Developing a Multiple-Document-Processing Performance Assessment for Epistemic Literacy

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ABSTRACT
The LAK15 theme "shifts the focus from data to impact", noting the potential for Learning Analytics based on existing technologies to have scalable impact on learning for people of all ages. For such demand and potential in scalability to be met the challenges of addressing higher-order thinking skills should be addressed. This paper discuses one such approach – the creation of an analytic and task model to probe epistemic cognition in complex literacy tasks. The research uses existing technologies in novel ways to build a conceptually grounded model of trace-indicators for epistemic-commitments in information seeking behaviors. We argue that such an evidence centered approach is fundamental to realizing the potential of analytics, which should maintain a strong association with learning theory.

Categories and Subject Descriptors
K.3.1 [**Computers and Education**]: Computer Uses in Education – *collaborative learning.*

General Terms
Measurement, Documentation, Design, Human Factors,

Keywords
Learning analytics; epistemic cognition; educational assessment; discourse analytics; social learning analytics

1. INTRODUCTION
Despite the prevalence of internet use, many students experience difficulties in their web based information-seeking activities [48]. The searching, selecting, and processing of complex documents and multi-media on the web can be seen as a component of literacy [36] and is related to epistemic cognition – the ways in which people conceptualize the: certainty, simplicity, source, and justification of knowledge [32]. In particular, the ways in which students source, corroborate, and integrate claims – key facets of literacy for mature internet use [39] – are related to their epistemic cognition in information seeking and literacy tasks [1, 8, 16, 31, 44–46]. By epistemic cognition, we mean the broad set of models across which there is a broad agreement on two main areas of interest, cognitions regarding: what knowledge is; and how one comes to know, as Mason, Boldrin and Ariasi [32] summarise:

There are two dimensions within the first area (knowledge):

- *Certainty of knowledge: the degree to which knowledge is conceived as stable or changing, ranging from absolute to tentative and evolving knowledge;*
- *Simplicity of knowledge: the degree to which knowledge is conceived as compartmentalized or interrelated, ranging from knowledge as made up of discrete and simple facts to knowledge as complex and comprising interrelated concepts.*

There are also two dimensions which can be identified within the second area (knowing):

- *Source of knowledge: the relationship between knower and known, ranging from the belief that knowledge resides outside the self and is transmitted, to the belief that it is constructed by the self*
- *The justification for knowing: what makes a sufficient knowledge claim, ranging from the belief in observation or authority as sources, to the belief in the use of rules of inquiry and evaluation of expertise* [32, p.69]

Along with the increase in internet use has come an increasing prevalence of ICTs (Information and Communications Technologies) such as Virtual Learning Environments, bringing a growing interest in learning analytics: the use of trace-data from such systems to make claims about learning [12]. However, presently even within the computer supported collaborative learning literature, only a minority of measures assess process data including dialogue data, with most relying on self-report measures [19]. Little research in epistemic cognition has taken a learning analytic approach, taking trace data as a data source for analysis [for related exceptions, see for example, 11, 18, 21, 22, 28, 47]. There is untapped potential here; as Winne notes:

> *trace data operationalize what learners do as they do it. Trace data avoid shortcomings of (a) asking leaners what they believe they do and (b) asking learners to perform mental calculations of unknown kinds (c) using sample fractions of past or possible future experiences that have unknown size and biases. When traces are faithful operational definitions of theoretical cognitive and metacognitive operations, they provide sturdy grounds for testing theories about when, whether, and how [self regulated learning] processes affect learning* [49, p.275]

This potential could – as we discuss in this paper – address recent calls for a focus on literacy assessments, through trace data based performance assessment and the development of evidence centered design [15, 27]. Such an approach should consider the elements of *'evidence centered design'* [35] which moves through an evidence-based analysis of: (1) the high-level constructs we aim to probe, (2) the types of behavior indicative of those constructs, and (3) the types of task likely to elicit salient indicators; to develop performance assessments [10, 29, 43], which as Pellegrino notes, "do not offer a direct pipeline into a student's mind. […] an [performance] assessment is a tool designed to observe students' behavior and produce data that can

