

Epistemology, Pedagogy, Assessment and Learning Analytics

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ABSTRACT

There is a well-established literature examining the relationships between epistemology (the nature of knowledge), pedagogy (the nature of learning and teaching), and assessment. Learning Analytics (LA) is a new assessment technology and should engage with this literature since it has implications for when and why different LA tools might be deployed. This paper discusses these issues, relating them to an example construct, epistemic beliefs – beliefs about the nature of knowledge – for which analytics grounded in pragmatic, sociocultural theory might be well placed to explore. This example is particularly interesting given the role of epistemic beliefs in the everyday knowledge judgements students make in their information processing. Traditional psychological approaches to measuring epistemic beliefs have parallels with high stakes testing regimes; this paper outlines an alternative LA for epistemic beliefs which might be readily applied to other areas of interest. Such sociocultural approaches afford opportunity for engaging LA directly in high quality pedagogy.

Categories and Subject Descriptors

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

General Terms

Measurement, Documentation, Design, Human Factors, Theory,

Keywords

Learning analytics; epistemology; pedagogy; educational assessment; discourse analytics; social learning analytics

1. INTRODUCTION

“Assessment is one area where notions of truth, accuracy and fairness have a very practical purchase in everyday life” [62]. It sits at the heart of learning, but is hugely controversial. This is directly relevant to Learning Analytics (LA), because – we argue – LA implicitly or explicitly promote particular assessment regimes.

Presently, many education systems are predicated on assessment regimes seeking to accredit knowledge and skills gained by students through formal assessments – often exam-based.

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LAK '13, April 08 - 12 2013, Leuven, Belgium
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Proponents of such exams suggest they are the fairest way to assess competence and learning under controlled, reliable, conditions. Assessment, pedagogy and curriculum are fundamentally related [26], but many regimes of what has come to be termed ‘high stakes’ testing are criticised. For example, standardised assessments, including the Programme for International Student Assessment (PISA), American Standardised Assessment Tests (SATs) and English National Curriculum assessments (Sats), face myriad problems. Not least among these is that the exams are criticised comprehensively (e.g. [12, 23, 29]) for failing to represent adequately the types of problem people are likely to face in their everyday lives (external validity), and that they fail to represent an adequate conceptualisation of what it means to know – of what knowledge is (internal validity). The latter claim is that, while assessments clearly measure something, a good grade does not necessarily reflect mastery [12]. These fundamental issues are highlighted in a significant body of research (e.g. [12, 23, 29]), and one of the objectives in writing this paper is to clarify the implications of these issues for the Learning Analytics community.

In this paper, Section 2 considers the relationship between assessment systems and the sorts of epistemic challenges students might encounter. Section 3 introduces the concept of epistemic beliefs, and Section 4 goes on to discuss the relationships between LA, epistemology, pedagogy and assessment. Section 4.2.1 then introduces pragmatic, sociocultural approaches to LA, which we suggest are well placed to probe or assess facets of learning which other LA may not adequately address. To exemplify this argument, we draw a parallel between the psychometric measurement of epistemic beliefs and high stakes testing regimes (Section 5). Our suggestion is that pragmatic, sociocultural approaches offer alternative LA which are well placed for exploring these areas of learning (Section 6). The final section discusses the role for established LA in this pragmatic, sociocultural LA. Throughout the paper, we particularly associate our approach to LA with that of Assessment for Learning (AfL) which uses continuous assessment with formative feedback to facilitate learning, in contrast to a focus on summative assessment, often through examinations.

2. WHY WORRY ABOUT EPISTEMOLOGY?

A primary concern of this paper is the relationship between epistemology, pedagogy and assessment. Epistemology is the philosophical study of what knowledge is, and what it means for someone to ‘know’ something. Central to the field of epistemology are questions regarding the nature of truth, the nature of justification, and types of knowledge, e.g. knowing *how* (skills), or knowing *that* (facts). Whatever ‘knowledge’ is, “*it is uncontroversial, pre-philosophically, that education aims at the*

imparting of knowledge: students are educated in part so that they may come to know things.” [54]. Thus, pedagogy may be seen in part to be the study of *how* to impart this knowledge to students – the science and development of approaches to teaching and learning for knowledge. However, epistemology’s relationship to the more familiar concepts of pedagogy and assessment is a topic of educational debate [12, 15, 32, 62], and we will consider this in relation to LA throughout this paper.

Harlen [26] depicted a triadic relationship between pedagogy, assessment, and practice. Influenced by this, and Katz’s [31] description of “competency, epistemology and pedagogy: curriculum’s holy trinity” we depict the triad as in Figure 1¹.

