MANIFOLD RELATIONAL UNDERSTANDING:
Moving beyond the mind-as-container metaphor in Educational Technology

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ABSTRACT

This paper calls for a change in our theoretical perspectives on the nature of understanding as ideas embedded in the mind-as-container metaphor. In particular, it is suggested that we should adopt Bereiter's [1] postulation that understanding is best understood as resulting from the ways an individual may be positioned relative to the knowledge object. As such, it is proposed that understanding be viewed as an emergent phenomenon resulting from interacting relational perspectives. This form of understanding, herein termed manifold relational understanding, is contrasted against current mental models approaches and a study designed to foster manifold relational understanding is discussed. Implications for the design educational technology are examined.

1. INTRODUCTION

In this paper I argue for a change in theoretical perspective on the concept of understanding. I suggest that current educational designs take strong advantage of the effects we can achieve from the use of computer mediated discourse [2]. However, to now move forward and produce more effective collaborative knowledge building environments we must, as Carl Bereiter [1] suggests, abandon the "mind-as-container" metaphor and along with it our current notions of understanding that are embedded within that view.

Many of the criticisms that our current school systems face can be traced back to the idea that our students are graduating with poor understanding or clear misconceptions of the subject matter that was covered [3]. Indeed, participation in the knowledge economy requires that students not only have a deep understanding of their knowledge, but that they also have the ability and metacognitive skills necessary to deepen their understandings when they so choose. Hargraves echoes this point when he states: "A fundamental issue we have to address is whether we are serious about all young people having the kind of learning that enables them to participate at the highest levels of the knowledge economy… The first challenge is whether we want deep learning and creativity for all our students, not just for those from the most affluent and privileged environments." [4] (p. 46). How students achieve deep understanding is arguably the most important research question for educational theory to address in preparing students for knowledge based economies. The first step, then, is to determine what we mean by 'understanding'. As we shall see further on, there are a variety of approaches to the concept of understanding that hold promise. We should keep in mind, however, Nickerson's [5] observation that "understanding is a true paradox: the more one learns about some aspect of the world, the more aware one is likely to become of the depth of one's ignorance of it." (p. 236). Assuredly, this is equally true for understanding understanding.

While Hewitt [6] argues that knowledge building and current collaborative discourse environments like *Knowledge Forum*® can promote deeper understanding, Collins [7] suggests that current designs are limited and that "there needs to be a richer research environment, where the kinds of tasks that researchers carry out in the world become meaningful to students. In such a research environment, understanding would serve a larger goal of accomplishing meaningful tasks.." (p. 47) While, on the surface this appears to be a worthwhile goal, it is unclear what innovations to [collaborative discourse] design might produce a richer research environment. One way to proceed might be to question what we mean by understanding itself. Below, I give a quick review of some contemporary views of understanding and then take on the challenge of imagining what the next generation of collaborative discourse designs might look like if we successfully shift our theoretical perspective on understanding away from the mind-as-container metaphor.

2. DISCUSSION

2.1. Contemporary views of understanding

David Hume's 18th-century belief that he was examining the principles which regulate our understandingsuggests, that for Hume [8] (1777/1962)[1]

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[1] Hume, D. (1777) An Enquiry Concerning Human Understanding (1777 edition) is also available at: http://www.etext.leeds.ac.uk/hume/ehu/ehupbsb.htm#index-div2-N943628287 retrieved on November 5, 2004.

the application of such 'law' results in the reasoned or experiential knowledge for the individual. As such, the understandings are indistinguishable from the knowledge, and that they indeed can be the same thing. However, Hume also talks about the "process of the understanding" where, presumably the laws or principles regulating understanding are applied during the development of the knowledge.

