A Constructivist Approach to Teaching: Implications in Teaching Computer Networking

Catherine Chen

The rapidly changing, increasingly complex business world requires college graduates to use multiple, complex skills to solve business problems. Conventional teaching strategies that mainly consist of lectures may not be effective to prepare these students for employment. Constructivist learning theory, which uses construction kits to assist learners to construct knowledge and emphasizes presenting learning activity in a meaningful context, provides an alternative theoretical foundation for rethinking and redesigning teaching practices. This paper presents the constructivist theory and offers examples of teaching practices based on the theory for teaching basic computer networking concepts.

Introduction

The Information Age is based on rapidly increasing and changing information, and the goal of education is no longer to train students to store and retrieve mastered information. The ability to recall and explain a concept does not necessarily reflect understanding, nor does it guarantee that students can apply and use the concept in a meaningful way (Julyan & Duckworth, 1996). The goal of education in this new age is to prepare students to use their skills to solve real-world problems; yet, education has been criticized for failing the task. The common reason cited is that the learning experience provided in school is so different from the experience in the real world that students cannot transfer the skills between the two environments (Brown, Collins, & Duguid, 1989; Duffy & Jonassen, 1992; Hiebert et al., 1996; Schank, 1997; Sternberg, 1985).

From a different perspective, concepts and theories are difficult to learn because they are not observable. Ordinary inductive processes are not effective for constructing theoretical models because learners cannot observe the entities that comprise the models. In a high-technology work environment, neither the equipment's functioning nor the mental activity of an expert diagnosing a problem is visible, so observation alone is unlikely to foster conceptual development in traditional apprenticeship activities (Resnick, 1986). Nevertheless, an understanding of computer networking is increasingly important in a high-tech business world. Business graduates from colleges and universities need to have working concepts in computer networking to be able to communicate intelligently with computer networking professionals. Graduates of end-user computing related programs may assume the roles of network administrators. For these graduates, a comprehensive understanding and hands-on experience of computer networking are important parts of their employment preparation.

Recognizing the need, the Organizational Systems Research Association (OSRA, 1996) developed and revised the Organizational and End-User Information Systems Curriculum Model for Undergraduate Education in Information Technology, which includes a Communications Technologies (OEIS-6) course. Crews and Ray (1998) used the Delphi technique to poll OSRA members who had taught business telecommunication to form a consensus on the course content. After five rounds of inquiry, the panel reached common consent on 10 topics and 30 subtopics for a college/university course in telecommunication with an emphasis on end-user computing. The ten topics include local area

Catherine Chen is Assistant Professor, Information Systems and Operations Management Department, Ball State University, Muncie, Indiana.

networks, wide area networks, communication media, communication hardware, telecommunication systems, emerging technologies, network topologies, data signals, conceptual foundations, and social and ethical issues (p. 15). This result provides a guideline for what to teach in a computer networking class; yet, many questions remain regarding how to teach computer networking concepts. Computer networking concepts often are technical, and students may not have much of a knowledge base for learning the course content.

I started teaching a university-level introduction to computer networking class in 1999. After using the conventional teaching approach with many charts, figures, drawings, graphics, and PowerPoint presentations, I realized that students continued to have difficulty understanding the material. I then started to use objects such as ropes, strings, and building blocks in the classroom to build and provide three-dimensional displays of the concepts for discussion. Students responded to the new approach in a very positive way, so I continued to develop and refine these techniques. As von Glasersfeld (1995) states, learning theories provide a solid conceptual foundation for the teaching practices that teachers have been doing without theoretical foundation. The theoretical foundation for using objects in teaching, I believe, is constructivism.

Purpose

The purpose of this paper is to provide a theoretical foundation for using a constructivist approach in teaching computer networking. In addition, this paper shares practical examples based on constructivist theory to be used in a computer networking class. It is also the goal of this paper to invite educators to share their teaching practices.

Review of Literature

The literature review section reviews the relevant learning theories, behaviorism, cognitivism, and constructivism. It then reviews learning environments, the teacher's role, the learner's role, and assessment in the constructivist approach to teaching.

Learning Theories

This section provides a brief review of behaviorism and cognitivism. It continues with a more detailed review of constructivism, since this learning theory is the foundation for the proposed teaching approach. This section, however, will not review a recent movement, situated learning (e.g., Lave, 1990; Lave & Wenger, 1991; Rogoff & Lave, 1984), because I do not view situated learning per se as the foundation of the proposed teaching practice.