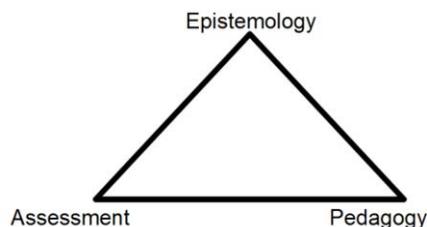


Figure 1: The Epistemology–Assessment–Pedagogy triad

In this picture, epistemology *could* be seen as driving assessments that are aimed at uncovering student knowledge, and driving pedagogy to build high quality knowledge to that end. In this view, assessment is targetted at the learning of high level knowledge – it is assessment *for* learning. However, these relationships are not fixed; neither pedagogies nor epistemologies necessarily *entail* the other [13] (although they may implicate). Furthermore, as we will explore in this paper, assessment is always concerned with devising proxies for “knowledge”, around which there are philosophical (epistemological) and methodological issues. Some epistemological stances hold that it is not possible to ‘map’ the knowledge that students hold onto their responses in assessments in reliable and valid ways. This issue is further confounded by the methodological limitations of all assessment methods, and by extension LA. The situation is, therefore, a complex one – which facet of the triad has primacy over the others is not clear in either theory or practice, and may be dynamic according to need and circumstance. However, relationships between the three can certainly be identified, and throughout this paper we draw out some of these with respect to LA – which may be conceptualised as a component of assessment. Furthermore, we suggest that, although the relationship may not be a necessary one, assessment regimes do implicate particular epistemological stances.

Consider the following example from Denmark to illustrate the argument that implicitly or explicitly, epistemological assumptions fundamentally shape pedagogy and assessment, and hence, the kinds of LA that one deploys to achieve those ends. In Denmark, a pilot project was conducted permitting the use of the internet (but not communication sites) to support students in five

of the school leaver subject exams². This made it possible to set questions requiring the use of multimedia and individual internet search. For example, a student might be asked to write about a poet whom they have not studied (and rote learned about), based on a poem by them and that of a contemporary, a short biography and perhaps an image from the time. They may be given unfamiliar resources, and permitted to source information for themselves from the internet. Thus, while Danish students are expected to evidence ‘knowledge-that’ – knowledge of facts – they must also exhibit a higher level of ‘knowing-how’, for example around information processing, synthesis, and metacognitive abilities – which remain unassessed in countries restricting access to external resources which might enhance the student’s capability. While this is of course simply one other (controlled) context, the example illustrates how even within a system reliant on exams, those exams might be conducted on a rather different epistemological grounding. Assessment regimes such as the Danish example may be taken to reflect a holistic epistemology in which *how* one comes to know is as important as *what* one comes to know, and in which it makes little sense to pick out individual tokens of knowledge in decontextualized ways [9, 11, 13, 31].

We can contrast such assessments with high stakes testing regimes whose construct validity and external validity have been questioned. For instance, Davis [10][12] argues that such instruments neither assess those facets of learning they set out to test, nor those facets of learning which would likely be utilized in the everyday deployment of knowledge in any particular domain. Davis has argued that high stakes testing is inadequate for understanding learning, in so far as its construal of that learning is necessarily restricted by a desire for highly reliable metrics of success. As such, it must exclude the nuanced understanding of student meaning-making, and the social context in which learning occurs, and how knowledge is constituted and enacted. He argues that this, as opposed to acquisition, is the appropriate way to talk about knowledge. Davis draws on notions of situated cognition [48] and sociocultural approaches [46] – particularly Säljö’s “Literacy, Digital Literacy and Epistemic Practices: The Co-Evolution of Hybrid Minds and External Memory Systems” [47]. Säljö highlights that:

From the learning and literacy points of view, such tools [memory aides and knowledge management systems of various sorts] imply that users’ knowledge and skills, as it were, are parasitic on the collective insights that have emerged over a long time and which have been entered into the instrument in a crystallized form: algorithms, grammatical rules and concepts, etc. The user will manipulate the artificial memory system in a number of ways in order to see what comes out of the processing that goes on in the machine [47]

However,

Engaging with external memory systems thus requires familiarity with a varied set of epistemic practices that range from deciphering letters on a page through familiarity with meaning-making in relation to discourses and genres of texts and other media, to meta-knowledge about how such resources may be used. [47].

¹ We could also introduce the notion of ‘folk psychology’ as a mediating factor between teacher’s views on knowledge, and pedagogy – for example, if we hold that some (particular) children will *never* learn x, we are unlikely to attempt to teach it (a pedagogical ‘move’) regardless of our epistemological stance regarding the nature of ‘x’ [41]. Although, in that paper [41] Olson and Bruner implicate epistemology in a number of their points regarding ‘folk pedagogy’.

² Steen Lassen (a Danish Education Minister) on the piloting of internet access in exams: <http://vimeo.com/8889340> subsequently adopted by some Danish universities [8].

