Towards knowledge-transforming in writing argumentative essays from multiple sources: A methodological approach

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ABSTRACT: Skillful essay writers successfully transform knowledge from multiple sources. However, when post-secondary writers draft essays after researching the articles, they often face challenges to engage in knowledge transforming, a complex process simultaneously involving reading comprehension, writing production and metacognitive monitoring (Bereiter & Scardamalia, 1987). We describe a two-facet methodological approach to model linguistic properties that distinguish knowledge-telling evidential sentences from knowledge-transforming ones in disciplinary argumentative writing. We collected and coded 40 post-secondary disciplinary argumentative essays based on an assigned argumentation framework and Bloom's taxonomy (Sadker & Sadker, 2006). We use these coded argumentation schemes to develop a computational tool to generate writing analytics to scaffold writers towards more knowledge transforming processes.

Keywords: Argumentation, writing, text analysis, knowledge telling, knowledge transforming

1   INTRODUCTION

To develop well-structured arguments in essays, students need to form and present claims and adjoin credible evidence to support arguments. This entails successfully navigating between a rhetorical problem space and a content problem space (Bereiter & Scardamalia, 1987). In the rhetorical problem space, students work to design, structure, and precisely and coherently communicate claims and supportive evidence. Solving rhetorical problems accomplishes argumentative goals. Simultaneously, in the content problem space, students process information they identify and mine from multiple sources. As they compare facts, reasons and explanations, evaluate and generalize findings, and establish semantic relationships among key concepts, opportunities arise to coordinate evidence relating to claims positioned in the rhetorical space.

In this process, students actively rework drafts to fit parameters of the writing task and its goals. Bereiter & Scardamalia (1987) modeled interactions among discourse and content processing, and metacognitive monitoring as a composite process called knowledge transforming. Because this process triggers reflective thinking while writing, Bereiter & Scardamalia (1987) argue that knowledge transforming promotes learning.

Producing knowledge-transforming texts is a challenge for many post-secondary writers. Research indicates student writers often fail to paraphrase, interpret, and evaluate content in sources; construct novel associations across multiple sources; and integrate multiply-sourced information into a coherent structure (Bereiter & Scardamalia, 1987; Aull, 2015; Boscolo, Ariasi, Favero, & Ballarin, 2011; Dong, 1996; Flower et al, 1990; Petrić, 2007). As a result, under-skilled post-secondary writers often engage in a more limited text production process termed knowledge telling. Writers who

generate knowledge-transforming text typically use monitoring and planning strategies that develop a coherent text. In contrast, writers who produce knowledge-telling texts focus overly on generating basic text, e.g., staying on topic and repeating facts from sources. In the knowledge-telling process of writing, interactions between the content problem space and the rhetorical problem space are few, limited in complexity and unproductive. We hypothesise writing analytics can be generated to help struggling writers move from knowledge telling toward knowledge transforming. Such analytics should invite writers to engage in knowledge transforming processes while practicing writing, reading, and arguing strategies that help them navigate between the content and rhetorical spaces.

We present a methodological approach to identify knowledge transforming in evidential sentences situated in disciplinary argumentative essays generated by post-secondary students. Specifically, we seek to identify when students transform source information by applying evidence to promote argumentative claims. Hemberger, Kuhn, Matos, & Shi (2017) posited that coordinating evidence with claims is essential to skilled argumentative writing. Thus, the final goals of our research are (a) to develop an ensemble off computational algorithms to analyze linguistic properties of evidential sentences in an argumentative essay relative to information available in sources, and (b) generate learning analytics that scaffold knowledge transforming as writers bring evidence to support claims. The computational tool will use linguistic properties of evidential sentences as standards for tailoring learning analytics in form of metacognitive prompts to writers helping them go beyond merely restating information borrowed from sources to engage in knowledge transforming.