Our 20th-century notions of understanding do not seem to vary too far from what Hume was postulating. In the field of cognitive science, Nickerson's [5] paper on *Understanding Understanding* stands out as one of the most comprehensive examinations of the topic to date. While Nickerson does not equate knowledge with understanding as Hume did, he does note that understanding is dependent upon one's knowledge and that understanding cannot even emerge if there is not an adequate amount of knowledge. For Nickerson, understanding has more to do with the way the knowledge is represented when working on a problem. In this respect, an expert will have deep understanding of the problem; whereas, a novice is likely to have poor or no understanding of the problem. In this context, developing understanding means engaging in the processes that help individuals produce sophisticated expert-like mental models from their knowledge and apply it to the problem at hand.

Nickerson [5] reports that developing understanding involves going beyond surface structure by creating a "deep structure trace" which represents elements of the situation that are not explicit in the surface representation. He elaborates, "A deep-structure trace must be constructed by the understander, and its construction requires utilizing various types of knowledge that the understander must bring to the situation. In the absence of that knowledge, a correct understanding of the situation cannot be developed." (p. 233)

Nickerson's representational view of understanding relies heavily upon the mind-as-container metaphor. From this stance, one could describe gaining expertise as the novice developing representations that are isomorphic to that of the expert's mental model. This idea is pervasive across cognitive science and into education. Skemp [9] for example, in *The Psychology of Learning Mathematics*, divides the representations into two types: relational understanding and instrumental understanding. Within mathematics education, instrumental understanding means simply knowing the algorithms or procedures for solving a problem. Relational understanding, on the other hand, involves generating solutions from principled knowledge. In some respects, Skemp is taking the notion of understanding as instrumental or relational representations back closer to Hume's original ideas.

Dedre Gentner has also used the term relational understanding. In this work, the term relational understanding is emerging from structure-mapping theory and similarity comparisons [10] and is quite distinct from Skemp's use of the term. However, both uses of the term relational rely quite heavily upon the mind-as-container metaphor. The role of the mind-as-container metaphor, in representational models is explained in the *Stanford Encyclopedia of Philosophy*: "When someone learns a particular fact, for example, when Kai learns that many astronomers no longer classify Pluto as a planet, he or she acquires a new belief -- in this case, Kai acquires the belief that many astronomers no longer classify Pluto as a planet. The fact in question -- or, more accurately, a representation, symbol, or characterization of that fact -- may be stored in memory and accessed or recalled when necessary. To have a fact represented in the mind in this way is to possess the corresponding belief."[2]

2.2. Rejecting the mind-as-container metaphor

Bereiter [1] describes the mind-as-container metaphor as a folk theory that has served us well in the past but has been thwarting educational innovation for some time now. New ways of studying cognition such as research on neural networks allow us to ask the question, where is the knowledge [11]? Research on neural networks reveals that while a network can generate and possess knowledge as dynamic patterns, that knowledge only exists in the interactions of the network within the environment that does not require any representational knowledge (see, for example, Kelso [12]). Nowhere does the knowledge sit in the head, rather, it emerges from the interactions of the network as dynamic patterns. Consequently, these new models of cognition provide us with an alternative metaphor to the mind-as-container view that has dominated for the last few hundred years. Bereiter [1] uses the neural network example to suggest that alternative metaphors to the container view are viable and that we must abandon the notion that we are "putting" knowledge into students' heads. Indeed, Bereiter claims boldly that "the mind is not in the head". He is not alone in making this claim, for in 1998 Varela noted "… the brain appears as a dynamical process (and not a syntactic one) of real time variables with a rich self-organizing capacity (and not a

[2] Stanford Encyclopedia of Philosophy (2002) available (as retrieved on Nov. 5, 2004) at http://www.faculty.ucr.edu/~eschwitz/SchwitzPapers/BeliefEntry030227.html

representational machinery). So in this sense the mind is not in the head since it is roots [*sic*] in the body as a whole and also in the extended environment where the organism finds itself." [3,4]

If understanding is tied to the notion of mental representations that exist as part of the mind-as-container metaphor and we reject the notion of the mind-as-container, then we must rethink what this means for our notions of understanding. Below I examine non mind-as-container models of understanding.