Säljö is making an epistemological claim, specifically, a sociocultural, pragmatist claim: that there are important literacies and practices to be mastered in learning; that those should themselves be objects of assessment; and language and discourse are critical filters on our grasp of the world. Such an epistemology has implications for how we teach, what we assess, and which analytics techniques might be deployed. ‘Success’ can no longer be defined as a matter of regurgitating, unaided, the correct information in a two hour exam. Such an epistemology also – we argue – offers a perspective on why it is that, even in those technologically advanced societies which assess knowledge in less abstracted, socially embedded ways – such as Denmark – information retrieval (IR) and processing via the internet and search engines is a significant area of difficulty for students [59]; namely, that although this provides some wider access to information, this does not equate to knowledge. Student engagement with information should consider both the kinds of knowledge which we might call transferable competencies or skills – including those higher order skills often known as metacognitive abilities – and more propositional or fact based knowledge. In this context, we might consider information management, and IR not only as a means to an ends, but as a way to encourage interaction with a complex network of information. As argued by Tsai, as not only:

...a cognitive tool or a metacognitive tool; rather, it can be perceived and used as an epistemological tool. When the Internet is used as an epistemological tool for instruction, learners are encouraged to evaluate the merits of information and knowledge acquired from Internet-based environments, and to explore the nature of learning and knowledge construction. [57]

In this conception, learners are encouraged to think about the context, reliability, validity, certainty, and connectedness of knowledge.

To summarise, this section has argued that a consideration of epistemology is important to LA in two related senses:

- The ways that we assess, the sorts of tasks we set and the kinds of learning we believe to take place (and aim for) are bound up in our notions of epistemology. LA are not objective or neutral: data does not “speak for itself” but has been designed by a team who, implicitly or explicitly, perpetuate the pedagogical and epistemological assumptions that come with any assessment instrument.
- The Danish example shows concretely how epistemology relates to assessment regimes. When knowledge is seen as something that can only be evidenced in contextualised activity, and when it is embedded in one’s physical and digital environment, the role of the internet is redefined as a metacognitive tool which cannot be excluded in assessment.

These epistemological considerations foreground the quality of a student’s enquiry processes as important, not just whether they get the right answer. Analytics that provide process traces become particularly important, as we shall discuss in Section 6.

3. EPISTEMIC BELIEFS

One facet of students’ dynamic interaction with the world of information relates to how they conceptualise the information they require to answer any particular question – their *epistemic beliefs* regarding the nature of the question, and how it may be answered. The sorts of assessment, and pedagogy, which students are exposed to will relate to the types of epistemic challenge they encounter in their education – systems with a focus on ‘right

answerism’ and limited access to external epistemic resources offer fewer opportunities for challenging knowledge claims [12, 31]. This paper thus talks about two related concepts:

1. **Epistemology:** Which we introduce above, and is related to the philosophical analysis and conceptualisation of curriculum content and assessment for knowledge
2. **Epistemic Beliefs:** Which we now introduce, and relates to the intrapersonal, psychological conceptualisations that individuals hold regarding knowledge

Indeed, a key component of AfL may be the disambiguation of the epistemic requirements of questions – in terms of understanding the question, its context, and the knowledge required to answer the question [2].

Table 1 indicates four dimensions of epistemic beliefs, for which there is general agreement across the various models of belief³. These dimensions are useful to consider in relation to student understanding of knowledge domains. For example, in the context of search engine IR tasks, “epistemological beliefs are a lens for a learner’s views on what is to be learnt” [4]. In such tasks, student search activity may be analysed using the dimensions in Table 1 (e.g. [38]), providing a lens onto students’ understanding of their own learning, task demands, and how to meet those demands.

Table 1: Dimensions of epistemic belief (adapted from [39])

Dimension	Description
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 compartmentalised or interrelated, ranging from knowledge as made up of discrete and simple facts to knowledge as complex and comprising interrelated concepts
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
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

Epistemic beliefs are thus one example of the type of construct which sociocultural LA may probe. However, they are also a particularly *good* example given epistemic beliefs’ relationship to our everyday dealings with the world of information, and their relationship to pedagogy, assessment, and classroom practices [28]. Section 5 will discuss epistemic beliefs in relation to their measurement, but we shall first introduce some established approaches to pedagogy.

4. OUR LEARNING ANALYTICS ARE OUR PEDAGOGY

Buckingham Shum [6] has used the shorthand “our LA are our pedagogy” – a relationship which we explore in this section.

³ See e.g. [53] for a review of the multiple theoretical frameworks

4.1 Pedagogy and LA?

The relationship between LA and pedagogy is important because they are both bound up in epistemology – what knowledge is. This section explicitly introduces the relationship between a number of established pedagogic approaches and LA. These are not intended as comprehensive reviews, but rather as brief overviews of how the relationship between pedagogy and LA might be conceptualised. The following section expands on some key ideas here, before moving on to explicate the core topic of this paper – a sociocultural learning analytic – and one proposed instantiation of an LA based on this approach.

4.1.1 Transactional or instructionalist approach

Transactional approaches hold that learning entails the transfer of knowledge from the knower (teacher) to the learner (student). They are characterized by a perspective on assessment in which success is ‘out there’, in the degree of correspondence between the claims that learners make, and the facts that they have been taught.

Analytics Implications: LA based on transactional approaches – both in learning, and more broadly – will tend to focus on very simple metrics such as test scores and hit counters, as opposed to any deeper analysis of project outputs or processes.

4.1.2 Constructivist approach

Constructivist models hold that learning occurs in the guided experimentation of the learner (student) on the world, typically in classrooms in which such experimentation is age-targeted, and guided by a teacher. Constructivist models are likely to hold a notion of success which highlights construction, with learners experimenting with their environment, and being capable of using tools which are appropriate for their given age.

