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A CONSTRUCTIVIST MODEL FOR THINKING ABOUT LEARNING ONLINE

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ABSTRACT

This paper provides a brief overview of constructivist learning theory and explores its implications for instruction in terms of the design of online learning environments that are learner-centered, knowledge-centered, assessment-centered, and community centered. It then presents a model for organizing thinking about technology-mediated learning within a social constructivist frame. The RCET model distinguishes three interacting domains of knowledge construction -- conceptualization, representation, and use -- within which the unique affordances and constraints of the online medium and their effects on learning can be scrutinized. It is hoped that so narrowing the focus of inquiry might guide research to pursue findings which can meaningfully inform practice and advance online learning.

KEYWORDS

online learning, constructivism, instruction, theoretical model, representations, conceptualizations, use

I. INTRODUCTION

This paper explores constructivist theory and how it might inform research and practice in online learning. It begins with an overview of constructivist theory and some of its more important and/or compelling instantiations – cognitive constructivism, constructionism, social constructivism, situated learning, distributed cognition. It then explores some implications constructivism might have for instruction in general, and online learning in particular, in terms of the development of the four kinds of learning environments advocated by Bransford, Brown and Cocking in *How People Learn* [1]. Finally, it presents a constructivist model for thinking about the effects that online environments may have on learning in terms of the unique external representations of knowledge they afford, of their particular effects on student conceptualizations of knowledge, and of the social uses made of knowledge and through which knowledge is constructed online.

II. CONSTRUCTIVIST THEORY

"Constructivist" is the name given to theories of learning grounded in an epistemological alternative to objectivist theories of knowledge. Central to such alternative, and to constructivism in general, is the notion that meaning is imposed on the world rather than extant in it. Both objectivism and constructivism agree there is a real world we experience. However, while objectivists believe that meaning exists in that world to be discovered by us, constructivists believe that we impose meaning on it [2]. They hold that meaning is constructed in our minds as we interact with the physical, social, and mental worlds we

inhabit, and that we make sense of our experiences by building and adjusting such internal knowledge structures that collect and organize our perceptions of and reflections on reality.

"Constructivism," then, refers to a set of psychological theories that share common assumptions about knowing and learning. Although constructivist theories have implications for pedagogy and instruction, they are not theories of either. According to constructivists, all learning involves mental construction, no matter how one is taught. All learning, they argue, occurs in our minds as we create and adjust internal mental structures to accommodate our ever growing and ever changing stores of knowledge. Thus, according to constructivists, all learning is an active process and all knowledge is unique to the individual, whether acquired from lecture and text or discovered through experience. According to constructivists, all learning is therefore intimately tied to experience and the contexts of experience, no matter how or where that learning takes place [1].

While constructivist theories share common assumptions about the nature of learning and the construction of knowledge, they diverge in focus; particular theories and theorists explore and highlight particular aspects of constructivism. In the paragraphs which follow, I will briefly describe some of those foci. I have chosen these for their importance to the field, for their articulation of significant threads in the constructivist mosaic, and for their potential relevance to online learning.

A. Cognitive Constructivism

I will begin with what is sometimes called *cognitive constructivism* (although all constructivist theories are essentially cognitive) and the genetic epistemology of Jean Piaget [3,4]. Piaget is very important to educational psychology because, working in an era dominated by Behaviorist theories which held that we can know nothing about what happens in our minds and so shouldn't try, he turned his attention exactly there. Piaget is called a cognitive constructivist both because his main concern was the internal development of mental structures, and because he thus opened the door for the development of cognitive psychology. Indeed, many cognitive psychologists accept a weak form of cognitive constructivism, in that they focus on the internal construction of mental structures while none-the-less maintaining a belief in some sort of meaning existing in the world (see Mayer [5].

Piaget was a biologist who in his early career observed how organisms, specifically mollusks, reacted to their environment. He applied that approach to studying how children learn. Not surprisingly, Piaget believed that children learn by interacting with the environments in which they find themselves. Learning occurs, he maintained, through the cognitive processing of environmental interactions and the corresponding construction of mental structures to make sense of them. He called these mental structures *schema* and posited two kinds of cognitive processing involved in schema construction. In *assimilation*, new knowledge is incorporated into existing schemas in much the same way a new wing is added to a building. In *accommodation*, new knowledge conflicts with existing schemas which accordingly must be altered to incorporate it. The analogy here might be remodeling.

Piaget called himself an epistemologist because he was concerned with knowledge and knowing. He called himself a genetic epistemologist because he believed the ways we structure knowledge internally are determined by our genetic make up, and that these change as we mature. Through his observations of children, Piaget identified four distinct developmental stages, each distinguished by characteristic kinds of mental processing. The *sensori-motor stage*, which is pre-linguistic, is characterized by kinesthetic understandings and organizations of experience, while the *pre-operational stage* is characterized by egocentrism, the organization of knowledge relative to oneself. In the *concrete operational stage*, knowledge is organized in logical categories but still linked to concrete experience. It is only in the

formal operational stage, according to Piaget, that knowledge is abstracted from experience and formal reasoning can occur. Although Piaget believed that individuals went through these cognitive stages in order as a natural result of maturation, there is some evidence that in his later years he came to believe that some individuals never reached any formal operational levels, and that no individuals thought formally in all domains. Indeed, most modern Piagetians hold this view.