2 RELATED WORK AND THEORETICAL MODEL

Citations in an essay – references to and quotes of source information – have been classified with respect to various linguistic functions (see Petrić, 2007). We elaborated Bereiter and Scardamalia's (1987) model contrasting knowledge telling and knowledge transforming by additionally categorizing evidential sentences in argumentative writing in terms of Bloom's taxonomy of the cognitive domain (Sadker & Sadker, 2006; Table 1). The taxonomy describes a progression of thinking processes across knowledge, comprehension, application, analysis, synthesis and evaluation. While not without criticism (e.g., see Darwazeh, 2017) it has potential to supply an underlying framework for developing informative, specific and useful learning analytics to guide learners in advancing from knowledge-telling to knowledge transforming. According to Bereiter and Scardamalia's (1987) writing model, students engaged in knowledge telling neglect cognitive and metacognitive operations that transform knowledge. Using Bloom's taxonomy to classify writers' evidential sentences could reflect underlying cognitive and metacognitive processes writers engage in. Bloom's knowledge classification aligns with

Table 1: Framework for classifying evidential sentences in argumentative writing

Category	Operationalization	Writing Mode
Knowledge	paraphrased/copied information from a source	Knowledge telling
Comprehension	elaborated source information	Knowledge transforming
Application	source information applied to the real-world context	Knowledge transforming
Analysis	inferential additions to information mentioned in sources	Knowledge transforming
Synthesis	integrating information from different sources or a proposition	Knowledge transforming
Evaluation	evaluating or discrediting source information	Knowledge transforming

Bereiter and Scardamalia's knowledge-telling model where writers focus on generating basic text. Bloom's comprehension, application, analysis, synthesis and evaluation categories reflect Bereiter and Scardamalia's knowledge transforming category where writers coordinate and create knowledge. Thus, classifying students' evidential sentences in terms of Bloom's taxonomy forms a basis for analytics to guide students toward producing knowledge transforming texts with arguments strengthened by more thorough articulation of content with evidence.

3 METHOD

3.1 Corpus and writing task

Our corpus was 40 argumentative essays written by undergraduates enrolled in various disciplinary majors and registered in an introductory educational psychology course in a Western Canadian university. Students were assigned a 1500-2000 word argumentative essay on a specific disciplinary issue of their choice. Essays were required to present (a) at least three arguments supported with evidence gathered from 5-7 sources students selected from 160 sources in the course repository, (b) at least one counterargument with evidence, and (c) rebuttal(s) to the counterargument(s).

3.2 Hand coding – codebook

Sentences were sampling units. Since we focus on analyzing arguments and evidence, we coded sentences in the essay body (excluding the introduction paragraph, conclusion paragraph, and headings) in terms of argumentation, writing mode and relationality.

For argumentation, we coded sentences in one of five categories: *Argument (A)*, a sub claim supporting the thesis statement (main claim); *Evidence (E)*, sentences providing support to the argument; *Counterargument (C)*, counter claims; and *Rebuttal (R)*, sentences discrediting the counterargument; *Not applicable (NA)*, a sentence that did not fit any argumentation category, e.g., definition or background information. For Writing mode, categories (Table 1) referred to Bereiter and Scardamalia's knowledge transforming model (1987) elaborated by Bloom's taxonomy of the cognitive domain following Sadker & Sadker (2006). A 3-point scale quantified relationality in terms of each argument's (or sub argument's) linkage to the thesis statement (or main argument), and the relation of evidence to arguments (sub arguments): 0 indicated *not related*, 1 described *far-fetched*, and 2 described *related*. The coding method is illustrated in the Figure 1. The sentence coded as argument (A) receives a rating on its relation to thesis statement. The sentence coded as evidence receives a rating on its relation to the preceding argument.

3.3 Hand coding – interrater agreement

To reach high interrater agreement among three coders, coding proceeded in three rounds of train together → code independently → calculate reliability. In round 1, two randomly selected essays were collaboratively coded followed by independently coding four randomly selected essays. Altogether,