2.3. Moving Beyond mind-as-container views of understanding

David Perkins [13] argues against the traditional representational view of understanding in favour of a performance view where understanding is defined as *the ability to think and act flexibly with what one knows.* By concentrating on performance, Perkins presents a view of understanding that could be independent of the mind-as-container metaphor, but upon closer inspection we see that he relies on, among others, representational knowledge in the generation of explanation through what Perkins et al. [3] call an "explanation structure". According to Perkins et al., an explanation structure "…is a rich network of explanatory relationships that are encoded mentally in any of the many ways the mind has available--through words, images, cases in point, anecdotes, formal principles, and so on. This explanation structure is more than a memorized explanation: It is *extensible* and *revisable*." [3] (p. 74) Therefore, to have understanding is to have an extensible and revisable networks of relationships that can help us explain relevant aspects of the concept or topic at hand. Perkins et al. [3] stop short of moving understanding outside the mind-as-container metaphor since they also include an "access framework for understanding" that includes access to representational knowledge. The authors explain, "We call knowledge, representation, retrieval mechanisms, and construction mechanisms the four dimensions of the Access Framework. They are not so much separate categories as they are somewhat separately analyzable aspects of the information processing required for 'understanding performances'." [3](p. 75)

Bereiter [1] goes further than Perkins and treats both understanding and knowledge as outside the mind-as-container metaphor. Unlike Hume's 18th-century representation of understanding as equivalent to the knowing [8], or Nickerson's [5] postulation that understanding is determined by how one's knowledge corresponds to what is in the head of an expert, or Perkins's conjecture that understanding is a matter of being able to perform a number of thought-demanding cognitive tasks in a new way [14], Bereiter [1] suggests that understanding be viewed as a set of relationships between the knower and the object of understanding. Thus, for Bereiter, teaching for understanding means cultivating varied and rich relations between the learner and the object of knowledge and developing them collectively into a "relationship capable of supporting intelligent action" [1] (p. 101).

To aid the reader in understanding what sort of rich relationships one might have with a knowledge object, Bereiter suggests that we think about how we understand other people. He writes, "High on the list of things we try to understand in our daily lives are other people—not people in general, but the particular people who matter to us, each one of whom presents a distinctive problem of understanding. Although understanding other people is widely recognized as hard to do, we seem to have little difficulty understanding what it means to understand other people." [1] (p. 101)

Extrapolating from the list Bereiter provides, we can imagine that among the kinds of things one might do to understand a person better (and develop a set of rich and varied relationships with that person or knowledge object) are: *developing multiple relationships to the person or object* –e.g., getting to know a person as a friend, colleague, spouse etc; *promoting reflection about intelligent actions in relation to the person or object*—ie., since intelligent action and understanding are bound together, reflecting on our actions could be beneficial in promoting our understanding; *building on intrinsic interest in the object*—interest can motive you to understand people or knowledge objects (and disinterest can maintain poor understanding); *positioning the knowledge object within a network of relationships*—e.g., getting to see how the person or object is situated within the larger networks out in the world; *engaging in explanatory discourse about the object*—engaging in explanation will promote better understanding; *identifying and recognizing misconceptions concerning the object*—e.g., while there is no complete way to understand a person, there are wrong ways of understanding them and these need to be corrected; *engaging in discussion aimed at advancing understanding of the person or object*—e.g., the kinds of water-

[3] As viewed at http://www.expo-cosmos.or.jp/letter/letter12e.html on November 5, 2004. [28] Francisco Varela, Cosmos Web Forum letter 12e

[4] Varela's untimely death in 2001 has stalled the publication of a book by Thompson and Varela [29] titled, " Lived bodies: Why the mind is not in the head".

cooler discussions that people might have about the motivations of their boss or mutual colleague can promote understanding; *supporting the construction of a narrative about the person or knowledge object*—constructing narratives can promote understanding and listening to such narratives can indicate the speakers level of understanding about a person or knowledge object; *encouraging analyses about deep features of the object*—in the case of a person, this might mean noticing recurrent patterns of behavior or thought; *highlighting and exploring insightful solutions concerning the object*—reflecting on insightful solutions to problems concerning people or knowledge objects can advance understanding; and finally, *engage in complex involvement with the object*—simply stated—complex activity with people or knowledge objects can promote better understanding.