Why is cognitive constructivism important to us? It is important because it clearly locates learning in the mind of the individual and because it defines it as an active process of mental construction linked to interactions with the environment. Moreover, stage theory reminds us that knowledge is constructed in very different ways by people in different stages of development; that, for example, novices to a field construct meaning differently than experts. Cognitive constructivism also posits the interrelated process of assimilation and accommodation (or similar mechanisms, see Rumelhart and Norman [6]) to accomplish mental construction, and so links all new learning to learners' pre-existing knowledge, bringing the issue of misconceptions and their nature more clearly in focus. Cognitive constructivism gives us the notion of knowledge organized internally as mental schemas that are in some broad sense peculiarly human. Mental schema have been variously characterized and studied, for example, as frames [7] representing particular scenes, scripts [8] representing complex actions, mental models [9] representing causality, and semantic networks [10] representing relationships among ideas. All of these characterizations tell us something about the ways in which learners naturally organize and construct knowledge, hence suggest organizations of instruction that reflect and so support them.

B. Constructionism

Seymour Papert [11, 12] is a mathematician who studied for five years with Piaget before becoming involved with the emerging discipline of computer science at MIT. Papert coined the term *constructionism* to distinguish his particular constructivist focus [12] which "attaches special importance to the role of constructions in the world as a support for those in the head" (p.142) from cognitive constructivism (although they are, in fact, clearly related) What makes Papert and other constructionists (see, for example, Resnick [13], diSessa, [14]) of particular interest to us is that they are specifically concerned with the kinds of constructions that are supported by computing technologies. Andy diSessa [14], for example, writes:

> *"Computers can be the technical foundation of a new and dramatically enhanced literacy, . . . which will have penetration and depth of influence comparable to what we have already experienced in coming to achieve a mass, text-based literacy."* (pg. 4)

Constructionists maintain that computers have the unique capacity to represent abstract ideas in concrete and malleable forms. Papert and his colleagues developed the Logo programming language and variations on it to study these ideas in practice. Their work has demonstrated ways in which computer-based constructions can indeed make abstract concepts more accessible and more readily internalized as mental schema. Constructivists believe that computer-based constructions are personally created, hence more readily linked to existing knowledge (assimilation). They further maintain that computer-based constructions can be used to interrogate existing schema, as in the case of certain simulations, and so lead to changes in knowledge structures and the remediation of misconceptions (accommodation). Constructionism, in short, is important to us because it suggests ways in which computer-based construction activities can be used to support corresponding mental constructions.

C. Social Constructivism

Social constructivism is perhaps the most common version of constructivism currently in favor and so the theoretical framework normally evoked by the term "constructivism." Learning theories are called *social constructivist* when their main concern is with knowledge construction through social interactions. Social constructivist theories derive primarily from the work of Lev Vygotsky [15, 16], a Russian contemporary of Piaget whose work was suppressed by the Stalinists and rediscovered in the 1960s. Vygotsky maintained that, while taking place in individual minds, all learning results from social interaction, and that meaning is socially constructed through communication, activity, and interactions with others. He believed that cognitive skills and patterns of thinking are not primarily determined by innate factors (as in genetic epistemology), but rather are the products of the activities practiced in the social institutions of the culture in which the individual lives. Consequently, the history of the society in which one is reared and one's personal history are crucial determinants of the ways in which an individual will think. Even the solitary scholar alone in his room, Vygotsky argued, engages the artifacts and tools of his culture, and through them, their authors and the larger society. Moreover, such scholar's current activity is enabled by and so situated in a history of social and cultural interactions that have shaped her knowledge, attitudes, skills and behaviors.

Vygotsky viewed the construction of meaning as a two part, reciprocal process. According to Vygotsky, meanings are first enacted socially and then internalized individually; internal conceptualizations, in turn, guide social interactions. As we have discussed, Piaget [13] focused on the second part of this process, schema construction, which he viewed, in an important sense, as genetically determined. Vygotsky focused on the first part of the process, the social construction of meaning, which he saw as culturally determined. Interestingly, whereas Piaget was concerned with the development of cognitive schema through the internalization of environmental interactions, Vygotsky conversely viewed objects in the environment as having a psychological as well as a physical aspect, and so, as being psychologically determined. Objects in the environment including other people, he maintained, are in important ways what we perceive them to be, and their perceived properties are to a great extent culturally determined.

Vygotsky was particularly concerned with the role of language in thinking and learning. He believed that language and thought were intimately related. While at first a child seems to use language for superficial social interaction, at some point, he contended, this language is internalized to structure the child's thinking. Language was to him not merely an expression of the knowledge one has acquired. According to Vygotsky, there is a fundamental correspondence between thought and speech in terms of one providing resource to the other; language becoming essential in forming thought. Moreover, he viewed language as the crucial tool in the cognitive development process, in that advanced modes of thought are transmitted by means of words.