Sentence	Macro Structure	Argumentation	Writing mode	Relation to thesis statement/ argument
Meeting the different needs of learners and allowing them to be included in classrooms can result in children achieving educational success.	Intro			
Learner differences should be a primary concern when it comes to educating teachers and achieving inclusion, as the failure to incorporate learning needs can be disastrous for all students.	Intro			
While most schools focus on bringing underachieving students up, individuals who are of high ability are neglected.	Body	A		2
According to Northwestern University (2017), children are then left to rely on their parents to provide them with advanced instruction.	Body	E	Knowledge	2
Therefore, many students miss out on opportunities for achievement as many families cannot provide them with the resources such as tutoring services or enrichment activities.	Body	E	Comprehension	2
When teachers are given appropriate instruction, they are able to teach learners who need support.	Body	NA		

Figure 1: Codebook

those four essays comprised 28 paragraphs (per text: M=7, SD =1.41) and 245 sentences (per paragraph: M=8.75, SD =3.63). After independent coding, we calculated reliability using the AC1 statistic (Gwet, 2002) as this method corrects agreement among raters for the probability of chance agreement. Although inter-rater reliability was lower for Argumentation and Writing mode (0.67 and 0.77, respectively), differences arose in identifying argumentation categories because coders' failed to reliably identify evidential sentences. In addition, for Writing mode, coders struggled to discriminate synthesis from analysis, and analysis from comprehension. For round 2, we sharpened coding of Argumentation and Writing mode. In round 2, three coders coded two randomly selected student essays collaboratively followed by independently coding four randomly selected essays. Altogether, the four essays comprised 26 paragraphs (per text: M=5.2, SD=1.3) and 247 sentences (per paragraph: M=9.27, SD=2.47). Reliability of the argumentation mode was still low (0.76). Round 3 included collaboratively coding two randomly selected student essays followed by independently coding six randomly selected essays. Table 2 presents final inter-rater reliability results.

Table 2: IR reliability after the 3 rounds of "train together-code independently-calculate reliability"

Code	AC1 Reliability	Standard Error	95% CI
Macro-structure	0.97	0.01	[0.95, 0.99]
Argumentation	0.81	0.02	[0.77, 0.84]
Writing mode	0.83	0.02	[0.78, 0.87]
Relation to arguments/thesis	0.82	0.02	[0.78, 0.86]

In the Appendix, we illustrate codes within the Writing mode for each category of Bloom's taxonomy (Sadker & Sadker, 2006).

3.4 Extracting linguistic indices for sentences coded in Writing mode scheme

We propose modeling the following linguistic indices for each identified evidential sentence. The variables are grouped into: anaphoric devices, semantic overlap, and rhetorical connectives.

First, high accessibility (unstressed pronouns) and low accessibility anaphoric devices (full noun phrases and indefinite articles) will be computationally extracted. Sanders & Spooren (2007) pinpoint high accessibility markers in a sentence indicate continuation with previous topic, or the writer's tendency to stay on topic. Both are signs of knowledge-telling. Low accessibility markers, on the other hand, signal termination of current and activation of other topics. They indicate knowledge-transforming.

For each evidential sentence we will compute its semantic overlap with source text and with the preceding sentence (argument/counterargument/rebuttal/evidence). We hypothesize knowledge-telling sentences have higher semantic overlap with a source while knowledge-transforming sentences have lower semantic overlap with the source and the preceding sentence.

Seventeen rhetorical connectives will be calculated using the TAACO tool (see Crossley, Kyle & McNamara, 2016). We anticipate subsets of rhetorical connectives will predict knowledge telling and transforming. The analysis will provide substantial details.

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APPENDIX
Sample coded sentences

Category	Example Sentence
Knowledge	*When institutions and classrooms integrate self-directed learning into their curriculum, long term benefit have been observed through increased student retention and graduation rates (University of Texas at Austin, 2016).*
Comprehension	*With this type of learning, students can fully control their educational experience and focus on information they would like to explore.*
Application	*Having different interpretations based on cultural differences is a concern, particularly for schools in British Columbia and other Canadian metropolitan centers where we have and are projected to receive more international students particularly from Asia.*
Analysis	*Meaning engagement in some form of unstructured play could also result in an increase in academic performance.*
Synthesis	*However, this is not the case, because praise is not overly useful feedback, and if it is undeserved, it can cause students to feel like their teachers do not expect much from them.*
Evaluation	*One of the limitations is that the research is centered on a questionnaire survey which may result in certain biases including social desirability bias.*