The above list is not intended to be exhaustive. It is provided as an example of some of the many and varied relationships we might have with people we know or knowledge objects (conceptual artefacts) we are getting to know. This form of relational understanding is very different from the way Skemp or Gentner are using the term. To keep the distinction clear I will refer to Bereiter's form of relational understanding as *manifold relational understanding*—where manifold is meant to mean many and varied relations. It is important to emphasise that I am not saying the relationships are the understanding; rather, the understanding is a result of manifold ways one is positioned relative to the person or knowledge object. Next, I examine how understanding might emerge from manifold relational experiences.

2.4. Emergent understanding

Perkins et al. [3] postulation of an "explanation structure" gives us one means of imagining how understanding might emerge as our ability to generate explanations. But the Perkins et al. framework for generation of explanations is heavily dependant upon the mind-as-container metaphor by way of interaction with representational knowledge. How else might explanatory competence be generated without necessarily embracing the representational mental models? Pirie and Kieren [16] provide an alternative that sees understanding as a "…whole dynamic process and not as a single or multi-valued acquisition, nor as a linear combination of knowledge categories." (p. 165).

Pirie and Kieren's [15] model describes a theory of growth in mathematical understanding that was stimulated by the self-referencing systems described by Maturana and Varela [16]. The key features include 'don't need' boundaries, 'folding back', 'acting' and 'expressing' that occur at growing levels of understanding. Although the labels used by Pirie and Kieren are specialized for mathematics understanding, we can imagine each level as representing a unique relational positioning of the knower to the knowledge object. Movement across the levels requires students to engage in a process called 'folding back' We can describe 'folding back' as a process where a student revisits earlier understanding levels along with the demands of the new situation and then uses this information to inform her or his new thinking at the inner layer. As Towers and Davis [17] point out, "…the Dynamical Theory for the Growth of Mathematical Understanding considers mathematical understanding as an on-going process in which a learner responds to the problem of reorganising his or her knowledge structures by continually revisiting existing understandings to generate 'thicker' understandings. Pirie and Kieren have termed this process 'folding back'. The theory considers understanding in terms of a set of embedded levels or modes of knowledge building activity." [15] (p. 318)

'Folding back' looks very much like Ackerman's [18] 'diving in' and 'stepping out'. From a Piagetian stance on coordination of perspectives, Ackerman is building on Kegan's [19] Piagetian notion that deeper understanding grows out of iterations of movement in and out of embeddedness—or decentration and recentration. Folding-back, diving-in, and stepping-out are each possible mechanisms that would allow us to generate deeper understandings from experiences that provide new and growing relational perspectives for individuals. If we contrast 'folding-back' for example, with Nickerson's 'deep-structure trace' we see that the former is rooted in complex dynamic systems theory where the phenomenon emerges from interaction alone; whereas, the latter is grounded in causal reasoning within traditional information processing. Manifold relational understanding, then, allows understanding to emerge as part of the consequence of the interacting relational perspectives.

My effort at attempting to formulate understanding as an emergent process highlights one distinction between Bereiter's position on relationships and the one I am proposing. I am suggesting that understanding arises from the multiple relations an individual can have with a knowledge object; whereas, Bereiter maintains that there is only one relationship which may have many facets or aspects. As such, Bereiter points out that, "Understanding refers to that aspect of a relationship that has to do with its potential to support intelligent action." [1] (p. 112) My position, on the other hand, holds that one is positioned relative to multiple relationships with the knowledge object and that it is the interaction among the multiple relations that enables understanding to emerge in what Wilensky and Resnick [20] refer to as an 'emergent level'. It is this emergent level that supports intelligent action. In this context, understanding further advances through diving-in and stepping-out.