Another important concept in Vygotsky's learning theory is his notion of the *zone of proximal development*, the distance between the actual development level as determined by independent problem solving and the level of potential development as determined through problem solving under adult guidance or in collaboration with more capable peers [16]. Vygotsky claimed that all learning occurs in this zone, which bridges the gap between what is known and what can be known, through adult/instructor guidance or peer collaboration.

Two other important learning theorists who are sometimes considered social constructivists are Jerome Bruner and John Dewey. A major theme in the theoretical framework of Bruner [17, 18] is that learning is an active process in which learners construct new ideas or concepts based upon their current knowledge. He believed that the individual's cognitive structures gave meaning and organization to such active experiences and allowed her to learn. Bruner is deemed a social constructivist because of the

central role he saw language and other people playing in this process. Similarly, Dewey [19], although he predates the social constructivist movement, is sometimes considered a social constructivist because he understood thought as the product of interaction with the environment, because of the importance he placed on active learning, and because of the central role language and social interaction plays in his notions of teaching and learning.

Why is social constructivism important to us? Social constructivism reminds us that learning is essentially a social activity, that meaning is constructed through communication, collaborative activity, and interactions with others. It highlights the role of social interactions in meaning making, especially the support of more knowledgeable others in knowledge construction. Social constructivism, moreover, encourages us to consider the critical function of language as the vehicle of thought, hence of knowing and learning, and the ways in which knowledge and knowing are culturally and historically determined and realized.

D. Situated Learning / Distributed Cognition

Vygotsky's disciple Alexei Leont'ev [20] took his mentor's ideas one step further. He contended that internal and external constructions of knowledge could not be understood apart from culture and the tools and artifacts which shaped them. He accordingly developed methodologies for examining what he viewed as the seamless and mutually transforming processes of knowledge construction in terms of the activities in which they were embedded. Activities, he maintained, are driven by motives, performed through actions, oriented to goals, and implemented through operations. Learning thus can (and only can, according to Leont'ev) be analyzed in terms of the hierarchical activity structures in which it evolves. Many social constructivist theories similarly view thinking and learning as part of and inseparable from whole activity systems in which they are embedded that include culture, community, tools and symbols.

Situated learning, for example, explores learning as situated in communities of practice. Situative theorists argue that learning as it normally occurs is a function of the activity, context and culture in which it takes place and hence inseparable from participation in the communities which support it [21, 22, 23]. An important concept in such theories is the notion of *legitimate peripheral participation*, which argues that mastery of knowledge and skills requires newcomers to gradually move towards full and complex engagement with communities of practice [22, 23]. In school contexts, this is operationalized as *cognitive apprenticeship* [21], in which students work on authentic problems with the help of more expert adults and peers, and/or as *knowledge building communities* [24], in which students work collaboratively to co-construct knowledge corpora. The situative perspective encourages us to conceptualize learning as an apprenticeship process in which the individual gradually moves from peripheral to full participation in scholarly activities.

A particularly important modern instantiation of Leont'ev's work can also be found in theories of *distributed cognition*. Theories of distributed cognition maintain that thinking, hence learning, does not take place solely inside the mind of individuals, but rather that it is socially distributed among individuals and the tools and artifacts of a culture [25, 26, 27]. Radical versions of distributed learning theories maintain that, although individual cognitions cannot be dismissed, thinking and learning in general should be conceived and studied as principally distributed, with joint, socially mediated learning activities in cultural contexts as the proper units of analysis [25, 26]. Weaker versions of distributed learning distinguish between individual and distributed thinking and learning, but view these as linked through interdependent and dynamic interactions [28, 29]. What the concept of distributed cognition, however conceived, provides us is the idea that thinking and learning are supported by, mediated through, and in

some sense reside in, artifacts and tools. This is a particularly compelling and useful notion when considering learning online, where all learning is necessarily mediated through virtual artifacts and tools.

III. IMPLICATIONS FOR INSTRUCTION

As previously noted, constructivism is an epistemological theory and not a theory of instruction. In the field of education, however, our epistemological beliefs dictate, or should at least strongly inform, our pedagogical views. Indeed, in the previous section, we noted the importance of various versions of constructivism in terms of the ways in which they encourage us to think about learning. Particular conceptualizations of learning, in turn, suggest corresponding approaches to teaching.

Perhaps the most central implication constructivism holds for instruction is somewhat paradoxical. Constructivism locates meaning and meaning making squarely in the mind of individuals, and not in instruction. This is an important distinction. It suggests, for example, that although it may be possible to standardize instruction, it is not possible to standardize learning, a goal to which some online programs aspire. It also suggests that our concern should be focused more on the design of *learning environments*, and less on instructional design per se [1]. Although such contrast perhaps appears merely semantic, it may be especially important in online learning, because it urges us forgo our traditional focus on the delivery of instruction and the design of instructional materials, and to instead approach course development in terms of creating virtual spaces that foster and support active learning, Indeed, the authors of *How People Learn* contend that constructivism suggests we should be concerned with the design of particular kinds of learning environments, namely, learning environments that are learner-centered, knowledge-centered, assessment centered, and community-centered. In the following paragraphs, I explore each of these, and their application to online learning, in turn.

