Towards the Design of A Representational Tool To Scaffold Students' Epistemic Understanding of Psychology in Higher Education

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Abstract. The paper calls for a consideration of students' understanding of the nature of knowledge and knowing (termed their *epistemic cognition*) in the design of AIED applications in ill-defined domains. The importance of students' epistemic cognition is discussed with reference to both the characteristics of ill-defined subject matter in general, and to specific domains. It is suggested that, although common characteristics can be identified across many domains, the nature of knowledge, such as how knowledge is justified, is different in each area of study. Hence a domain-specific consideration is also necessary in designing effective applications. The paper discusses an interview-based study of psychology students' epistemic cognition in the context of writing a formally assessed essay. The findings inform the preliminary phase in the design of a representational tool to scaffold student learning. Although current representational tools are powerful, they do not scaffold students' epistemic understanding of the subject matter. The present design aims to address these issues.

Introduction

The distinction between ill-defined (or ill-structured) and well-defined subject matter has, typically, been made in the context of problem-solving [1]. Well-defined problems consist of a well-defined statement that presents all elements of the problem to the solver, and a finite number of operations that can be applied to reach a solution. A solution is unambiguously either correct or incorrect. In contrast, the initial and goal states of ill-defined problems are subject to interpretation, there is no formal structure to the problem-solving process, and the adequacy of solutions is judged against ill-defined criteria. This distinction has been taken to the level of domain [2, 3]. Well-defined domains are defined as those in which many phenomena are described consistently across cases by scientific principles and formal models. Examples of such domains are chemistry and physics. Ill-defined domains are those in which the phenomena under investigation cannot be conceived of within a well-defined framework, as the concepts involved cannot be ascribed a well-defined meaning. Moreover, the methods of investigation and analysis are subject to the same ill-definedness. Examples of such domains are psychology, philosophy, art and history.

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Kitchener [4] discusses the different processes involved in solving well-defined and ill-defined problems and argues that solving ill-defined problems is different in that it engages a level of processing above cognition and metacognition, which she terms *epistemic cognition*. This level of cognitive processing "is characterised as the processes an individual invokes to monitor the epistemic nature of problems and the truth value of alternative solutions" (p.225). There is a growing body of research on people's, particularly students', epistemic cognition under a variety of terms, such as epistemological beliefs, personal epistemology and epistemic resources [5-8]. At the risk of simplifying a complex concept, it can be said that a sophisticated understanding of knowledge and knowing entails an understanding of the complex, socially constructed nature of knowledge. Findings strongly suggest that epistemic cognition is linked to academic learning, and that the majority of students lack such an understanding of knowledge [9].

The paper first considers the characteristics of ill-defined domains and the difficulties they pose to learning. The concept of epistemic cognition and the importance of considering it in the design of AIED applications are then discussed within the context of ill-defined domains. More specifically, epistemic cognition is discussed in relation to both the general characteristics of ill-defined domains and the nature of knowledge and knowing within specific domains. It is argued that there are important domain differences in how knowledge is developed and how it is justified. Hence, it is suggested that, although ill-defined domains share common characteristics, it is necessary to also consider the nature of knowledge in specific areas of study when designing AIED applications. The paper then focuses on the domain of psychology and discusses preliminary design considerations of a representational tool to scaffold student learning. The design is grounded in an interview-based study of psychology students in higher education.

1. Ill-defined domains

1.1. Characteristics of ill-defined domains

The notion of ill-definedness has been considered, predominantly, within the context of problem-solving, but also at the level of domain [2, 10]. Similar characteristics have been identified at both levels of analysis. This section considers two analyses that come from an educational perspective. Jonassen [11] defines ill-defined problems by the following criteria: (a) they involve unknown elements, (b) there exists no unambiguously correct solution, there may be multiple solutions or no solution, (c) many paths exist to solving the problem, the validity of which cannot be judged by absolute criteria, and (d) solvers are often required to make personal judgements. Lynch et al. [10] consider ill-definedness at the level of domain and identify the following five characteristics from a review of the literature: (a) the lack of unambiguous criteria by which to verify the validity of solutions to problems, (b) that the development of formal theories is not compatible with the nature of ill-defined domains, (c) that even at a novice level solving problems in ill-defined domains involves a process of design and not application of formal theories, (d) the ubiquity of concepts that cannot be ascribed an absolute definition, and (e) that problems cannot be decomposed into independent subproblems. Both the above analyses consider similar

issues. Ill-defined subject matter is characterised by concepts that cannot be ascribed a precise meaning. Hence the issues we are dealing with, how we reason with them, and how we evaluate our reasoning, also cannot be defined precisely.