Of course, it is possible that Bereiter is talking about a point where understanding is achieved and I am talking about how understanding becomes established. Within a complex dynamic systems framework, a matured neural network may start out multi-relational with respect to a knowledge object and then the emergent level appears as equivalent to a single relationship with many different facets. While further advance on these ideas is beyond the scope of this paper, the discussion may be advanced by looking at a study where understanding is deepened by actively promoting manifold relational experiences. It should be noted that the following study is not presented to define manifold relational understanding per se; rather, it is presented as an interesting case that can open up our discussion of what we mean by understanding and how the understanding might advance.

2.5. An example of fostering Manifold Relational Understanding

In a series of studies, Nalini Chandra's [21] dissertation research investigates the impact of changing students' frame of reference on their ability to explain the phenomenon of seasons. (See also, Chandra et al. [22]. In one investigation, 16 grade 6 students first discussed exocentric explanations—that is, the perspective of the students was from outside, looking down upon the planetary motion (this is sometimes called God's view). To aid this perspective, Chandra had devised small cut-out people (called the Sky Home people) that were placed under clear plastic domes. These domes defined the field-of-view for the Sky Home people standing on earth (represented by a large diameter Styrofoam ball). By physically manipulating the Earth moving around the Sun with approximately 23.5 degrees of tilt, students, working in small groups, demonstrated that they could explain seasonal change from this exocentric frame of reference.

Next, the same groups of students were given the opportunity to explain seasonal change from an egocentric frame of reference. Students, working in small groups, were given the opportunity to use the computer program called *Starry Night*®. This program allows students to construct and animate astronomical phenomena where the screen reveals the actual sky as viewed from anywhere on Earth. Students were instructed to use the program to help them explore ideas they were working on with the 3-d Sky Home models. Students then had a chance to discuss their observations and discoveries in small and large group forums. Pre and post test data revealed that all students could produce better explanations of the seasons. A follow-up investigation further reveals that these enriched relational experiences also produced transfer effects in that the students were also able to better explain moon phases.

Chandra chose the topic of seasonal change because it is typically a challenge to teach. Sadler [23] and Woodruff et al. [24] have shown that students and adults have many misconceptions that persist in their post-curriculum explanations. Chandra demonstrates that students can overcome these misconceptions, however, by gaining multiple relationships to the conceptual artefacts. Specifically, her work demonstrates that gaining a facility to move between egocentric and exocentric frames improved student understanding. But how does that map on to relational understanding? Let us examine one transcript excerpt where Chandra [21] points out that M—a grade 6 female student—shows clear movement between the two perspectives and demonstrates both an ability and disposition to generate explanations from either frame:

At this point students have had experience with both the exocentric activities (3d globes and Sky Home people) and egocentric activities (with the Starry Night program where the students have positioned themselves either in Toronto or Buenos Aires). Within the Starry Night program, M is positioned at 45S (Buenos Aires) and C is at 45N (Toronto), but the pair of students also has the 3d models readily at hand. The students appear to be working on why shadows are longer or shorter (or light is indirect or direct) and how that relates to the season—June means Spring/Summer in Toronto, and Fall/Winter in Buenos Aires.

M: If we're in June both here. This guy (*back to globe focused on Sky Home person in 45N*) is going to have bigger shadow and it will have to be in front of him. **Exocentric**

C: But the shadows here are really short (*on screen*) **Egocentric**

M: Oh mine' s longer or yeah you're right. But look at how big they are here. **Egocentric**

C: But, they're behind here (*at 45 N*). Aren't they? **Egocentric**

Teacher: You have to figure that out are they behind you or in front of you? **Not coded**

C: The sun's up there (*looking on the screen*) and we're facing this way then… and the tree's shadows are right there, then they are behind aren't they? **Egocentric**

M: *(M goes up to C's screen)* I think so if that point [of the tree] and that would that if that was in front then that would be around there **Egocentric**