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be used to draw reasonable inferences about what students know." [37, p.261]. In this short paper we introduce some work, in progress at the time of writing, to undertake such an evidence-centered approach to designing a performance assessment – a tasks, related to a conceptual model of performance (or behavioral) expectations, with tools to capture data around those behavioral traces – for epistemic cognition. This is done in the context of complex multiple document processing tasks in which students read and synthesise information from multiple documents. Such tasks are designed to probe high-level literacy skills, and – as we discuss further below – are established as a tool in epistemic cognition research. As such, we first introduce the construct of interest, alongside behavioral indicators of those constructs. We then introduce the tasks design for our development of learning analytics in this area, before concluding with some general points on lessons learned thus far.

2. A Model of Epistemic Cognition

A starting question for evidence centered design is, "What are students supposed to do when they study multiple documents? And what kind of mental representation of such materials do they form?" [39, p.65]; in answering those questions Rouet, later built on by Rouet and Britt, developed a literacy model: the Multiple Documents—Task-based Relevance Assessment and Content Extraction (MD-TRACE) model [40].

In this model, there are 5 main steps: task model construction; information need assessment; document processing; task product creation; task product assessment. These steps unfold interactively (i.e. they are not linear), and represent a more complex view on text processing, in particular with regard to the third step in which the relevance of documents to the information need is assessed, the document model updated, and the process of information seeking iterated over. As Rouet [39] (citing [7]) notes, crucial to developing such literacy – and mature internet use – students should be taught:

1. Skill of *integration*: the ability to connect prior and new information, including across documents, and including where claims are inconsistent or contradictory
2. Skill of *sourcing*: the ability to identify parameters that characterize the author and conditions of production of the information
3. Skill of *corroboration*: the ability to check information against multiple sources for its accuracy

Indeed, building on the epistemic cognition literature, Bråten, et al., [5] outline the empirical evidence linking epistemic-cognition to the MD-TRACE model as indicated in Table 1 which shows a summary of the hypothesized relationships between MD-TRACE and epistemic cognition facets.

We are, here, particularly interested in the class of constructs related to how students engage higher level literacy skills of information selection and evaluation, creation and identification of ties between and within documents, and development of outputs based on these activities which might be more or less elaborated in their form. Here we note that in terms of observable indicators there are a number of key behaviors of interest:

1. How students select information through corroboration and reference to source-authority, and how these strategies are used in isolation, or combination – for example by corroborating across multiple sources, whilst making reference to the qualities of those sources.
2. How students connect claims across and within sources whether claims are considered and stated in isolation, or integrated and synthesized while seeking information, and creating output texts.
3. How students take claims and use them in task oriented ways; whether claims are stated without evaluation, or are evaluated and elaborated (independently of their synthesis with other claims).

Table 1 MD-TRACE and epistemic cognition relationships [5]

Facet of cognition	Less adaptive	More adaptive
Simplicity	Accumulation of facts, prefer simple sources	Integrated, downplay simple sources
Certainty	Single document sourcing	Corroboration, represents complex perspectives and views showing the diversity of angles
Source	Emphasizes own opinion, differentiates between sources less	Emphasizes source characteristics, distinguishes between source trustworthiness
Justification	Emphasizes authority, less corroboration	Emphasizes use of argument schema and combination of corroboration and authority

Therefore we take it that when sourcing information – through selecting individual or multiple sources – those selections should be taken to as commitments to authority and corroboration, analysed in connection with student's linguistic 'stance taking' towards these actions. Such sourcing does not stand alone; it is embedded in and connected to the continued seeking of information, extraction and synthesis of claims, and deploying of that information in task-specific contexts. For example, through trace indicators such as logs of document use, or identification of key markers linking claims to their sourcing documents, we might identify that a particular claim has been sourced from a document; in such cases, it is of interest to also identify whether or not sourcing metadata (dates, authorship, genre, etc.) has been discussed or not. This is particularly interesting given that, as Kobayashi [26] indicated through a controlled experimental design, while participants given 2 texts of varying quality are more likely to favor high quality sources, they make little reference to source features (on average only 1.85 out of 10 features); and rarely (<6% of the 154 participants) explicitly use source information for justifying their evaluation of the text's explanation, that is, they do not make connections between source metadata and their evaluative stance.