Behaviorism. Basing their approach on Thorndike's stimulus-response principle, behaviorists view learning as a result of stimuli and responses through the use of rewards (von Glasersfeld, 1995). This approach emphasizes performance rather than the reasons that the learner performs a certain way. Educators who use this framework break a content area into component subskills, sequence them, and then transmit them to students mostly by direct instruction such as lectures or reading assignments. This teaching approach assumes that once students have learned the parts, they can put them together as a whole and apply them when needed (Bredo, 1997; Fosnot, 1996). Further, students are viewed as passive learners who need external motivation and are affected by reinforcement (Skinner, 1953). The behaviorist tradition dominated educational thinking and designs for many decades.

Cognitivism. In the 1960s cognitive psychology signaled a major conceptual shift from the behaviorist tradition (Anderson, Reder, & Simon, 1995; Bredo, 1997). In contrast to behaviorism, cognitive psychology focuses directly on the structure and operation of the human mind.

One of the main influences on cognitive psychology was the development of the information processing approach (Anderson, 1985). Information processing theory is a branch of cognitive psychology concerned with the way humans collect, store, modify, and interpret information from the environment; how the information is retrieved and stored; and how people use the knowledge and information in their activities. The way knowledge is represented and coded for storage in the human memory and the internal processing mechanisms underlying behavior are the concerns of information processing theory (Lachman, Lachman, & Butterfield, 1979).

Information processing theory generated a wealth of research that provided insight into how components of the processing system function. Yet, critics viewed information processing research as overly focused on thinking and problem representation and not taking context and social aspects into consideration (Cooper, 1993). The information processing perspective is helpful when interpreting the construction of personal knowledge (constructivism), in that all human beings are viewed as processing information by using a common set of processing components, although each individual may have a unique knowledge structure.

Constructivism. Constructivism is an outgrowth of cognitive science. Constructivism views learning as a process of knowledge construction, with concept development and comprehensive understanding as the goals (Fosnot, 1996; Resnick, 1986). Phye (1997) states that constructivism is a movement that combines cognition from a developmental perspective with other important issues, such as motivation, self-directed learning, and a focus on the social context of learning.

According to von Glasersfeld (1996), there are two main aspects of constructivism. First, learning is a process of knowledge construction instead of absorption. We construct knowledge based on our own perceptions and conceptions of our world; therefore, each of us constructs a different meaning or concept (Duffy & Jonassen, 1992; Fosnot, 1996; von Glasersfeld, 1996). Learning, in constructivists' view, requires the building of conceptual structures through reflection and abstraction (Schuman, 1987; von Glasersfeld, 1995). Since each learner has to construct his or her knowledge, concepts cannot be transmitted from teacher to learner by means of words (Schank, 1997; von Glasersfeld, 1996). Learning occurs only when the learners are actively involved in the construction and reorganization of concepts.

Second, knowledge is highly related to the environment in which the learner experiences and constructs the knowledge (Duffy & Jonassen, 1992; Resnick, 1986; von Glasersfeld, 1996). In other words, understanding is indexed by experience. Therefore, constructivists emphasize cognitive experience in authentic activities. The context need not be the real world of work, however, to be authentic; rather, learning activities should employ the type of tasks that are the ordinary practices of the culture (Brown et al., 1989; Duffy & Jonassen, 1992; Resnick, 1987).

The second main aspect of constructivism is similar to situated learning. Situated learning "takes the theory of social and ecological interaction as its basis…" and emphasizes the "information structures in the contents of people's interactions" (Greeno, 1997, p. 5); therefore, situated learning emphasizes social interaction. Constructivism, on the other hand, emphasizes context and environment.

One of the recommendations of constructivism is to engage students in building objects (Kafai & Resnick, 1996). According to Resnick (1986), this is a promising approach to assist learners in constructing theoretical constructs because it creates the "means of objectifying constructs, that is, building physical displays that allow explicit representation of key theoretical constructs" (p. 6).

This objectifying approach serves several purposes. First, it becomes possible to manipulate these objects and observe the effects, and by doing so the presentation of the concept is visible. Second, manipulating objects allows learners to raise their own questions, generate their own hypotheses, and then test the hypotheses (Fosnot, 1996). Third, object displays ensure that individuals talk about the same thing and have visible references for the discussion (Resnick, 1986).