C: yeah so it's [the shadow] behind [the tree] **Egocentric**

M: Yeah it is behind, but look at here. (*She directs C to her screen in Buenos Aires now at 45S* .) **Egocentric**

Teachers: Which way are you facing M? **Not coded**

M: North **Egocentric**

Teacher: which way are the guys in the picture facing? **Not coded**

C: OHHH, so you have to turn around **Egocentric**

M: OH! **Not coded**

C: so M's not facing the sun!! So it's in front of them [the trees] and its really big. **Egocentric**

M: So it's behind me so it's [sun] casting a shadow in FRONT of me. And that one is casting a shadow behind you. **Egocentric**

M: So wait, you're in Toronto and …I'm down here and you're up here… (*At this point M has the globe and is pointing to different places on it and placing the model people on 45 N and 45 S*.) **Exocentric**

M: and I have a shadow… **Not coded**

C: Since you're not facing the sun the sun shines on you and then it goes a big shadow **Egocentric**

M: I'm facing north it's casting a shadow in front of me **Egocentric**

M: the big shadow is in front. So this guy is going to be this guy and this guy is going to be this guy. (*She is pointing between the pictures and the globe*.) **Exocentric**

In the above excerpt we see M providing explanations from both egocentric and exocentric views where there was no evidence of her ability to generate explanations from an egocentric frame at the neither the beginning of the study nor at the introduction of *Starry Night*. That is the behaviour we can see easily, and code. However, to see how this excerpt demonstrates that there is a change in understanding we need to step back and think about how Bereiter suggests we will see relational understanding manifest itself. Bereiter writes, "*Understanding implies abilities and dispositions with respect to an object of knowledge sufficient to support intelligent behaviour*." [1] (p. 101). If the object of knowledge in this case is seasonal change, then we see that M has the disposition to move between the egocentric and exocentric views combined with the ability to generate explanations within each frame.

We can further speculate that each frame of reference may be linked to one or more developing relational perspectives. The egocentric view, for example, appears to promote the *construction of a narrative about the object*. The exocentric view, on the other hand, appears to *promote explanatory discourse about the object*. Together, working with the multiple views appears to *engage* the pair *in discussion aimed at advancing understanding of the knowledge object*. While there are undoubtedly even more relational perspectives on the knowledge object (seasonal change) it seems evident that the instructional practice has provided a rich set of experiences upon which students can build their manifold relational understanding of seasonal change.

3. SOME IMPLICATIONS FOR DESIGN

What can we summarize so far about teaching for understanding? Building relational understanding means building relations between the student and the knowledge object that is to be understood [1]. Thus, the mind-as-container metaphor is replaced with the physical object metaphor—with the proviso that the physical object is an immaterial conceptual artefact. Furthermore, as with trying to understand a person, no one can teach you such 'understanding' directly. Understanding can emerge when someone teaches us things about the person and better understanding will result from richer and more varied experiences with the knowledge object. As we may postulate from Chandra's [21] example above, neither can we teach the explanations directly—indeed, the explanations are **not** the understanding—rather, we teach something like changing frames of reference and from that students can develop their relational understanding. In short then, we don't teach students to perform, we teach them to relate.

Given that our collaborative groupware designs already promote discourse, we are already moving students toward a relational view of understanding by getting students to explain, debate, compare and analyse their ideas collectively. As noted earlier, these are the sort of activities that promote relational stances. But richer and more varied experiences can also help students relate better. In the introduction, for example, I pointed out that Allan Collins has called for our designs to provide richer research environments where the tasks are very meaningful for students. Although Collins is basing this suggestion from the stance of education as apprenticeship, heeding his advice would ensure designs that promote relational understanding very well. I would argue however, that the criteria of meaningful, interesting, and authentic problems is present in Chandra's teaching and it is accomplished outside of the apprenticeship metaphor. In Chandra's work, the computer program *Starry Night* serves to provide the students with direct experience that might only come otherwise from out of the classroom experiences. Since Starry Night can simulate the live sky and allow you to manipulate numerous variables at the same time, this program allows students to work on authentic problems in an authentic fashion. From this observation, we can see that the implication for collaborative discourse design is that we should integrate simulation software where applicable. Merging discourse environments with simulation software may be one way to provide meaningful, interesting, and authentic problems to the students. Of course, the chance that such an environment will be helpful will increase greatly if the students are encouraged to generate appropriate problems on their own that they are interested in bringing into these environments.