1.2. Learning in ill-defined domains

Even within a constructivist framework, students must be given some form of 'building blocks' with which to construct. These 'building blocks' must be accepted by the learner at face value, because they form the domain itself, the questions that are asked and the ways in which these are addressed. Learners must comprehend what the knowledge constructing enterprise within the given domain is about and what tools are used to develop knowledge, before they can go on to develop their personal understanding of it. Given the above characteristics of ill-defined domains, these 'building blocks' cannot be defined precisely. The complexity and ambiguity are present at the novice level. Understanding knowledge in ill-defined domains and how to construct it requires an understanding of how to work with this complexity and ambiguity to reach conclusions. In other words, understanding the processes involved in justifying knowledge. This relates to one's understanding of the nature of knowledge and knowing (*epistemic cognition*), which is discussed in the following section.

2. Epistemic cognition

2.1. Defining epistemic cognition and its importance in learning

Epistemic cognition is a slippery concept that is difficult to discuss in concrete terms. It is, broadly, defined as people's ideas about the nature of knowledge and knowing [9]. It is, typically, conceived of as deriving from philosophical epistemology, which is concerned with the nature of knowledge, its sources and limits [12]. Beginning with William Perry's [8] empirical work on students' intellectual development, educational psychologists became interested in individuals' understanding of the nature of knowledge and knowing. However, the link between philosophical epistemology and epistemic cognition is not direct, although this is not clear in the literature. Epistemic understanding is conceived of in an educational sense. For example, when considering people's ideas about the source of knowledge, researchers are not referring to their beliefs about the fallibility of the senses, but to their understanding of knowledge as something that is constructed by the learner, rather than coming from authority. For the purpose of illustrating what epistemic cognition refers to (though an oversimplification), it can be said that conceptions range from viewing knowledge as a direct representation of an objective truth, to understanding that knowledge is relative to methods of observation and conceptual analysis with some positions better supported than others.

Several theoretical frameworks have been developed to describe this aspect of people's thinking (e.g. personal epistemology [9], epistemological resources, [5], epistemological beliefs [6]). Although there are similarities, in essence, each approach reflects a different conceptualisation and each dictates a different methodological approach. These differences are fundamental. Is epistemic cognition a trait-like characteristic that develops in 'stages', a multidimensional system of independent

beliefs, or a set of context-dependent resources? Can it be 'measured' independently of context by interviews and questionnaires, or only deduced from specific contexts? This lack of a coherent theory and methodology has impeded research into this important aspect of learning going beyond a narrow audience within educational psychology. However, despite this theoretical abstruseness, research to date strongly suggests that it plays a significant role in learning. Empirical findings have related epistemic cognition to various aspects of learning, such as cognitive processing strategies, conceptual change learning and academic achievement (see [9] and [13] for an overview of the main frameworks and empirical work).

The approach adopted in the present research will be described at a general level, as it is beyond the scope of this paper to consider theoretical issues in detail. Epistemic cognition is defined here as people's understanding of how knowledge is justified (what makes a belief knowledge). In other words, not only a high level idea that some positions are better supported than others, but an understanding of why. It is conceived of as a context-dependent conception and not a stable belief that guides behaviour. In accordance with a sociocultural approach, it is postulated that epistemic cognition is formed through the way that knowledge is communicated to learners from experts, written materials, and their discussions with peers. The implications of this are that the way that we design teaching applications will impact on how learners understand the nature of the subject matter. And that, in order to understand how students' conceptions are formed and how we might support a more 'sophisticated' understanding, we need to study how they engage with subject matter in specific educational contexts.

2.2. Epistemic cognition in relation to ill-defined domain characteristics

A theoretical analysis places epistemic cognition at the centre of learning in ill-defined domains. Students' understanding of how knowledge is justified will determine their conception of what domain knowledge is and how to go about understanding it. For example, students that conceive of knowledge as a direct representation of reality that is justified by direct observation will likely seek the 'truth' amongst conflicting interpretations and alternative solutions. For example, a history student that views knowledge as accurate accounts of past events will likely conceive of knowledge constructing as identifying the truth in historians' interpretations. Even if students understand that knowledge is a socially constructed representation that emerges from considering empirical evidence and reasoned argument, they may not fully understand how empirical evidence is based on theoretical frameworks. For example, a psychology student that understands that 'intelligence' can be defined in many ways, but lacks an understanding of the dependency of empirical evidence on the method by which it was collected, is likely to draw unjustified conclusions from it.