In constructivism, constructing an understanding requires that the learners have the opportunities to articulate their ideas, to test those ideas through experimentation and conversation, and to consider connections between the phenomena that they are examining and other applications of the concept (Dykstra, 1996; Nesher, 1989; Julyan & Duckworth, 1996). The opportunity for learners to discuss and clarify their experiences is essential, because it encourages self-organization and reflective abstraction. This reflective abstraction is the driving force of learning (Fosnot, 1996; Perkins, 1992). Dialogue within a community promotes further thinking. A constructivist classroom is seen as a community engaged in activity, reflection, and conversation (Fosnot, 1996).

Starting with the assumptions that knowledge is constructed and that the environment in which the construction takes place is highly related to the knowledge, Spiro, Feltovich, Jacobson, and Coulson (1992) proposed a Cognitive Flexibility Theory. They maintain that for students to achieve advanced knowledge acquisition, multiple presentations that revisit the same concepts in different contexts, at different times, and for different purposes are essential for obtaining mastery.

Perkins (1992) proposed two variations of constructivism: BIG (beyond the information given) constructivism and WIG (without information given) constructivism. A teacher using a BIG approach would directly introduce the concepts, provide examples, and then engage students in activities that challenge them to apply and refine their initial understanding through the use of multiple applications and examples. This approach presents information to the learners but stresses the need to go beyond the information given. In contrast, a WIG approach would not present the concept. It is a discovery-learning approach to teaching. Instead, learners would be presented with phenomena and then encouraged to explain the phenomena with their existing knowledge. Learners would discover for themselves, and the teacher would scaffold the process without providing answers. In Perkins' view (1992), an exclusive WIG approach is inefficient and ineffective and fails to present past achievements to students. However, education without any WIG instruction would not engage students in learning the processes of discovery and idea construction.

Learning Environment

Perkins (1992) identified five facets of a learning environment, not all of which are always present. An information bank is any resource that provides information about a topic, such as the teacher, a textbook, videos, or the Internet. Symbol pads are surfaces for the construction and manipulation of symbols; examples are notebooks, word processors, and drawing software applications. Construction kits are sets of modular parts that students can use to make things, such as Legos and laboratory tools. Phenomenaria are artificially limited arenas where students can investigate phenomena. Computer simulations in which students can investigate and observe physics phenomena are phenomenaria, for example. Task managers are the agents that guide the learning activity and provide feedback. Classic task managers are the teacher and texts.

Although construction kits sound similar to symbol pads, they are designed with a different emphasis. Students use symbol pads to record any structures that they have in mind, whereas construction kits are prefabricated parts or processes that students can use to build things. In constructivism, learners do not just receive and store information. They make interpretations of experience and elaborate and test those interpretations. Information banks therefore become less central with a constructivist approach. Symbol pads are not just for recording but working through ideas. The center of a constructivist-oriented learning environment is a construction kit or a phenomenarium, because these two provide tools for students to make sense of new information. In addition, students themselves are given much more task management responsibility (Perkins, 1992).

The Teacher's Role

Using a constructivist approach, teachers are challenged to provide teaching techniques that support students' construction of their understanding. Teachers need to make the concepts and phenomena interesting and important to the students (Julyan & Duckworth, 1996; Schank, 1997). The teacher should offer a variety of methods for exploration and provide various approaches.

Applying the Cognitive Flexibility Theory proposed by Spiro et al. (1992), content must be covered multiple times. Multiple implications and applications of the concept must be presented in realistic, meaningful contexts, and the inter-connections among knowledge components must be made explicit. No single presentation is sufficient to provide all pertinent information.

In addition, merely providing the experience is not sufficient; the teacher should ask questions and listen carefully to students' interpretations of the data. The teacher must push students to think as clearly as they can about their ideas. The teacher should perceive errors as the results of the learners' conceptions for the moment, because at that moment that is what makes sense to the student (Fosnot, 1996; von Glasersfeld, 1995). To modify students' misconceptions, the teacher will need to elicit an explanation as to how the students have arrived at their answers, and ask questions or provide a different presentation to allow the students to discover their errors and construct the correct concept (von Glasersfeld, 1995). This is when the objectifying theory becomes useful. By allowing students to manipulate objects, the concepts become visible, as do the misconceptions. Students may discover their misconceptions themselves because their designs do not make sense even to them.