A. Learner-Centered Learning Environments

Environments that are *learner-centered* acknowledge constructivist notions that individuals bring unique knowledge, skills, attitudes, and beliefs to the learning experience, and that there are many ways to structure experience and many different perspectives or meanings that can be gleaned from any event or concept [1]. Learner-centered teaching thus recognizes the importance of building on the conceptual and cultural knowledge that students bring with them to the learning experience, of linking learning to students' experiences, and of accepting and exploring multiple perspectives and divergent understandings. At the same time, learner-centered teaching must be concerned with diagnosing and remediating students' misconceptions. Constructivism suggests that such remediation requires accomodation; that is, that teachers must help students to make their thinking visible, to test it against experience, and to reconstruct more viable understandings.

Online learning poses many challenges to the development of learner-centered environments, the majority of which stem from the facts that all interactions therein are necessarily mediated through the online environment, and that most online courses must be created before students join them. At the same time, the very characteristics of the online medium that create such challenges offer unique affordances to learner-centeredness. For example, computer-based learning in general has long been supportive of individualized instruction. Indeed, when Carol Twigg [30] gathered together a group of innovative virtual educators to discuss paradigm changes in online learning, their overall conclusion was that individualization, which they termed *personalization*, was the key to innovation in distance education. Twigg thus argues that quality online learning should include initial assessments of students' knowledge and skills, individual study plans involving an array of interactive learning materials, and built-in,

continuous assessment with instantaneous feedback. Some researchers are even experimenting with adaptive hypermedia that adjusts to individual learning styles [31], but much more research and development needs to be done in the area of individualization.

While such approaches clearly address the conceptual knowledge students bring to their online experiences, as well as the diagnosis and remediation of student misconceptions, many would argue that they do little to build on students' unique knowledge and experiences, that they are culturally insensitive, and that they work against the consideration of multiple perspectives. Well-developed asynchronous online discussion, however, can do all of these things. Researchers have found online discussion to be more equitable and democratic [32, 33], more reflective [34, 35, 36], and in surprising ways more personal [37, 38] than traditional classroom discussions. While many educators thus believe that asynchronous discussion is uniquely suited to support learner-centered knowledge construction, research has yet to support such conclusions [39]. More research is clearly needed.

Similarly, we know very little about the relationship between learner characteristics and learning online. There is some evidence which suggests that independent learners [40], visual learners [41], and learners who are more motivated and have greater self-regulatory skills [42, 43] fare better in online courses. There is some evidence for gender [44, 45] and cultural differences [46] in online learning, but we need to learn much, much more in these areas. Finally, we have pretty good evidence that differing online learners, in fact, want quite different things from online courses [47]. If we would develop truly learner-centered online learning environments, we clearly have a lot more to learn.

B. Knowledge-Centered Learning Environments

Knowledge-centered learning environments, from a constructivist point of view, focus on the kinds and structures of information and activities that help students construct robust understandings of particular topics and disciplines [1]. The constructivist approach is concerned with support for the construction of internal knowledge structures through active learning. Constructivism likens knowledge-centered learning to learning a landscape by living in it and exploring it from a variety of perspectives [48, 49] and so argues for the design of learning environments that encourage analogous cognitive activity. Knowledge-centered learning similarly emphasizes sense-making and learning with understanding through in-depth explorations of topics. It puts less emphasis on the memorization of unconnected facts and procedures, and concentrates instead on learning in context, on the development of complex knowledge structures, on authentic problem solving, and on the "doing of" science, mathematics, history, etc. The constructivist argument is not that students do not need to learn facts and procedures, but rather that these are better learned when they are integrated within the rich corpora of their disciplines.

As with learner-centeredness, the online medium provides unique affordances and constraints to the development of knowledge-centered learning environments. On the one hand, because the Internet is clearly an information environment, online education seems ideally suited for knowledge-centered learning. The way in which courses are created and placed online, not only allows for the design and refinement of well-structured, knowledge-centered materials and activities, but supports a greater variety of ways in which information can be presented [50] than traditional lecture and text environments. Moreover, the Internet itself offers unprecedented access to information and authentic contexts [50] which can be easily incorporated into course materials and activities. At the same time, the nature of the online medium makes it possible for students to visit and revisit such diverse course materials and activities in ways and at times of their own choosing [49]. For example, Stanford University has created a set of digital learning objects (DLOs) which they term "courselets," and which are self-contained, integrated tutorials covering a small set of concepts to be used across science and engineering courses [51].

Courselets can be accessed by students who need to acquire or review particular concepts or skills, who are interested in the cross-curricular applications of these, or who want to extend their learning for whatever reason.