Furthermore, given the relationship between literacy and dialogue [see, for example, 42], and that document use may often involve spoken or written communication [40], dialogue is an important area of interest in both supporting, and probing complex literacy practices. As Goldman and Scardamalia [17] note, communication is key in collectively authoring written outputs, particularly around "constructive uses of authoritative sources," that engages students both in understanding what is being claimed, and how to contribute to developing new knowledge [17, p.260]. They argue that we need two foci:

1. Productive use of metadata and meta-discourse – credentials, dates, source locations, quote v paraphrase, citations, primary/secondary source, etc. are all important

parts of the discourse, and the discourse around this becomes an object for discourse (meta-discourse) too
2. Use of authoritative sources (i.e. stating claims, and citing sources), with a focus on discourse for idea improvement and knowledge-creation

The target of our interest, then, is multiple-document processing tasks in which students collaborate on the processing of a range of sources, in order to create an output document, and particularly tasks in which we – as researchers – have access to chat and document-logs. In line with this argument that collaborative discourse is of key interest to us, we suggest that the connections between trace-indicators of epistemic cognition and in particular, the kind of linguistic expressions associated with taking an 'epistemic stance' [23], some of which (e.g. 'because', 'I think', 'so') are also associated with the kind of educationally productive dialogue known as 'exploratory talk' [33] or accountable talk [34, 38] are key. These terms include: 'I think', 'he' or 'she' said, 'I don't know' 'I guess', 'I thought', epistemic adverbs such as 'maybe', 'probably', 'apparently', 'of course', and epistemic modal auxiliaries such as 'would', 'must', 'might', 'could', 'will', 'may'. Such stances indicate a linguistic positioning of the speaker(s) with regard to their linguistic target. That is, the most explanatory insights come, not from an analysis of trace data in isolation, but from the consideration of how facets of epistemic-trace are associated, and how 'epistemic stance' commits learners in particular ways through the use of their dialogue. Indeed, in earlier work [24], we have begun to model this approach on an existing data set.

It is thus that the analysis of individual facets of trace in isolation will give only a partial insight into the ways in which people engage in: selecting multiple sources; claims around source authority; connecting pieces of information in complex ways; and so on, which in isolation are likely to give little insight into the complexity or otherwise of epistemic cognition. The challenge, then, is to operationalize the facets of epistemic cognition of interest, in such a way as to understand their connections, in the context of tasks. One to which we now turn.

3. Tasks for Epistemic Performance

An evidence-centered design process for epistemic cognition should build on the typical pattern in that research domain, particularly around multiple document processing[1]. This research has typically involved a psychometric assessment, alongside some task – constructing an argument, or summarizing information – using a number of pre-selected documents, selected for their variability in terms of credibility and information. In addition, recent work has been conducted on the impact of epistemic cognition on comprehension of multiple *online* sources – which may vary radically in the nature of their sources and justifications – on the basis that students who perceive knowledge as simple and finite may conduct brief and perfunctory searches with little recourse to integration or multiple sourcing [2, 6]. As such, "exploring students' thought processes during online searching allows [the] examination of personal epistemology not as a decontextualized set of beliefs, but as an activated, situated aspect of cognition that influences the knowledge construction process" [20, p.43].

In the research described in this paper, two collaborative tasks are deployed: a multiple document processing task, and a more open ended search-based information seeking task. The study employs a between subjects design with both groups engaging with an open-ended socio-scientific topic. Comparisons will be drawn between trace indicators in both tasks as a means to explore development of analytics around the more open ended information seeking tasks. In both cases an existing psychometric instrument will be used [described in, 4], and the task is to work with a partner to produce an etherpad based summary of the "best supported claims" from the information found, or provided. These summaries will then be peer-assessed against a rubric, with the rubric items mapping to constructs in the psychometric assessment. In addition, trace data will be gathered including: pages viewed (including search engine pages viewed – from which queries can be extracted); and chat data between partners. Again, our suggestion is that through this trace data we can identify indicators to be mapped to the constructs probed by the psychometric, and output document.