It will be the teacher's decision to use the BIG (beyond the information given) or the WIG (without the information given) approach. Many agree that for introductory learning, BIG is more effective, while WIG is more appropriate for advanced learning (Perkins, 1992, Schank, 1997; Spiro et al., 1992).

Both Schank (1997) and Julyan and Duckworth (1996) agree that an atmosphere of playfulness is important. As long as students are having fun, they are motivated and attentive, and it also helps to release the frustration inherent in constructing understanding.

The Learner's Role

Constructivism places the learner in the center of the learning process; however, little discussion has focused on learners themselves and how they experience the approach. Perkins (1992) identified three demands imposed on learners, cognitive complexity, task management, and acceptance of the approach. The constructivist approach usually confronts learners with construction kits or with phenomenaria which are complex and challenging. Most constructivist instruction intentionally presents learners with situations that make them examine their existing knowledge and structures, forcing them to reorganize and construct new models. The learners, not the teacher, are responsible for defending, proving, justifying, and communicating their ideas to the classroom. These types of tasks place a very high cognitive demand on the learners. Learners are no longer able simply to memorize the content and repeat it on tests and assignments.

Second, learners are asked to take on more responsibility for task management than in conventional instruction. This shift of responsibility is necessary if students are to become autonomous thinkers and learners; yet, many students are not used to managing their own learning. Perkins (1992) suggests that, to help with both cognitive complexity and task management, the teacher should make sure that just enough help and guidance is provided, but not too much. It would be difficult, however, for a teacher to support large groups of students. This is where the support that comes from working in groups can be helpful to students.

Third, some students may not want to do the hard work of constructing their understanding and taking on the responsibility of managing their learning. As teachers, we probably have heard students' reactions such as "What do you want?" and "I don't know what you want." From the students' perspective, they are being asked to discover concepts for themselves when they thought that they could be told the concepts, do some exercises, and move on. A constructivist approach asks students to think both about the concept and the process of learning the concept, and many students may not buy in to the teaching approach (Perkins, 1992).

Assessment

The most criticized aspect of constructivism is assessment. Instructional designers ask what to assess and how to assess (Dick, 1992). If the process of construction is the essence of learning, should the process or the result of the process be assessed? If concepts constructed may vary from student to student, what criteria should be used for evaluation?

Jonassen (1992) recommends evaluation strategies that are consistent with the two main aspects in constructivism, namely, learning is a process of construction, and context is important in the learning process. He suggests that effective assessment should be part of the instructional process. Students' demonstrations of knowledge acquisition, their products, should be noted as only part of the evaluation; the process should also be evaluated.

The second suggestion is that evaluation should occur in contexts that are as rich and complex as those used in instruction. Jonassen (1992) states that "simplified, decontextualized problems are inappropriate outcomes for constructivistic environments" (p. 141). Since it is important to present multiple perspectives in a constructivist learning environment, the evaluation process should also reflect and accept multiple perspectives. Evaluation therefore requires a panel of reviewers, and each reviewer should have the credentials for evaluating students from a meaningful perspective (Jonassen, 1992). Allowing for multiple perspectives does mean the absence of standards.

A Constructivist Approach to Teaching Computer Networking

The general constructivist learning principles helped me rethink and redesign my teaching practices when it was clear that the traditional lecture/ presentation approach was not effective in teaching the introduction to computer networking class. The contents of the class include most of the ten topics identified in Crews and Ray's (1998) study, with additional units on network operating systems and network administration and support. This class starts with the topics listed in Crews and Ray's study, and students then work in groups to set up server-based and peer-to-peer networks, install network operating systems, create and manage user accounts, and perform other network administration and support activities. Providing hands-on computer experience may not be an option for some teachers, but if it is, a great many materials are available to assist and support this teaching approach.

The focus of this paper is on teaching basic networking concepts. The students' backgrounds, the general approach used, and the group project assignments will be described to provide an overall structure of the class. Finally, examples of using objects to objectify network topology concepts and using construction kits for students to learn network architectures will be presented.

Students' Background

The prerequisite for the class is an introduction to computers class. Students enrolled in the networking class have a limited understanding of computer hardware; however, the majority of students are either majoring or minoring in business information technology and have had several computer software application courses at the time of enrolling in this computer networking class. This usually is an evening class that meets once a week for two hours and forty minutes.