On the other hand, as Shank [52] reminds us, information is not knowledge. The abundant possibilities for presentation and creation of knowledge, the near infinite access to information, the freedom learners have to access and navigate course materials, in short, the enormous potential of online learning challenges knowledge-centered course design because knowledge is constructed in individual minds and does not exist outside them. It is hard to know what information, what kinds of presentations, what sorts of learning activities, in what combinations best support knowledge construction in which learners. It is probably impossible. We can, however, explore the cognitive effects of much smaller intellectual landscapes. Richard Mayer [53], for example, has spent nearly two decades investigating optimum combinations and sequencing of multimedia to support secondary school students' learning of scientific explanations. Similar studies might be made, for example, of characteristic types of DLOs, which are increasingly available to be linked to online courses and/or programs [54].

In a similar vein, it would be useful to investigate optimal online environments for supporting the construction of particular concepts and skills in specific subject areas. There has been some research, for example, that suggests online learning in general is more supportive of conceptual learning and less supportive of procedural learning than learning in traditional classrooms [55]. Such findings deserve further investigation in diverse subject domains. Similarly, it might be useful to explore how knowledge is constructed through various online activities (eg., discussion, collaboration, written assignments, simulations) or combinations of activities, again within specific subject areas and among particular populations of learners.

C. Assessment-Centered Learning Environments

Most learning theories recognize the importance of assessment and feedback. Indeed, according to constructivists, learning results from our reflections on feedback from environmental interactions. What is perhaps different about constructivist approaches to assessment are their emphases on the importance of the individual's processing of environmental feedback and so on the design of *assessment-centered* environments [1] that provide ongoing meaningful feedback to learners. Constructivism suggests that self-assessment is integral to learning, and so implies that opportunities for the same should occur continuously and be embedded within learning activities. Constructivist theory also implies that it is especially important to encourage learners to continuously construct and reconstruct their knowledge, to evolve and change their understandings, in response to feedback. Thus, constructivist approaches contend that good assessment practices are those that value revision and the processes of knowledge construction. Because constructivism views knowledge as complex mental structures, constructivist approaches further contend that good assessment practices emphasize learning with understanding and the application of knowledge, and not the memorization of isolated facts and procedures.

In many ways, the online environment offers considerable support for the development of assessment-centered learning. To begin with, online course platforms provide very complete records of student work, including user logs and discussion transcripts as well as more traditional course assignments and quizzes and tests, and so can support multiple and varied forms of assessment. In addition, most course platforms also provide tools for embedding assessments within student work, and for managing course assignments and grading and making these transparent to students. Moreover, as previously noted, computer-based assessments can be embedded in courses to give automated and instantaneous feedback [30]. For example, the CAPA system, which generates and scores random tests, is being used at Michigan State to

provide science students multiple opportunities to take weekly quizzes, helping them to identify and correct their own misconceptions [56].

On the other hand, assessment and feedback can be particularly taxing for online instructors. To begin with, the lack of regular face-to-face meetings makes frequent, regular feedback critical. Online instructors typically need to develop and assess many more assignments over the course of a semester than face-to-face instructors, who have the opportunity to informally assess and remediate student understandings in the classroom. In addition, online learners expect a much faster turn around on their assignments than traditional students. Moreover, while automated assessments are easily managed online, some research suggests that students learn better from personal feedback tailored specifically to their needs [57] than from automated feedback, especially when learning involves higher order understanding and the application of knowledge [58]. One solution to this conundrum may be found in Bill Pelz's [59] first principle of effective online pedagogy: "Let the students do (most of) the work." (p 33). Pelz suggests having students lead discussions based on text chapters, locate and discuss web resource, check and grade their own homework, and provide initial feedback to each other on assignments. The instructor, he argues, can then concentrate on thoughtfully providing the necessary structure and direction, supportive and corrective feedback when necessary, and final evaluations.

Indeed, the whole area of assessment in online courses and its relationship to learning is perhaps the least researched in the field. For example, we have some indications that the ways in which online discussion is assessed impacts the nature of that discussion [60], but we know little of the relationship between online discussion and learning, and almost nothing of the impact of the assessments on other online activities. Clearly, a great deal more research on assessment in online courses is needed.

D. Community-Centered Learning Environments

Finally, constructivist theory views learning as, to a greater or lesser degree, a social activity. It situates learning in communities and cultures. Thus constructivist approaches emphasize the importance of designing learning environments that are also *community-centered* [1]. Community-centered design is here understood on two levels – the degree to which a learning environment supports the social construction of knowledge and the development of a learning community, and the degree to which it connects to students' larger community and culture. On the first level, constructivism implies that learning is strengthened by environments which support and value the participation of all students, whose social norms encourage collaboration, the negotiation of meaning, and the search for understanding, and in which multiple perspectives are respected and incorporated into collective meaning making. On the second level, constructivism suggests that learning is enhanced when it is related to students' interests and experiences, when it is situated in authentic "real world" problem solving, and when it is linked to and resonates with the larger culture.