Analytics Implications: LA with a focus on constructivist approaches of learning will focus on *progress*, particularly through a set of materials, resources or tools selected and arranged by the teacher.

4.1.3 Subjectivist or affect based approach

Subjectivist perspectives can be characterised as deemphasizing learning qua academia, in pursuit of personal affect. While individual affect is a concern for educationalists, it is rarely if ever the *overarching* concern in the consideration of learning. However, for example in IR, subjectivist approaches are more interested in whether the user is ‘satisfied’ with the information they have found, than whether the information is ‘good’.

Analytics Implications: In tandem with other approaches, LA based on ‘subjectivist’ approaches are likely to provide motivation assessments for understanding *why* someone is (or is not) undertaking particular actions (see, e.g. [20]). Such analytics may focus on explicit moves (feedback forms, affect-based semantic markup such as blog tagging) alongside more implicit analysis such as sentiment analysis of communication data.

4.1.4 Apprenticeship approach

Apprenticeship approaches are sometimes used in LA with an interest in whether the learner has become part of a community of activity. In this view, success is about ‘being part of’ a given group; it is bound up in notions of communities of practice – that ‘to know x’ is to act towards x in some way that is defined by (or reflected in) the behaviours of some community or other.

Analytics Implications: Analytics based on apprenticeship approaches are likely to focus on classifying expert and novice users, and the shift from novice to expert. Such analysis may explore behavioural markers which mirror those made by

‘experts’, but may not explore the reasons or meanings implicated in such moves.

4.1.5 Connectivist approach

Connectivism [55] claims to highlight a perspective on epistemology which translates into a LA framework. Within this view, learning is about understanding how to connect ideas appropriately, and where to find such information. The suggestion is that in the case of the connectivist knower “the act of knowing is offloaded onto the network itself” [55]. Within this perspective then, success is about building connections between ideas.

Analytics Implications: Connectivist approaches use network analysis to explore the ‘connectedness’ of a learner’s knowledge – in terms of both concepts, and social connections. Analytics would look at how networks’ size, quality and changes over time can serve as proxies for effective learning.

4.1.6 Pragmatic, sociocultural approach

Pragmatic approaches (building on for example, Dewey [16]) hold that learning occurs in the development of – and negotiation of – a mutually shared perspective between learners. Such approaches focus less on truth – where truth reflects facts about the world – than how meaning is co-constructed, and used in context. Pragmatists suggest that, as human knowers, our conception of some given thing is bound up in our understanding of its practical application – and that is all. When we attempt to understand truth beyond such a conceptualisation of practical activity, we are likely to fail. Thus, success is in *use* – the measure of success is how useful the information is for the purposes it is employed; it is socioculturally embedded and mediated, and may be in flux as activities are defined and redefined.

Analytics Implications: Pragmatic approaches have traditionally focused less on assessing the products of learning (except where they are being used *for* something), and more on the process. Analytics tools in sociocultural approaches encourage learners to reflect on their own activity, in an attempt to understand how they can develop their skills in information processing, in their own particular contexts. Analytics within this approach might attend particularly to quality of discourse for learning, for creating a mutuality of perspectives [18] including in collaborative IR tasks [22, 27, 35]. Our previous work is in this tradition, drawing on sociocultural discourse analysis [40], argumentation theory [60, 61] and argumentation in sensemaking deliberation [45]. This research foregrounds *how* students interact with information; make sense of it in their context; and co-construct meaning in shared contexts. These are on-going processes which highlight the question of how LA fits into the context of AfL and pedagogy.

4.2 Epistemology and LA

The stance we take with regard to the relationship between epistemology, assessment and LA relates to the issue of whether we envisage analytics as a form of diagnosis on the one hand or a kind of biofeedback on the other – is LA (and assessment) the end point of, or a component of, pedagogy. In the former we seek to accredit learning through defining behavioural proxies taken as evidence of knowledge and competencies. LA may also be used to support learners in their own self-regulated learning activities, giving them feedback on changes they make and their impact on learning outcomes, but without – generally – making strong evaluative judgments regarding such changes. The former is thus more closely aligned with assessment *of* learning – often instantiated in high stakes summative assessment, while the latter is closer to Assessment *for* Learning – in which assessment is a continuous process through which formative feedback may be

given to further develop the students learning (see e.g. [3, 23]). If process-centric competencies are declared to be part of the summative assessment criteria, then the two categories converge.

The relationships highlighted in 4.1.1-4.1.6 serve as general pointers to the sorts of relationships we might see between pedagogy and LA. There we also highlight views on learning, alongside notions of how success may be defined within these approaches; that is, when these systems might accredit knowledge to the student. Fundamentally, this accreditation implicates epistemological stances regarding when knowledge may be claimed (or not). These are general claims, but illustrative of how such notions relate to those of LA, in particular notions of:

- **Mastering curriculum content:** this is the dominant focus of analytics approaches at present, seeking behavioural markers using e-assessment technologies of varying sophistication, in order to generate summaries at varying granularities, for both individuals and cohorts. (Particularly transactional and some constructivist approaches)
- **Evidencing membership and processes:** this approach to LA looks for behavioural proxies which indicate a student is part of a particular subgroup; positive feedback is given towards moving students into 'successful' subgroups, but little attention is paid to the qualities of those groups except instrumentally. (Particularly affect-based, apprenticeship, and possibly connectivist approaches)
- **Success is use:** this approach looks for students developing personal and collective representations of curriculum content, and engagement in sensemaking about not only this material, but also their own analytics. Social Learning Analytics [7, 21] in which students are encouraged and supported to do so may work towards this end. (Particularly pragmatist approaches).