First Day of Class

In the first class period, a pretest, called a "get-to-know-you" questionnaire to ease test anxiety, is administered to all students to identify their knowledge of computer networking. Meanwhile, three-by-five-inch index cards are distributed to students to make name cards. After the pretest and name cards are collected, the cards are then used for an icebreaker. The name cards are mixed into pairs and handed back to students, but not to the owners of the cards. For example, John would get Josh's card and Josh would get John's card. If possible, students who do not know each other are matched. Students are then asked to take a few minutes to get to know each other and share a funny story, and each student tells the story to the class. This exercise establishes a playful learning atmosphere and a sense of community. Playfulness motivates students, and a sense of community encourages students to articulate their ideas (Fosnot, 1996; Julyan & Duckworth, 1996; Schank, 1997). Motivation and willingness to participate are essential for students to take part in their construction of concepts.

Students are then asked to introduce themselves and to share with the class the computer networking experience they have had, either from previous courses or jobs. Again, this helps students to know each other as well as providing information on students' existing computer networking knowledge that the instructor might not have received in the pretest. Information gathered from the pretest and the students' introductions provides indications of how much knowledge students already have to allow them to construct new networking concepts. This is also a first step toward creating a unique community of learning among this particular group of students. In addition, it allows the teacher to ensure that heterogeneous groups are formed to encourage discussion throughout the semester, as discussion and clarification help learners construct and reorganize their concept structures (Fosnot, 1996; Perkins, 1992).

General Approach

Since the majority of students in this class have limited hardware knowledge, and since network-related hardware concepts are main components of the course content, Perkins' (1992) BIG (beyond information given) constructivist approach is used. I use a brief PowerPoint slide presentation in each class period to provide key concepts, and the slide presentation is posted a few days before the class period on Blackboard, software that allows instructors to post class materials on or communicate via the Internet.

Students are told in the first class period that the class will have a hands-on approach, and they are expected to explain, explore, and discuss what is presented. They are told, to their delight, that lectures will be kept to a minimum. Students are made aware that they must take responsibility for their own learning by participating in class discussions, keeping up with the reading, following the instructions and guidelines in assignments, checking Blackboard, and checking the e-Gradebook on a regular basis. I use the e-Gradebook software to post assignments and test grades on the Internet. I explain to students that to make a nearly three-hour evening class interesting, a variety of activities will be used, but students will have to do their share to make it work. This gets students to buy in (Perkins, 1992) to a constructivist approach.

Generally, the class starts with a 40-minute PowerPoint presentation on the concepts covered for the class period. Various hands-on activities follow. Construction kits (Perkins, 1992) are used frequently to assist students in their construction of concepts. In most cases, I ask questions and students explain the phenomena or demonstration.

At the conclusion of the class, students work in groups to go over questions, either from a handout or from the textbook. Then, the class as a whole goes over the questions, with one of the groups leading the discussion. This provides another opportunity for students to discuss the concepts in groups and as a class, and to reflect on what they have learned that day. Furthermore, this provides an opportunity for me to ask questions on the interrelationships among concepts and challenge students to examine their overall understanding. As constructivism stresses, presenting the material in multiple passes with multiple formats assists students to build constructs with multiple concepts (Perkins, 1992; Spiro et al., 1992).

Group Projects

Students are required to complete three group projects. Students are divided into 3- to 4-person groups. The first project asks students to gather computer network information on a business of their choice. Students work on this project out of class after network hardware and architecture are covered as class topics. Students identify and visit a business, collect information on the computer network used in the business, relate the collected information to the course content, and reflect on what they learned in the class. Students submit one report from each group for evaluation and present their findings orally in class. This project allows students to put the concepts they learn in a real-world context and gather information on the hardware problems and obstacles network personnel encounter. Meanwhile, this project provides an opportunity for students to reflect on their learning. Students frequently indicate that seeing the real thing and asking questions is a great help in clarifying their understanding.

In the latter half of the semester, students have the opportunity to connect computers in networks, install network operating systems, and try out network administration tasks. Since this hands-on activity is not evaluated and students do not earn points, it is not considered a formal project. Due to facility constraints, students are divided into two large groups, and each large group is divided into 3- or 4-person groups. While one large group works on the computers, the other large group works on the second project, network design. These two large groups rotate their tasks so that every student has the opportunity to complete both exercises.