At first glance, it might seem that online learning is particularly ill-suited to the development of community-centered learning environments on the first aforementioned level. Indeed, some communication theorists have argued that the lack of the vocal and visual cues available in face-to-face learning diminishes the quality of social interactions online to such an extent as to render the social construction of knowledge all but impossible [61, 62, 63]. Researchers experienced with online teaching and learning, however, contest this view. What is important, they contend, is not media capabilities, but rather personal perceptions [35, 36, 64, 65, 66]. Their research demonstrates that participants in online courses often feel less psychological distance between themselves and their classmates, in part because they evolve text-based mechanisms to replace vocal and verbal affective indicators. In addition, researchers have documented relationships between learners' perceptions of social presence and their

satisfaction in, and perceived learning from, online courses [39, 67] which at least suggest the development of community-centered environments. In addition, they have identified particular teacher behaviors [68, 69] and activity structures [60, 70] that foster perceived social presence and the development of community. Thus, not only does it seem clear that we can design for community-centered learning, but we have some preliminary ideas of how to go about it. Further research is, of course, indicated.

The second level of development of community-centered learning environments, making connections to students' larger community and culture, is less well-documented, perhaps because it seems much more straightforward. The interconnectedness of Internet sites and their frequent updating makes it quite easy, to a greater or lesser degree, to situate learning in authentic, real world problems and link it to local communities and cultures. Indeed, links to the Internet, as previously noted, make it possible to explore a variety of world cultures to an extent that would not otherwise be possible. And as previously noted, one can also design online discussion and learning activities that engage students' interests and experiences. Anecdotal accounts suggest such strategies are very effective in supporting learning, but rigorous research in these areas is clearly indicated.

IV. THE RCET MODEL

Constructivism is a theory of learning, not of instruction. However, as we saw in the previous section, constructivist theory can inform pedagogy and instruction. Indeed, constructivism may be especially well-suited for informing teaching and learning online, but, as we also saw, a good deal more research along these lines is clearly needed. In particular, although we have considerable findings supporting and explaining constructivist approaches in face-to-face learning environments, it is not at all clear that these are applicable in online environments. Thus, more directed research focusing on explicit features of online learning environments (see Mayer [53]) and conceptualized within specific aspects of a constructivist frame might yield important results.

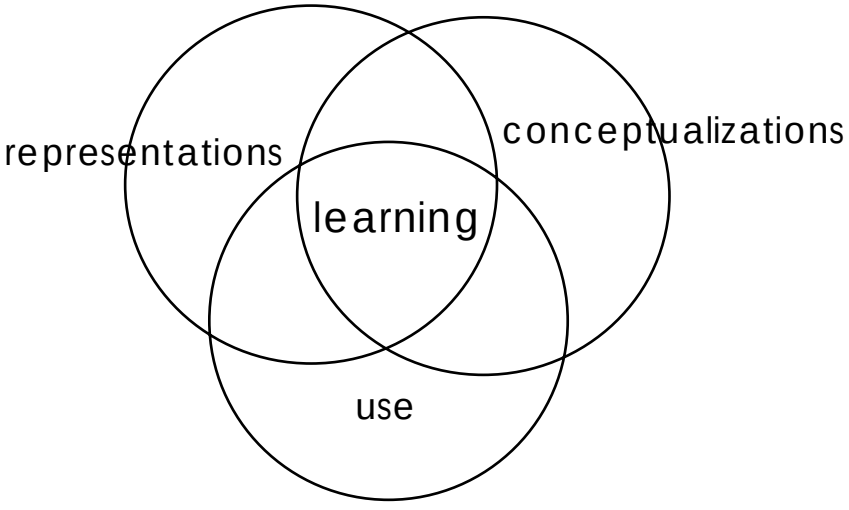

Figure 1: RCET Model of Technology Supported Learning

In the Research Center for Educational Technology (RCET), we have been developing a constructivist model to help us think about teaching and learning in face-to-face ubiquitous computing environments [71]. I believe it might also be useful for organizing thinking about learning in virtual ubiquitous

computing environments as well, and so help guide both the design of constructivist research and the development of related practices in online learning. Specifically, the model distinguishes three interacting domains of knowledge construction within which the effects of the unique affordances and constraints of online environments can be isolated and explored.

Models help us to make sense of our world. They help us to visualize a phenomenon, to isolate its significant components, to explore specific interactions among them. The RCET model is designed to direct our study of the effects of ubiquitous computing contexts and particular technologies on learning, and so to inform the practice of technology-mediated teaching and learning. It envisions the effects of educational technologies on learning as determined through their effects on the external representations of knowledge available to and/or created by learners, their effects on learners' internal conceptualizations and organization of knowledge, and their effects on the social interactions through and around which knowledge is negotiated and constructed (Figure 1). Although the model clearly places learning at the intersection of representation, conceptualization, and use, it allows us to separately investigate the mediating effects of technology in each of these domains, and to describe how such effects, in turn, impact learning. In the following paragraphs, each of the components of the model is briefly described and ways in which each might support and focus our thinking about learning online are considered.

A. Representation of Knowledge

We begin with *representation*, what theories of distributed cognition refer to as the artifacts and tools through which knowledge is constructed. We use the term *representation* broadly to refer to the myriad ways human beings externally construct and present what they know [71]. The model thus asks us to consider the specific kinds of external representations of knowledge used in online courses, especially those unique to online environments, and to explore their effects on online learning.