These three broad conceptualisations of LA relate to the issue of whether or not we are deemed to consume, discover, or create (internally or/and externally) knowledge – is it 'out there' for us to take, do we need to investigate to find it, or is it formed in our developing understandings of the relationships between entities and the new representations we create in such activities? This is not a claim about the learning or pedagogy, but a related claim about the status of knowledge, and its assessment, which we discuss further in section 6.4 with reference to one particular example.

4.2.1 Pragmatism and sociocultural approaches to assessment

The nuance of claims surrounding epistemology and assessment is important. In the introduction we referred to research arguing that conventional exams are designed to maximise the reliability of results, at the cost of straitjacketing what can be defined as learning (poor internal or construct validity) and thus what constitutes evidence of learning (poor external validity). Moreover, if we are to argue that individual tokens of knowledge cannot be identified (and 'owned'), then we should accept that "the content of a specific item of knowledge depends in part on how it is related to other knowledge" [10]. Thus, sociocultural setting, interaction, and the purposes for which any artefact or knowledge – in the broadest sense – is being used, are all of fundamental importance in understanding how people make meaning, and learn. Contextual sensitivity is thus a key facet of pragmatist approaches.

Pragmatic approaches, broadly, are likely to focus on the dynamic nature of information needs, and the discourse and other artefacts

which mediate our relationship with information in the world. It is not a postmodern approach, in the sense that postmodern approaches take either a relativist approach (there is no fixed truth) or a normative one (the dominant theme is correct at that time) to knowledge, but rather one which focuses on use, and meaning, over accreditation of facts to things in the world.

4.2.1.1 Pragmatic Analytics Revisited

As described in Section 4.1.6, pragmatic approaches have traditionally focused less on assessing the products of learning, and more on the process. LA in these approaches might encourage learners to reflect on their own contextualised activity, in order to instil an ethos and capacity to become reflective practitioners. The key development with the emergence of digital LA is that previously ephemeral processes are now persistent, not just for researchers studying those processes, but for the learners and educators co-constructing those processes. Moreover, the process traces are now amenable to computational analysis which opens new possibilities for assessment and feedback, both formative, and possibly even summative (e.g. where the assessment regime defines those process skills to be an important form of student evidence).

Given the salience of context in this approach, it deserves further explication. As with LA generally, context may be taken as very mechanistic, for example the claim that a person in place/course/role/ability band 'x' should see resource 'y', or other approaches which would include time, topic, or social-group resource discovery. No doubt some of these features will prove useful, and indeed the use of semantic web technology in social learning analytics [21] may be particularly interesting. However, in addition to temporal, linguistic, aptitude, and geo-spatial markers, we draw attention to the following:

1. We emphasise the discourse in which, and through which, context is constituted [17, 44]. That is, we take the discourse to have a multifaceted role in constituting, and helping learners make sense of, the context.
2. Discourse is fundamentally associated with the sensemaking which occurs in respect of any particular task being undertaken; the *use* being targeted is fundamental to context. Stark examples highlight this importance, for example where we ask students to critique versus summarise a paper we expect rather different outcomes. Assessment regimes which make this explicit may facilitate capture of context around 'doing x for purpose y' LA
3. These assessment systems (2, above), and the broad range of tools, technological and otherwise, which people utilise also act as mediating artefacts impacting on how people perceive their task, and its solution – mediating the context of use.

We have, therefore, expounded a view of LA which highlights the importance of context. This relates to a salient point for epistemic beliefs that:

A sophisticated epistemology entails context-sensitive judgements. Thus they point out that it is not very sophisticated to view the idea that the earth is round rather than flat as 'tentative' whereas theories of dinosaur extinction do require a more tentative stance [1].

Similarly, building spurious connections between ideas as a way of indicating a complex view of knowledge (within the simplicity dimension) is likely to be less sophisticated than those who understand the need for moderation, and so on. Context is thus

key to understanding epistemic beliefs, the analysis of which seems highly suited to the *biofeedback* approach to formative assessment analytics, introduced earlier.

The next section further expands this claim in the context of psychological assessment of epistemic beliefs, firstly in ‘mainstream’ psychological approaches, and then that of the discursive approach – which similarly holds context and discourse to be fundamental to understanding thinking. Section 6 then returns to LA, drawing out the relationship between analytics, and the measurement of epistemic beliefs in our illustrative example for sociocultural, pragmatic analytics.