Another currently popular way to introduce authenticity to the classroom is through project based learning. Norway, for example, has embarked on a country-wide implementation of ICT integrated with project based learning [25]. Given a stance that understanding is relational, it is reasonable to assume that anything that has students 'doing' activity with the knowledge objects is likely to help students relate. The challenge is to design project based learning activities that focus the 'doing' on the knowledge object and the immediate tasks required to advance this goal and not on tertiary tasks tangential to the focal problem. For example, it might be a good idea to have students build a Moon or Mars rover if your goal is have students understand how to build a Moon or Mars rover, but it is probably not a good project from a relational understanding point of view to help students understand gravity. Too many tertiary tasks are generated that dilute the experiences with any one conceptual artefact such as gravity. Of course, this is always a danger in any project based learning activity. To militate against such an effect, I believe that relational understanding could be enhanced in project based learning if our groupware discourse environments were designed to integrate the projects so that the students were supported in maintaining their focus on a few critical target conceptual artefacts.

The final implication for collaborative discourse groupware design to be addressed concerns mobile computing. Clearly, putting mobile computing in the hands of the students and placing them in the field comes as close as we reasonably can to Collin's apprenticeship experience given the realities of today's classroom. However, this introduces the same challenges that we have in both simulation software integration and project based learning. Mobility computing allows the students to collect field data, record experiences, observe and in some cases, manipulate the environment or experiment. All of these experiences should definitely increase relational understanding **if** the students can maintain a focus on the target conceptual artefact(s). Like project based learning the potential to dilute the relational experience for one or two target objects is great. Collaborative discourse environments should be modified (and be running on the mobile device) so that they help students maintain a conceptual object focus.

It is implied in the introduction that a shift in theoretical perspective away from the mind-as-container driven ideas of understanding will take at least a decade to be fully realized in our collaborative groupware designs. Part of the reason for the extended time frame emanates from the speculation that we will need to develop our innovations carefully from within a design research methodology [26]. Each innovation will need to be tested and refined in iterative trials that will undoubtedly lead to refinements, and at times, radical renovations. The supposition presented here is that exploring manifold relational understanding will enable us to discover the kind of ontological innovation theories diSessa and Cobb [27] describe. Consequently, it is unlikely that extensive hypothesis testing of manifold relational understanding would be prudent at this time given our lack of specificity on how it is achieved and how one can measure it. Rather, if we use the concept as a guide post for the design of the next generation of collaborative discourse environments, we will most likely understand the concept well enough that we can later identify the critical hypothesis to test.

4. CONCLUSIONS

In this paper I have attempted to show that the next generation of groupware needs to abandon the mind-as-container metaphor in favour of the knowledge object metaphor. The representational view of knowledge in the mind has helped cognitive science in the past and will still be useful from time to time in the future [1]. However, to treat the representational view as literally describing knowledge is stored in the mind is limiting how we might design the next generation of computer supported collaborative environments. One way to move ahead is to change our metaphors from knowledge in the mind to knowledge objects that are collaboratively generated in our collaborative discourse environments. In making such a shift, it is argued that we must also rethink our notions of understanding since they are greatly constrained by our epistemological conceptions.

In proposing an alternative way to think about understanding this paper suggests that it be viewed as the result of one's relational positioning with respect to a knowledge object and that deep understanding is achieved as manifold relational understanding. In this context, understanding is viewed as emergent phenomena resulting as a product of interactions within our complex dynamic systems. Finally, I suggest that the concept of manifold relational understanding will aid us in integrating simulation software, project based learning, and mobile computing into our collaborative groupware environments in effective and important ways.

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