The second project presents students with a scenario of a fictitious company named ToyQuest. In this scenario, students are hired as new network administrators and are asked to revise an existing single-floor token ring network plan to incorporate new Ethernet workstations on a second floor, forming a new network. Other information provided includes a diagram of the existing networks for ToyQuest, floor plans, the number of workstations and network utilization in each department, and a statement indicating that the company has plans to expand to the third floor in the near future. Students take all these parameters into consideration to determine the type and quantity of network media to use and the additional hardware needed. Students then shop for the hardware on the Internet to get the best pricing. Finally, students prepare a proposal with a budget detailing the hardware, the quantity, and the costs. The reports are graded based on both the design and the budget. This project provides an opportunity for students to go "beyond the information given" (Perkins, 1992). Students must apply the networking concepts they have learned and integrate them to design the most desirable plan using the appropriate hardware. At the same time, they need to be concerned about pricing, as in the real world. This project is rich in context and complex as an evaluation tool (Jonassen, 1992).

The third project is about network administration. After students have hands-on experience with network installation, user management, and other administrative functions, they revisit the business from which they gathered information for the first project. The focus of this visit, however, is on the administrative aspect of networking, such as the network operating systems used, account and user management, network security issues, disaster recovery plans, and other administrative issues and concerns. The requirements are similar to those of the first project.

Students finish all three projects with the same group members. The goal is to develop a good teamwork experience and allow time for students to work out their differences and manage any conflicts that they might have.

Objectifying Network Topology Concepts

Ropes, key rings, and post-it notes can be used to objectify (Resnick, 1986) bus, ring, and star topologies. These substitutes are also accompanied with actual cables, connectors, and network cards. To objectify a bus topology, each student sitting in the front row is asked to hold on to a point of the rope and pretend to be a computer. I ask questions about what would be needed for cabling a bus topology. When students answer, "terminator," I tie knots on each end of the rope as terminators. This set up then is used for discussing the characteristics of a bus topology, how signals travel, and what happens when a cable breaks or computers break down. This discussion then leads to the advantages and disadvantages of a bus topology. At the same time, various cables, terminators, network cards are presented and available for students to manipulate.

For a ring network, the same rope then is tied to a ring with a key ring on it. To simulate a ring topology, students sitting on both sides of a pathway are computers and hold the rope to form a circle. The key ring on the rope is the token for the token ring. A post-it note is posted on the token key ring to signify a message. With this setting, I can ask questions about the characteristics, the signals, the effect of computer break down, advantages, disadvantages, and other related questions to encourage students to articulate their thinking and clarify their ideas. Another rope can then be added to form a Fiber Distributed Data Interface (FDDI), and the similarity and differences between token ring and FDDI can be discussed with the physical displays as references.

The same principle can be used to discuss star topology. One student holds several shorter ropes at one end to represent the switch, and several students who represent computers hold the other ends of these ropes. As Resnick (1986) points out, this approach makes the presentation of the concepts visible. Students raise questions. Some of the questions can be answered by more experienced students in the class, and others by me. I try to do the asking, however, and let students do the explaining. Discussion and communication become easier because both students and I have the objects as reference and are talking about the same thing.

Using Construction Kits to Construct Network Architecture

Network architecture usually is confusing to students because there are many hardware elements involved, such as cables, connectors, hubs, switches, bridges, routers, and firewalls. In addition, topology and speed affect the use of these hardware elements. To help students assemble these, I use children's building blocks, ropes, and strings. Again, students are divided into groups of three or four. Each group is provided with wooden building blocks in various sizes as well as ropes and strings in various thicknesses and textures. Smaller cube blocks simulate workstations, larger cube blocks simulate file servers, and other sizes simulate printers, switches, routers, and other hardware. For networking media, fishing lines simulate fiber optic cables. Thicker, less flexible strings can be thicknet coaxial cables. With these, students are asked to build a wide variety of network architectures ranging from simple bus networks to complex networks consisting of multiple topologies. This construction kit helps students construct the basic concepts of computer networking, including network topologies, communication media, and communications hardware as listed in Crews and Ray's (1998) study.