5. MEASURING EPISTEMIC BELIEFS

The complexity of epistemic cognition suggests a particular perspective on how we are to understand these beliefs. No approach ‘mirrors’ reality with a true, immutable, incontrovertible perspective on a learner’s epistemic cognition. This concern is a dual one. Firstly, it is a methodological concern regarding our access to the world, our ability to ‘get at’ what is out there. Secondly, it is a conceptual and psychological concern, regarding the nature of epistemic cognition and whether it itself is stable – developmentally, and across domains – or shaped in some way by resources or beliefs. These two concerns are reflected in the epistemic beliefs literature. Firstly, cognitive developmental models [33, 34] suggest that individuals progress through a sequence of increasingly sophisticated epistemic beliefs, while multidimensional perspectives [28; 52] suggest that epistemic beliefs can be separated into dimensions, within which levels of sophistication can be identified [24]. However, both of these assume a fixed uni-directional developmental trajectory, where beliefs are seen as global across (and within) domains. The resources view, in contrast, emphasizes the interaction of believer, with resources, highlighting that at various points in any task a cognizer may invoke differing resources [25].

Secondly, methodologically the developmental models have tended towards interviews and laboratory tasks, while multidimensional models have emphasised paper and pencil self-report measures [14]. Both of these approaches reflect the fixed perspective on beliefs from which theory they stem. Importantly, although three major survey instruments have been developed and deployed, – including in IR tasks [37, 52] – they are heavily criticised for their psychometric properties [14]. Furthermore, while some studies have used interview [1, 39], think-aloud protocols [1, 19] or systematic observation [51] such methods may be limited in their insights, particularly where self-report data is to be used and interpreted by researchers. Importantly, they are also not appropriate for the study of online, collaborative, or geographically and temporally spread activities – in particular, online IR, or information processing more broadly. These approaches reflect the epistemology of current assessment regimes, as indicated in Section 2, and seem to implicate the view of ‘fixed’ psychological constructs – whether intelligence, or epistemic beliefs, as further discussed throughout Section 3.

In contrast, while those adopting a resources view of epistemic beliefs may also utilize such methods – in particular those involving think aloud and interview data – they also accord well with Österholm’s discursive stance, which suggests that we should not see beliefs and communication as “two separate ‘objects’ that can affect each other, but as more integrated aspects of cognition and/or behaviour” [42]. The resources view describes “the activity, the discourse, as the site where epistemological beliefs come to existence, through explicit or implicit references to prior experiences (epistemological resources)” [43].

Österholm’s argument is that the resources perspective can be combined with Hammer and Elby’s [25] resources model. In this model epistemic beliefs are not viewed as fixed, or developing cognitive models ranging over one or more domains, but are rather seen as dependent upon the resources available to the cognizer at any time. This view of epistemic beliefs as “theory-in-action” – in which context, domain, culture, and task conditions interact – accords well with the idea that context is fundamental to understanding meaning.

5.1 Learning Analytics and Trace Data

While Österholm is primarily interested in spoken interactions, LA may extend this interest into the exploration of users’ interactions with artefacts. A tool for such analysis may come through the use of trace data, which is more or less implicitly created by the student. For example, Stadler and Bromme [56] analysed the ways participants found, extracted, and moved information – which could be used to explore information about their beliefs (e.g. visiting few websites indicates trust in those sites visited [24]). Importantly in this study, users were either given evaluation prompts regarding multiple documents in the medical domain, or not, and those who received such prompts subsequently recalled more facts and were better able to evaluate sources. If systems of prompts promote laziness, we should be concerned. Where, however, they improve outcomes, analytics should explore the best ways to implement them effectively and sustainably to support high quality pedagogy and AfL.

Furthermore, Greene et al. [24] point out that many behaviours which would ordinarily be difficult to observe can be explicitly elicited in the context of Computer Based Learning Environments (CBLEs), for example:

...participants who report belief in objective truth and omniscient authority may self-regulate quite differently than participants with a desire to evaluate multiple forms of justification. Likewise, participants who believe in the inherent subjectivity of all knowledge may, on average, select more representations than those who look for an objective truth. [24]

The claim is thus that epistemic beliefs will be brought to bear on knowledge tasks in ways that can be meaningfully captured, in particular using technology systems (e.g. the way people represent knowledge in mind maps). Trace data thus offers direct access to real-time behaviours in unobtrusive ways, and is thus high in external validity, although it is of course within the context of the system which is set up to capture such information. Furthermore, while trace data is unobtrusive, it may give an incomplete picture. In particular, people may have reasons for some behaviours which cannot be probed using such data; these reasons may range from epistemic (as discussed above, for example with regard to the ‘flat earth’ issue), to practical (ICT failures), to pragmatic (the demands of the task place a short time restriction on the activity), and so on. Thus, it is important to remember that while analytics regarding epistemic beliefs may be – at best – a dirty lens onto those beliefs, when analytics are considered *in action* as a tool for sensemaking, they may provide an insightful tool for learners to dissect their own metacognitive and self-regulatory behaviours.

6. TRACE FOR EPISTEMIC BELIEFS

Trace data thus provides one means by which epistemic beliefs could be examined. However, trace could refer to many things, and as discussed in sections 4.1.1-4.1.5 the data collected may not represent an appropriate teaching epistemology, nor capture adequately student epistemologies (see section 2). The next section will discuss some LA which may address this issue.