Therefore, in communicating the nature of ill-defined subject matter, we need to also communicate to students that concepts can be defined, valid solutions can be reached in spite of uncertainty, and that personal judgements need to be justified. There is strong evidence that many students view knowledge as 'discovery' of reality or an utterly subjective enterprise [9]. Thus we need to consider what conception students are forming from the educational experiences we design and how we can support them in understanding how knowledge is constructed. This should be considered at the level of domain. Each domain deals with different areas of experience and so the nature of the

subject matter and, consequently, how knowledge of it is justified are different, as discussed in the following section.

2.3. Epistemic cognition in relation to specific domains

Although domains can be classified as well-defined or ill-defined, there are important differences between them. For example, the design of a usable interface to an airport control system, answering a question on the impact of colonisation on the culture of aborigines, critiquing the literary status of a particular novel, diagnosing a medical condition, considering the legal justification of a war, and considering the influence of the home environment on children's self-esteem, are all ill-defined subjects. However, the nature of knowledge in each is quite different, as is the process of answering them and justifying the validity of that answer. For example, what counts as justification in philosophy is reasoned argument, what counts as justification in cognitive science is empirical evidence derived from a reasoned theoretical framework, and what counts as justification in a court of law is reasoned argument based around empirical evidence that is of a different nature.

Knowledge domains have been categorised along other dimensions, such as Biglan's [14] classification along the hard/soft, pure/applied and life/non-life dimensions. Each categorisation will necessarily generalise on domain differences. The well-/ill-defined dimension is not criticised as irrelevant. Rather, it is argued that if the aim of AIED applications is to teach domain knowledge, this distinction is not adequate on its own, particularly if we consider what the nature of knowing is in each domain.

It is a difficult task to consider the nature of knowledge and knowing. This is not least because there is no correct way of conceiving of it. Scientists, science educators and philosophers of science disagree between and amongst themselves about the nature of human knowledge [15]. Moreover, ill-defined domains in particular are characterised by the lack of a single paradigmatic approach to knowledge development. However, this does not mean we can ignore the issue. In designing educational technology we need to consider what conception of knowledge and knowing we are communicating to learners.

2.4. The design of AIED applications to support epistemic understanding

Research within the AIED community has considered the impact on learning of many learner characteristics, such as motivation and metacognition [16]. Particularly as there is an increased interest in designing applications for ill-defined domains, it is timely to consider the impact of epistemic cognition on learning. This is not meant to imply that epistemic cognition is not relevant to learning within well-defined domains. For example, there is substantial research that investigates how to convey the notion of "science-in-the-making" as opposed to "science-as-discovery", particularly within the context of collaborative systems [17]. However, it is especially relevant to teaching ill-defined subject matter, as working with knowledge from a novice level requires an understanding of the relative validity of different theoretical ideas and methodological tools.

Computer technology is potentially well-suited to teaching the epistemic nature of ill-defined subject matter [2, 18, 19]. For example, non-linearity allows the context-

sensitivity of concept definitions to be illustrated by linking multiple definitions of concepts to different contexts. The structure of arguments and counterarguments can be represented visually. Case studies and evidence for and against a claim can be represented in various mediums. The strength of links between claims and arguments or evidence can be represented diagrammatically.

Some research into collaborative systems has considered learners' epistemic understanding [17]. This has focused on issues of representing knowledge to learners. For example, Belvedere [20] allows students to link hypotheses to data that support or falsify it. SenseMaker [17] uses argument maps to scaffold an understanding of the relationship between theory and evidence. However, such systems to date have focused on well-defined domains. Mapping representations have been used to represent ill-defined domains (for example [21, 22]), and although they are complex and powerful, their design does not relate to an epistemic understanding of the subject matter. Some systems scaffold an understanding of the complexity and structure of the subject matter [23], but not an understanding of the validity of claims and how this is assessed. The aim of the research described in the following sections is to explore how students' epistemic cognition shapes their approach to constructing knowledge of ill-defined subject matter in the domain of psychology. The further aim is from this research to develop a representational tool to explore how engaging them in representing material in a particular way might challenge their conceptions of the nature of knowledge.