Clearly, external knowledge representations enable and shape human learning. In most formal learning (and a very large part of informal learning as well), external representations of knowledge precede and shape the construction of internal conceptualizations [20]. In turn, we use external representations of knowledge to communicate our internal conceptualizations and to share them with others. Representations, then, are in one sense a bridge between *conceptualization* and *use*, between internal, individual knowledge construction and the external, social construction of knowledge. Because they structure knowledge in particular ways and so afford certain kinds of meaning making while constraining others, representations are also the stuff thinking and learning are made of. Spoken and written language, for example, numbers and mathematical symbol systems, musical notation and music itself, various types of graphical and visual representations are all tools human beings have invented to construct, represent, manipulate, interrogate, preserve, and communicate differing kinds of knowledge in quite different ways. Indeed, recent psychological research suggests that we correspondingly employ multiple mental systems to construct differing kinds of meanings [72, 73].

Online learning environments support new kinds of knowledge representations [74, 75] and have the potential to provide access to a much greater variety and a much, much greater quantity of representations of knowledge [50]. The RCET model encourages us to explore such representations and their affects on learning, to pay close attention to the ways in which we represent the concepts we wish to present. Richard Mayer's [53] extensive investigations of combinations and sequences of differing media representations, for example, suggest that some of these are more conducive to learning scientific explanations than others. Mayer's work is particularly interesting in that he links external representations to internal conceptualizations and the construction of knowledge. More work is clearly needed along similar lines, especially explorations of the uses of video and simulations in online environments, as is the

use of digital learning objects in online courses [51, 54]. Of particular interest also are the tools for representing and constructing knowledge we provide for learners [11, 12, 13, 14]. Jim Hewitt's [76] research on patterns of interactivity in online discussion, for example, suggest that such patterns are as much a function of features of the interface as they are a result of pedagogical efforts. Similarly, Scardamalia and Bereiter's [24] work on computer-supported collaborative learning suggests particular representations of knowledge are more supportive of collaboration than others. Clearly, a good deal more investigations into tools for supporting discussion and collaboration online are needed, as are studies of computer-based tools for scaffolding thinking and learning [77]. Finally, initial findings in these areas suggest that studies of online course interfaces in general and their effects on learning might also be important [78].

The RCET model can help guide such research because it not only focuses our attention on particular online representations of knowledge, but asks us to consider specifically what kinds of thinking and learning they afford and constrain (See Parker and Gemino [55]). The model thus asks us to explore not only what kinds of representations work and don't work in online courses, but why they have particular effects on learning. This makes findings more generalizable and so much more useful in informing the practice of online education.

In terms of practice, the RCET model encourages course developers and online instructors to seriously consider the ways in which they represent the concepts and skills they want students to acquire, and perhaps experiment with differing representations that take advantage of the unique capabilities of the online medium. Similarly, the model encourages designers and instructors to think hard about the kinds of activities and tools they ask students to engage and whether or not these really achieve the purposes for which they are intended. In short, the RCET model can help guide the practice of online education by focusing attention on the ways in which knowledge is represented in online courses. This is particularly important in the online environment because all learning therein is mediated through such representations.

B. Conceptualization of Knowledge

The notion of the conceptualization of knowledge in the RCET model is similar in function to what Piaget [3, 4] identified as the development of mental schemas. We use the term *conceptualization* in the model to refer to the unique ways in which knowledge is represented and organized in individuals' minds as well as the ways in which such knowledge is processed and manipulated internally, to the multiple ways in which human beings mentally process, represent, organize and manipulate information and so make sense of the world. We assume that conceptualizations are developed through our interactions with environments (including social as well as physical environments, and cognitive interactions with our own internal conceptual environments themselves), and that they are built up over time into interrelated mental structures. We assume that they are thus unique to each individual. We use the term "conceptualization" to embrace multiple kinds of knowledge and multiple ways of knowing, because we are not convinced that meaning making is inseparable from language [72, 73], and to include both cognitive organization and mental processing, because we believe these two are essentially indivisible [79]. We also use the term "conceptualization" to highlight our emphasis on technological support for what Bransford, Brown, and Cocking [1] call *learning with understanding*, the organization and processing of information in coherent conceptual frameworks that are more meaningful, hence, more accessible and more useful.

The RCET model thus asks us to consider the ways in which particular technologies and technology environments afford and constrain specific conceptualizations of knowledge. Whereas the domain of representation of knowledge considers external knowledge construction, the domain of conceptualization of knowledge focuses our attention on the internal, mental construction of knowledge. In terms of online

learning, it asks us to consider what kinds of mental processing, what kinds of internal organizations of knowledge, and what kinds of cognitive schema are particularly supported by online technologies, etc. in particular), and what kinds of conceptualizations are perhaps ill-supported by the same. For example, we have some evidence that online learning is particularly supportive of the construction of abstract concepts and less supportive than face-to-face environments of the construction of procedural knowledge [55]. It could be very informative to expand on this research and explore precisely the ways in which online learners process conceptual and procedural knowledge. Similarly, there is some evidence that threaded discussion particularly affords the development of knowledge structures which integrate multiple perspectives [39]. If we knew better how such development occurs, it might help us better understand why, and so help us design online courses to particularly support it. Analogous research on the kinds of conceptualizations supported by specific online learning environments might be very fruitful, extending in important ways our understanding, not only of online learning, but of learning in general.

