that convey aspects of argumentation. As such, our model of LSA narrows the probabilistic space and maps more dependencies across concepts. This model removes dimensions that contain noise in assessing written argumentation, and retains dimensions that discriminate clearly between different aspects of written argumentation.

We combined the holistic method and the componential method of LSA. The holistic assessment method contributes to a more accurate measure of the overall quality of argumentation in an essay. The componential assessment method assesses a specific aspect of the argumentation in the essays (see: TABLE 1).

5. PRELEMINARY RESULTS

We handpicked the essays that were graded high by the instructors and we labelled them as gold standard essays, and we tested whether our LSA model would be able to identify the high graded essays from the rest. The heat map (Figure1) indicates that the augmented LSA model is able to discriminate, on its own, between the essays that are gold standards and the essays that are not. Dark blue colors at the bottom of the heat map are gold standard essays.

We re-run the augmented LSA model and computed through the combination of LSA-Cosine and LSA-Pearson to establish the degree of similarities across the essays assessed in terms of the quality of argumentation. We observed that the gold standard essay 1 shares more similarities, in terms of its argumentation characteristics, with other gold standard essays than with the non-gold standard essays. The componential comparison of the argumentation dimensions of, for example, <*paraphrasing*>-<*hedging*>, and <*arguing*>-<*stancing*>, and other argumentation concepts all consistently discriminate the gold standard essays from the rest of the essays.

6. CONCLUSIONS AND FUTURE WORK

This augmented LSA model has several advantages. It integrates the human judgment as part of its assessment through using the pre-graded essays to assess aspects of the argumentation in other essays. It offers an approach that can be adapted (calibrated) to analyze different aspects of argumentation in written text. We are working on further augmentation and validation of this LSA model. We hope to report on those results by the time of the conference.

Table 1. Some of the argumentation concepts

	LEXICAL INDICATORS (SEMANTIC MATRICES)
HEDGING	assume, believe, suppose, presume, …
STANCING	I assert, I stand, I hypothesize, …
ARGUING	observe, predict, ascribe, question, …
INDEXING	its, it, their, these, this, those, …
L-CONNECTORS	therefore, if, the, because, either, or, …
PARAPHRASING	indicated, proposed, suggested, ...
UNDERSTANDING	classify, associate, categorize, express, …
APPLYING	determine, examine, demonstrate, …
ELABORATING	extend, add, clarify, always, …

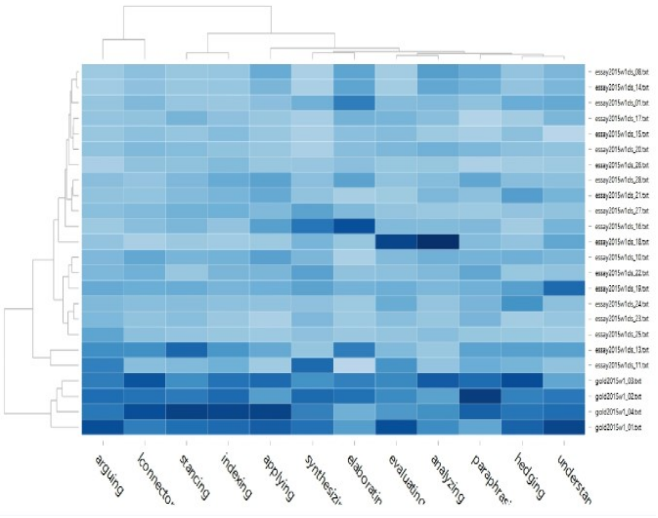

Figure 1. Heat map comparing essays in a course section

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