6.1 LA – Tools for Trace?

Building on sections 4.1.1-4.1.5, we can identify a number of analytic tools and their relationships to particular forms of data. Some forms of analytics rely on a belief that particular methods (self-report in particular) are: a) true reflections of reality, b) whole reflections of reality (i.e. they cover all the relevant ground) and c) probe ‘real’ constructs. However, while self-report measures may be useful particularly as discussion prompts with students, they are not necessarily *the most* useful approach for many purposes. In both assessment and psychological testing, they suffer from issues of validity (Sections 2 and 6.2). Thus, other LA tools may prove more useful.

Much LA thus delves into network analysis, in relation to social-networks, or in relation to concept networks based upon semantic relations identified more or less explicitly by the student. While these approaches offer useful insights into the sensemaking process, they too can fall into the trap of ‘accrediting’ group memberships, over group activities (section 4.1.4) or map networks, as opposed to map uses (section 4.1.5).

An interesting notion then, is attempting to delve further into the sensemaking significance behind particular semantic moves in a given environment. Thus, Greene et al. [24] (see 5.1) described one method of trace analysis for epistemic beliefs built on information moves. Other examples of such trace capture could also be structured such as to gather student data in particular ways – some of which may be quite naturalistic (capturing search queries, or Facebook posts to explore ‘problems’ encountered, or interactions made [36]), and others of which might push students into information structuring activity in which they would not otherwise engage, such as argument mapping.

6.2 Trace and Traceability

However, in encouraging such structuring by learners, and claiming capture information about what they are doing, some may argue that we are simply reifying the constructs we have set out to explore. That is, if we are interested in epistemic beliefs, and set up a system to push students to make epistemic beliefs explicit, it does not matter whether those students *have* underlying epistemic beliefs because the system forces them into making some (it makes them reify). While for psychologists who wish to uncover underlying beliefs this is problematic, we do not see this as a concern for our project, because in our discursive, sociocultural, pragmatic approach the interest is in beliefs as “theory-in-action”. In this view, the claim is not that the measurement of beliefs is not possible, but rather that when we take measurements, the discursive context is fundamental to the practices being observed, and the ways that the beliefs are instantiated in action. Thus, LA provides a means to tackle the static, decontextualized view of epistemic beliefs instantiated by questionnaire methods, offering a more authentic perspective on epistemic action than experimental contexts.

6.3 Discourse-centric Trace – A Path to Epistemic Cognition

A number of tools can be conceptualised to probe trace gathered around higher order thinking exercises, and some already exist. One example – which will be used for illustrative purposes here – is being developed at the Open University, based around the Cohere argument mapping tool [5] and previous work on sociocultural discourse-centric LA [36]. Cohere is a web application for mapping ideas, concepts and arguments, which can be annotated directly onto source websites. Users enter ideas – nodes with meaningful classifications – and are then invited to

“make the connection” with meaningfully labelled edges, to create a conceptual graph. Both ideas and connections may also be tagged, to add a further level of semantic data. Cohere is designed as a tool to enable users to build their own structures, but also to share these, and integrate the nodes and connections of other users, thus building up communities of enquiry around particular disciplinary topics.

Cohere facilitates exploring the ways that users create nodes, and the epistemic implications of such creation. At a basic level, this could simply be an analysis of the number of idea and connection types used. A more advanced analysis might compare individuals’ Cohere use on the same task, and provide analytics based on such comparison; these notions are discussed further below. However, neither of these explores the semantic qualities of ideas and connections. Using the broad epistemic ‘dimensions’ described above (Table 1) some correspondences between those descriptors, and possible trace can be identified as in Table 2⁴ which also gives ‘suggested guidance’, intended to be indicative of the sorts of challenges which might be posed to students to extend their epistemic cognition and probe their learning processes.

However, within the approach described above it should be understood that while the trace data given here is theoretically tied to the constructs, both the constructs and the trace should be seen in their situated context – as components of a sociocultural environment, interacting with the relevant agents (students, teachers, designers, etc.), and the wider cultures and subcultures. Thus, the possible trace markers and guidance are conceptually related to the work discussed above but these should be dynamic tools, and empirical work will be needed to explore the relationship between feedback given, representations allowed, student responses to feedback and the impact of this on learning.

6.4 Many Lenses on Epistemic Beliefs

Table 2 thus proposes one set of traces from which meaningful data could be captured. This is not, however, to dismiss other approaches discussed in Section 4.1. The epistemological approach discussed throughout this work is instead intended to indicate that what drives our Learning Analytics – and assessment – is not *what they are*, but rather, what we *do* with them. Our suggestion is that many of these approaches to LA – these dirty lenses on the world – provide insights into different levels of learning, and tools for meaning-making. For example, with this richer than normal data model in place, it is very simple, computationally, to feed back the number of ideas, and connection types used, but this may provoke meaningful dialogue regarding what these other types might be used for, or why they have not thus far been used. Similarly, constructive discourse might occur around the reasons why one student’s map is more connected (but perhaps not appropriately so) than another’s.