4. Analytic Potential – The Tool and its Data

We are concerned with those epistemic behaviors involved in literacy, particularly with regard to how sources of information are selected, integrated, and used to resource reasoning. By using a browser extension [described in, 9, 41] during the collaborative tasks, we can capture: the chat logs; document traces including which documents are opened, and what keywords and metadata from them is referred to; queries; and editing activity in the collaborative document editor (etherpad).

Our interest is not only in the presence of indicators, but in their co-occurrence. That is, while it is certainly of interest to note the number of resources opened, and references to source metadata (authorship, publication date, publisher, etc.) it is perhaps of more interest to identify the connections made between corroborative and authority-identification behaviours; students whom rely on authorities without corroborating, or those who look for repetition of information primitively 'corroborating' both engage in less sophisticated behavior than those who corroborate by using authoritative sources [see 24 for a preliminary description of this potential]. We are also particularly interested in the ways in which such connections are made between 'stance taking' language, which in other contexts has been taken as one indicator of the kind of 'exploratory' dialogue associated with improved educational outcomes [see 30], and better success in search tasks [25]. An open question at present is the scope of these connections – for example, two claims may not be 'connected' just because they appear in the same text; similarly claims made in chat settings. Thus, a method for segmenting data, to provide a topic-level, or other semantically meaningful 'stanza' [13, 14], is key.

Generally, then, this model focuses on *whom we believe, how we justify claims; and how holistic our view of knowledge is*. This provides a slight recasting of the perspective in Table 1 in identifying conceptually distinct objects of inquiry, with specified trace indicators for those constructs. In particular, note that 'certainty' is recast in light of connections between criteria for sourcing (sourcing, authority), explanation (mobilization, understanding), and claims made (complexity, holistic) around components of information such as its age, or geographic/cultural origin; that is, 'certainty' is seen as regarding connections between specific claims, metadata (publication date for example), and justificatory indicators (explanations for why dates might matter, for example). Thus, in Table 2 we provide a mapping of our trace indicators against the remaining relevant constructs. These are mapped against the epistemic cognition constructs described above and in Table 1; in each construct, the 'less

[1] Bråten [3] reviews the relevant literature (to 2008) in epistemic cognition and multiple document processing in the context of learning within internet technologies.

adaptive' element is given first, but it should be clear that in the case of each indicator – as described above with regard to authority seeking and corroboration – the presence of the indicator might indicate adaptive or maladaptive behavior.

Table 2 Mapping epistemic indicators to epistemic constructs

Psychometric construct	Trace construct	Indicator behavior	Rubric indicator
Justification	Sourcing: corroboration	Opening of multiple sources (URLs, etc.)	A range of sources are used
Justification	Sourcing: authority	Metadata referred to Individual sources being used on multiple occasions	Source quality is evaluated
Source	Mobilization: Match	Focus on question cue phrases	A range of relevant topics are covered
Source	Mobilization: understanding	Exploratory dialogue	Information is evaluated
Simplicity	Complexity: discrete	Single claims within meaningful segments	Claims are stated clearly, with precise definitions, quotations or figures.
Simplicity	Complexity: holistic	Number of claims within meaningful segments	Information is synthesized

In order to establish and validate such expectations, the relationships between the psychometric constructs probed in [4], the trace data gathered, and marks on the rubric-facets for the output documents will be assessed. These can be compared across the two task types, with the potential for insight regarding searching behavior coming from the information seeking task, and regarding use of known sources (for example, analysis of reliance on sources we know to be contradicted by other given evidence) in the multiple document processing task.

5. Conclusions

This paper describes an 'in progress' research study, designed to probe a key facet of high-level literacy skills; epistemic cognition. It uses the existing evidence, and constructs, in relation to a particular type of higher-order skills (literacy) to motivate a learning analytics approach to behavioral indicator identification, and task creation to illicit such behaviors. Such an approach opens the scope for learning analytics to directly support students in their information literacy; providing performance assessments of real world skills through real world behaviors.

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