This is an example of what Perkins (1992) refers to as a construction kit. These construction kits allow students to put their understanding on display. Their understanding and misconceptions become observable, and modifying students' misconceptions become much easier. In addition to using this construction kit in the network architecture unit, it can be used in the network topologies unit and in the local area and wide area network unit. By using the construction kit in different units, I present basic networking concepts in multiple passes as Spiro et al. (1992) recommend.

Conclusions

Today's business world requires graduates to have in-depth knowledge and to be able to use this knowledge to solve problems. The traditional teaching approach that breaks course content into sequenced components, presents concepts to students through lectures, and provides exercises may not be effective in teaching theories and concepts. Constructivism provides a conceptual foundation for rethinking and redesigning teaching practice. The principle that conceptual knowledge cannot be transferred from teacher to students by telling disputes the traditional didactic teaching strategies that consist mainly of lectures. The principle that knowledge exists in meaningful contexts, not just in individual heads, challenges teachers to present concepts through meaningful experiences and to provide situations where multiple, interrelated concepts apply so that students have the opportunity to construct a comprehensive understanding.

Constructivism provides a sound theoretical foundation for teaching any complex knowledge domain. This paper presented teaching practices that apply constructivism to teaching computer networking. These practices include using objects to build three-dimensional displays of networking concepts to promote discussion and clarification, using construction kits to allow students to raise questions and see their constructed concepts in action, building a friendly and safe learning atmosphere to encourage idea discussion and sharing, and supplying meaningful projects for students to bring in real-world experience.

Recommendations

Consistent with the constructivist theory, teachers should continue to construct and refine their teaching strategies; therefore, it is the goal of this paper to invite teachers to share and, working in teams, continue to develop and construct teaching practices that foster students' learning of useful knowledge.

To validate the constructivist approach in teaching computer networking concepts, empirical research is needed to investigate the effectiveness of this strategy. Experimental designs are needed to compare the effectiveness of various teaching approaches, such as lectures alone versus construction kits, on students' knowledge and understanding. Effectiveness should also include a measure of students' ability to use the knowledge to solve computer networking problems. The results of such investigations will be very beneficial for teachers to help them select the most effective strategies based on sound evidence.

References

Anderson, J. R. (1985). *Cognitive psychology and its implications*. New York: Freman.

Anderson, J., Reder, L., & Simon, H. (1995). *Applications and misapplications of cognitive psychology to mathematics education*. Retrieved July 23, 2001, from http://act.psy.cmu.edu/personal/ja/misapplied.html

Bredo, E. (1997). The social construction of learning. In G. D. Phye (Ed.), *Handbook of academic learning: Construction of knowledge* (pp. 3-45). San Diego, CA: Academic Press.

Brown, J. S., Collins, A., & Duguid, P. (1989). Situated cognition and the culture of learning. *Educational Researcher, 18*(1), 32-42.

Cooper, P. A. (1993). Paradigm shifts in designed instruction: From behaviorism to cognitivism to constructivism. *Educational Technology, 33*(5), 12-19.

Crews, T. B., & Ray, C. M. (1998). Course content for a telecommunication course in an end-user computing support program. *Office Systems Research Journal, 16*(2), 9-16.

Dick, W. (1992). An instructional designer's view of constructivism. In T. M. Duffy & D. H. Jonassen (Eds.), *Constructivism and the technology of instruction: A conversation* (pp. 91-98). Hillsdale, NJ: Lawrence Erlbaum Associates.

Duffy, T. M. & Jonassen, D. H. (1992). Constructivism: New implications for instructional technology. In T. M. Duffy & D. H. Jonassen (Eds.), *Constructivism and the technology of instruction: A conversation* (pp. 1-16). Hillsdale, NJ: Lawrence Erlbaum Associates.

Dykstra, Jr. D. (1996). Teaching introductory physics to college students. In C. T. Fosnot (Ed.). *Constructivism: Theory, perspectives, and practice* (pp. 182-204). New York: Teacher College Press.

Fosnot, C. T. (1996). Constructivism: A psychological theory of learning. In C. T. Fosnot (Ed.). *Constructivism: Theory, perspectives, and practice* (pp. 8-33). New York: Teacher College Press.

Greeno, J. G. (1997). On claims that answer the wrong questions. *Educational Researcher, 26*(1), 5-17.