The notion of conceptualizations in the RCET model also draws our attention to the importance of the knowledge structures and ways of knowing learners bring to their online experiences, and the compatibility between these and learning online. For example, the Dziubans' [40] study of the relationship between reactive behavior patterns and persistence in online courses suggests that independent learning behaviors are more conducive to persistence than dependent ones. Similar explorations of, for example, differing ways of conceptualizing factual knowledge and their effects on achievement in online courses might be very informative [31]. In addition, research on the effects of gender and culture on the ways in which students conceptualize knowledge in online environments might particularly inform studies of the influences of these characteristics on learning online.

The notion of the unique conceptualizations learners bring to online courses, suggests, at the very least, that online instructors need to be especially sensitive to such things as gender [44, 45] and cultural differences [46] in learners' mental models of communication. Indeed, the RCET model suggests that instructors should similarly be sensitive to any learner characteristics that might influence the ways in which students conceptualize knowledge [31, 40, 41, 47]. This is especially important in the online environment because that environment mediates all interactions between instructors and students and so the range of cues to student understandings may be reduced. Thus, the model also guides online educators to particularly consider ways in which they can exploit technologies available to them to support learners' knowledge construction, as well as ways in which they might ameliorate any constraints the medium might place on it.

C. Uses of Knowledge

In the RCET model, we use the term *use* to refer to the social activities and interactions through and around which knowledge is negotiated and constructed. Our notion of *use* is thus derived from social constructivist theories of learning, but, although theoretically consistent with, may be pragmatically different from, some such theories. In particular, the model distinguishes between *conceptualizations* of knowledge, which are seen as private and internal, and *uses* of knowledge, which are viewed as public and external, to artificially isolate different arenas within which we can consider the effects of technology on learning. We find value in exploring use apart from conceptualization and representation because it directs our attention to the ways in which technologies can affect classroom activity [29], in particular to explore the effects of technology on both social interactions and on the social activities involved in the kinds of external constructions of knowledge highlighted by constructionist thinkers [11, 12, 13, 14].

In this vein, there is a growing body of research that examines social contexts created through digital environments. Research on computer-supported collaborative learning has not only shown that computer-

based collaboration can enhance higher-order learning [24], but has identified particular program designs and features which support specific kinds of external constructions of knowledge [77, 80]. For example, Margaret Reil [81] found that papers written to be shared electronically with peers were more fluent, better organized, and clearer than papers written for a grade alone. Much in these approaches can and probably should be explored relative to online learning environments. In the online learning domain, research on computer-mediated communication has found asynchronous online class discussions to be more equitable and democratic [32] and more reflective [36] than traditional classroom discussion, and hasdocumented links between online interactions and learning 39, 66, 67, 82]. Interesting research in this area also links specific design features to particular discourse behaviors [76], and particular online teaching behaviors to student learning and course satisfaction [69].

The RCET model can help us make sense of findings such as these by suggesting that they reflect characteristic affordances and constraints such things as particular kinds of online interfaces, communication tools, and media mixes have on social interactions online, and so, the social construction of knowledge in online courses. Of particular interest may be the ways in which online communication tools support the external and collaborative construction of knowledge and how this affects learning. Of similar interest are online games and simulations [83]. The RCET model's notion of use can also help us make sense of the changing roles of instructors [69, 84] and students [85] in online learning environments, and the notion of the development of online learning communities [24, 86, 87, 88]. It moreover encourages us to explore new and evolving social conventions (of discourse, of interaction, of "netiquette") in online courses in relation to the larger culture of the Internet.

In terms of practice, the RCET model encourages online developers and course instructors to seriously consider the importance of social supports for knowledge construction and learning. This is especially important because the online environment may be inherently socially lean [61, 62, 63]. The model thus encourages online instructors in particular to make concerted efforts to project themselves into their courses [69, 84], to facilitate the development of social presence among their students [65], and to encourage the emergence of learning communities in their online classes [86, 87, 88].

V. SUMMARY AND DISCUSSION

In this paper, constructivism was identified as the term for a set of epistemological theories which are grounded in a belief that meaning is constructed in the minds of individuals through the cognitive processing of interactions in world and explored some important variations on this theme. Significant aspects of constructivist theories were shown to include the notion that learning is active, social and situated in particular physical, social and cognitive contexts, that it involves the ongoing development of complex and interrelated mental structures, and that the construction of knowledge is, to a greater or lesser degree distributed across individuals, tools and artifacts. Constructivism was moreover seen to have various implications for instruction, the most significant of which is to shift the focus of pedagogical design away from instruction and toward the design of learning environments that are learner-centered, knowledge-centered, assessment-centered, and community centered. Finally, a model for thinking about online learning in constructivist ways was proposed. The model explores the effects of online learning environments on thinking and learning in terms of their effects on external representations, individual conceptualizations, and social uses of knowledge. It hoped that by so narrowing the focus of our thinking about learning online, the model might help guide research to pursue findings which can meaningfully inform practice and advance online education.

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