3. A study of students' epistemic cognition in psychology in higher education

3.1. Study description

3.1.1. Study design

The aim of the study was to explore the impact students' epistemic cognition may have on the way they approach learning in an ill-defined domain. The domain was psychology, and the learning context was a formally assessed essay. Essay writing is not simply a process of utilising knowledge that has already been constructed (as in an exam), but involves a process of research and learning. Thus it allowed the opportunity to explore how students' epistemic cognition might shape the learning process within this context.

3.1.2. Participants

Eight participants were recruited from psychology courses at the University of Sussex that required them to write an essay as part of their formal assessment. Half were undergraduate students in their second year of study (all female with an age range of 20 to 41) and the other half were taught postgraduate students (3 female and 1 male with an age range from 25 to 37). They were paid for their participation in this study.

3.1.3. Data collection

Participants were interviewed twice, once before and once after they had completed their essay. Interviews were semi-structured and lasted approximately 45 minutes. They were asked to keep any handwritten notes, keep track of literature searches and

also include diary-like comments on anything that stood out during the writing process. They were also required to write their essay on a Microsoft Word document that was set-up with a macro to save a version of the document every 15mins.

The first interview focused on the essay writing process and included questions on their view of essay writing as a form of formal assessment, their perception of what structure an essay should have, commonalities in their writing process from past experience, and the tools they use (e.g. paper, mind-maps, word-processing). The second interview focused on the way they organise the material and prompted them to explain the specific subject of their essay, whether they have formed an opinion on the subject, whether they believe it is possible to form an opinion, their assessment of their knowledge and how they justify this assessment.

3.1.4. Missing data

Participant G dropped out after the first interview. The data from the Microsoft Word logs was incomplete for participants E, F and H, and participant B did not use the correct file.

3.2. Study findings and design implications

The data was analysed as separate case studies, as the small number of participants did not allow for any aggregation or statistical analyses. The aim was an in-depth analysis of individual students' approach. The analysis is not yet complete, so this section does not present the final findings from the study, only a subset. It is also beyond the scope of this paper to consider the theoretical aspect of the analysis that relates to the definition and study of epistemic cognition. Space limitations do not allow a detailed consideration of each case study or even the report of detailed quotes from the interviews. However, meaningful themes can be drawn out from the data. A few of these are presented together with design implications for a representational tool.

3.2.1. Knowing does not involve having a personal perspective

Participants B, C, D, E, F and H emphasise their lack of expertise that prevents them from being able to critique research findings. Participant E says she may sometimes disagree with experimental design, but would not have a better idea of how to design the study. Participant D reports she has great difficulty in forming her own opinion, as there is always conflicting evidence. Moreover, in the way they approach researching and writing their essays they do not appear to be trying to form their own opinion of the material. The issue is not that they report they cannot claim an opinion. Rather it is that, despite this, they mostly rate their knowledge as high. This indicates, that knowing for them is equated with knowing of 'stuff', of experts' opinions within the field, not of forming their own conception of it. It can of course be argued that, although the interview questions emphasised a broader context of knowing outside of the given assignment, they were possibly considering knowledge within the limits of their student status. However, although they cannot be expected to have such depth of understanding, as learners it should be something they strive for and consider part of knowing. A representational tool that highlights agency in knowing as a part of a knowledge representation may at least probe them to consider a more active role of themselves as learners in the knowledge constructing process. One way of achieving

this might be to require students to evaluate their confidence in the certainty of claims and the degree to which they understand the links between claims and empirical evidence (possibly using a colour coding scheme). For one participant at least, the interviews suggest that when asked to elaborate on their knowledge they began to question their knowledge ("yeah, quite a lot I don't know actually").

3.2.2. Considering the context of knowledge

Some participants indicated they had difficulty understanding the context-dependency of ill-defined concepts. For example, participant C does not consider the specific definitions of educational practice and culture that are adopted in the research she discusses and that this is only a subset of possible definitions. She does discuss the relative validity of different studies. However, only in terms of problems with their design, not the theoretical framework they are based upon. Participant E discuses that there are many factors that could be impacting on the social problem of bullying, but does not consider the contextual issues in the study of these factors. A representational tool could highlight this context-dependency of concept definitions by prompting students to specify how they were defined in a particular study. This could also highlight issues in comparing findings across studies and how, in the domain of psychology, the conceptual analysis of an issue impacts on what is considered important in empirical investigations.