Hiebert, J., Carpenter, T. P., Fennema, E., Fuson, K., Human, P., Murray, H., Olivier, A., & Wearen, D. (1996). Problem solving as a basis for reform in curriculum and instruction: The case of mathematics. *Educational Researcher, 25*(4), 12-21.

Jonassen, D. H. (1992). Evaluating constructivistic learning. In T. M. Duffy & D. H. Jonassen (Eds.), *Constructivism and the technology of instruction: A conversation* (pp. 137-148). Hillsdale, NJ: Lawrence Erlbaum Associates.

Julyan, C., & Duckworth, E. (1996). A constructivist perspective on teaching and learning science. In C. T. Fosnot (Ed.). *Constructivism: Theory, perspectives, and practice* (pp. 55-72). New York: Teacher College Press.

Kafai, Y., & Resnick, M. (1996). Introduction. In Y. Kafai & M. Resnick (Eds.), *Construction in practice: Designing, thinking, and learning in a digital world* (pp. 1-8). Mahwah, NJ: Lawrence Erlbaum Associates.

Lachman, R., Lachman, J., & Butterfield, E. (1979). *Cognitive psychology and information processing.* Hillsdale, NJ: Lawrence Erlbaum Associates.

Lave, J. (1990). The culture of acquisition and the practice of understanding. In J. W. Stigler, R. A. Shweder, & G. Herdt (Eds.), *Cultural psychology* (pp.309-327). Cambridge, England: Cambridge University Press.

Lave, L., & Wenger, E. (1991). *Situated learning: Legitimate peripheral participation*. Cambridge, England: Cambridge University Press.

Nesher, P. (1989). Microworlds in mathematical education: A pedagogical realism. In L. B. Resnick (Ed.), *Knowing, learning, and instruction: Essays in honor of Robert Glaser* (pp. 187-215). Hillsdale, NJ: Lawrence Erlbaum Associates.

Organizational Systems Research Association. (1996). *Organizational and end-user information systems curriculum model for undergraduate education in information technology.* Springfield, MO: OSRA.

Perkins, D. N. (1992). Technology meets constructivism: Do they make a marriage? In T. M. Duffy & D. H. Jonassen (Eds.), *Constructivism and the technology of instruction: A conversation* (pp. 45-55). Hillsdale, NJ: Lawrence Erlbaum Associates.

Phye, G. D. (1997). Learning and remembering: The basis for personal knowledge construction. In G. D. Phye (Ed.), *Handbook of academic learning: Construction of knowledge* (pp. 47-64). San Diego, CA: Academic Press.

Resnick, L. B. (1986). Introduction. In L. B. Resnick (Ed.), *Knowing, learning, and instruction: Essays in honor of Robert Glaser* (pp.1-24). Hillsdale, NJ: Lawrence Erlbaum Associates.

Resnick, L. B. (1987). Learning in school and out. *Educational Researcher, 16*, 13-20.

Rogoff, B., & Lave, J. (1984). *Everyday cognition: Its development in social context.* Cambridge, MA: Harvard University Press.

Schank, R. (1997). *Virtual learning: A revolutionary approach to building a highly skilled workforce.* New York: McGraw-Hill.

Schuman, L. A., 1987. *Plans and situated actions.* New York: Cambridge University Press.

Skinner, B. F. (1953). *Science and human behavior.* New York: Free Press.

Spiro, R. J., Feltovich, P. J., Jacobson, M. L., & Coulson, R. L. (1992). Cognitive flexibility, constructivism, and hypertext: Random access instruction for advanced knowledge acquisition in ill-structured domains. In T. M. Duffy & D. H. Jonassen (Eds.), *Constructivism and the technology of instruction: A conversation* (pp. 57-75). Hillsdale, NJ: Lawrence Erlbaum Associates.

Sternberg, E. R. (1985). Teaching critical thinking: Are we making critical mistakes? *Phi Delta Kappan, 67*(3), 194-198.

von Glasersfeld, E. (1995). A constructivist approach to teaching. In L. P. Steffe & J. Gale (Eds.), *Constructivism in education* (pp. 3-15). Hillsdale, NJ: Lawrence Erlbaum Associates.

von Glasersfeld, E. (1996). Introduction: Aspects of constructivism. In C. T. Fosnot (Ed.). *Constructivism: Theory, perspectives, and practice* (pp. 3-7). New York: Teacher College Press.