⁴ Following previous work [36] the basic analytic statistic is constructed as a percentage representation of the target type, over the total types created by the user. For example, the number of ‘opinion’ nodes created, as a percentage of the total number of nodes created by that user.

Table 2: Trace & Guidance for Epistemic Beliefs

	Trace	Guidance/Challenge
Certainty	Presence of competing claims (e.g. supports/challenges). Presence of stability markers – e.g. current references, geographic repetition.	Are there two sides to this idea? Could you explore XY contrasting example? Is this idea consistent across time/place? Have you looked at XY map?
Simplicity	Number of connections between nodes.	Are any of these ideas connected? Have you considered how WX and YZ might be connected?
Source	Presence of ‘I think’ or restatement of fact, few additional nodes made other than those created as quotations.	What do you think of these ideas? or How does the evidence relate to your view?
Justification	Judgments of relevance, and supporting or explanatory notes (‘this evidences/ explains x’). Ties to method ‘ideas’.	What evidence do we have for this idea? Is it ‘good’ evidence? Why/why not?

There is a strong relationship between analytics, assessment, pedagogy, and epistemology (Figure 1), which sociocultural analytics bridges well. Our approach should be seen as one of ‘many lenses’ for many contexts, used in combination with the more conventional forms of LA currently dominating. In the last section before concluding, we outline how the approaches discussed in Section 4.1 relate to epistemic beliefs, and some strengths and limitations of these approaches.

6.4.1 Lenses Onto the World

LA based on Transactional approaches. Approaches which emphasise fixed, ‘correct’ knowledge, over how those facts are used to display understanding, are likely to encourage lower epistemic cognition, and implicate more ‘realist’ epistemologies which see knowledge as a reflection of ‘things’ in the world.

LA based on Constructivist approaches. Similarly, there may be an overemphasis on a limited *range* of knowledge in constructivist approaches which emphasise development qua progression, but without considering the sociocultural context in which that progression occurs, nor the wide range of uses for which it may be deployed. This may be particularly true in constrained systems which guide students through pre-set tasks and levels of attainment to meet, pre-specified software, and so on, as compared to those exploring knowledge co-constructed in iterative dialogic discourse [49, 50]. Understanding the ways that students build knowledge claims – understanding connections, justifications, change over time, and nuance – is fundamental to understanding their epistemic beliefs. Knowing that a student is at stage x of y in development may be less significant.

LA based on Apprenticeship approaches. In a similar vein, apprenticeship approaches can offer useful insight into group membership and the development of a student’s thinking. However, the approach described in this paper suggests the best way in which to think about such approaches is with respect to the

functional role that such community membership plays in a student’s epistemic action, and their normative standards.

LA based on Subjectivist approaches. LA based on ‘affect’ could be useful to analysis of epistemic beliefs, with their analysis of ‘satisfaction’ with information, e.g. enquiry based learning [20]; self-efficacy in IR [58]; satisfaction with search results [30]. As such, affective analytics might be used to explore whether learners are prematurely satisfied with findings that a peer or educator deems to be inadequate, or if they have an appropriate sense of disquiet or frustration with a flawed argument or methodology.

7. CONCLUSIONS

This paper started with the premise that assessment, pedagogy and epistemology are fundamentally entwined. Furthermore, we suggested that a focus on high stakes assessment – which learning analytics may well be used to perpetuate – is detrimental to the wider enterprise of education, prioritising the reliability of tightly defined assessments over continuing, formative assessment for learning, and authentically situated learning which is harder to fit into formal examination contexts. This is problematic in so far as it limits the ways we can challenge students in assessments, and fails to reflect their encounters with knowledge claims in the world beyond the classroom walls.

We have highlighted that transactional approaches may emphasise use of facts; constructivist the broad (and contextual) application of skills; subjectivist the self-efficacy and motivators of students; apprenticeship the dynamic practical based learning which may occur through high level membership of communities of practice; connectivism the ability of students to build up, link and curate their knowledge ‘networks’. A sociocultural, pragmatic, approach may offer an additional toolset, alongside a theoretical frame through which to use other LA lenses. All are partial (in bias, and hence in their coverage of all that might be measured), but may be used in complementary ways.

Analytics from user traces provide a means to track and record previously ephemeral process data, which could benefit assessment *for* learning in significant new ways. Pragmatist approaches, which emphasise use and meaning-making over the accrediting of true statements may have an important role here. The grasp of curriculum facts and methods remains critical but the emphasis shifts to their effective, contextualised use, in argument structures, in discussion, in problem-solving. A focus on the sociocultural learning system draws attention to how analytics take into account the centrality of discourse for sensemaking, and in constituting “context”.

We have gone beyond “our learning analytics are our pedagogy” [6], arguing that they embody epistemological assumptions, and they perpetuate assessment regimes. Moreover, as with any tool, it is not only the design of the tool, but the way in which it is wielded in context, that defines its value.

8. ACKNOWLEDGEMENTS

We are grateful to Cindy Kerawalla and 3 anonymous reviewers for helpful comments on an earlier version of this paper.

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