3.2.3. Dealing with an unlimited conceptual space

Unsurprisingly, participants found it hard to narrow down the essay question to a scope they could manage. Participant C deals with this difficulty by first deciding what she wants to say, according to what argument she thinks is easiest to support, and then fitting the evidence to support her argument. She says "when writing your paper you can tweak it to make it look more valid, use stuff that supports your point and leave stuff that doesn't". The scope of her paper is quite limited, though she does not consider this an issue, and her self-assessment of her knowledge on the question is very high. Participant D talks in some detail about the difficulties she encountered when beginning a university course in history, where there was far less structure in the material that was given to her. She spent hours reading information, unable to filter through what was relevant. She has now consciously adopted the strategy of first reading textbooks and deciding what she wants to say and then focussing on specific research articles. She gives quite a broad overview of the topic, and indicates she has difficulty conceiving of it in a narrow sense. She says that the more she thinks about it the more things there were to include. Both participants face difficulty with the lack of boundaries in the conceptual analysis of the essay question. One could legitimately question how much understanding participant C has gained from the experience, as she deals with the difficulty by treating the exercise as a 'game'. Participant D attempts to form a broader picture of the issues, but is overwhelmed and is unable to integrate all the information into an understanding of her specific topic. She still, also rates her knowledge as quite high.

Both participants may be assisted by representing the broader picture of the issues, not only of the areas they have read about, but also of those that they are aware exist, but they have not had the time to study. Also indicating their perceived level of understanding in each area might also help to guide their learning. In the case of

participant C, it may help her understand the limited scope of her conceptual analysis and possibly prompt her to re-evaluate her assessment of her knowledge. Participant D may be aided in visualising what she does know and the adequacy of this for the purposes of the given essay, as opposed to fearing that she has not covered enough material. She may then be able to integrate and make sense of the material that she has covered.

The issue is that they are novices and, obviously, cannot cope with the full scope and complexity of the material. But they also have no conception of what their scope of understanding is or any guidance as to what level of consideration is appropriate. Knowledge of the specific issue cannot be isolated, it is embedded in the larger picture, which D is aware of, but does not know how to cope with, and C does not appear to be aware of. There is a need to represent that knowledge cannot emerge from a narrow consideration of a topic, but, equally, does not require a consideration of every conceivable issue.

3.3. Study limitations and future steps

The small number of participants allowed an in-depth analysis of their experience in this specific learning context. It also meant that the extent to which the findings can be generalised is limited. However, the results suggest that these students at least were facing difficulties in understanding the nature of their subject and that this had an effect on the particular learning experience. Given the ubiquity of essay writing as a form of formal assessment in higher education, this will not be a problem confined to a handful of learning experiences. We need to consider how the way we are representing knowledge to students, and the way we are asking them to represent their own knowledge, impacts on their thinking and learning.

The design process of the current tool is still at the early stages. Further research will explore what representations may be more effective in communicating a desired conception of knowledge and knowing. At the moment it is conceived of as a concept-mapping tool that students will use during the researching and writing of an essay. It will require them to identify aspects of their thinking such as their conceptual analysis of the relevant issues, the sources on which they based this and the adequacy of it. It will also include a representation of the empirical evidence that they use to support claims and how it addresses the issues identified in the conceptual analysis. It will also prompt them to rate (and possibly justify) their understanding. The results of an evaluation of such a tool will inform whether requiring students to represent their knowledge within a particular framework can influence the way they conceive of it.

4. Concluding comments

The aim of this paper was to highlight the importance of epistemic cognition in learning in ill-defined domains. Domains differ in the way they justify knowledge claims and this is an integral part of developing domain knowledge. There are, of course, many factors that affect learning in any given context. Research within the AIED community has evolved from its early roots in intelligent tutoring systems to designing technology-enhanced learning contexts of increasing complexity, such as collaborative learning and augmented reality. It has also expanded into a theoretical

framework of learning that goes beyond the cognitive to include the metacognitive and motivational aspects of learning. The present research takes this a step further and calls for an exploration of how students' epistemic cognition impacts on learning and how the design of AIED applications can scaffold students understanding of the nature of knowledge and knowing.

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