Using Microworlds in Teaching and Learning

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Abstract
Microworlds are cognitive learning tools that can be used to promote problem solving, critical thinking, discovery, and mental model development. These small, interactive, and programmable models of real world environments can create engaging and appealing environments for student learning based on Constructivist Principles: active participation, individual knowledge construction, resolution of disequilibrium, discovery, and meaningful learning contexts. The epistemology of the Microworld is discussed, examples are examined, and ways to promote active student learning are explored.

Microworlds are small, interactive, dynamic, real world environments that contain programmable objects that can be manipulated and studied (Hogle, 1995; Hoyles, Noss & Adamson, 2002; Sarama & Clements, 2002). The manipulation of objects within a narrowly specified knowledge domain first appeared in the field of Artificial Intelligence (AI) in the early 1970s. AI Researchers at MIT created small, restrictive knowledge domains as vehicles for understanding and using language, creating expert systems, and mimicking human information processing and reasoning. The first successful attempt at language interpretation using a microworld was Terry Winograd’s 1972 program called Shrdlu (Drake, 2000). Shrdlu is a microworld of blocks that accepts and responds to user commands typed in English; a good description appears at http://www-pcd.stanford.edu/~wonograd/shrdlu/.

A mathematician named Seymour Papert joined the Artificial Intelligence Laboratory at MIT and worked with colleagues to develop a programming language called Logo to help young children build and manipulate their own intellectual structures (Roblyer, 2003). Logo was combined with a robot shaped like a turtle; later the mechanical turtle was changed to an on screen turtle. Papert believed this combination would allow young children to learn math concepts in a “mathland” through experimentation, exploration, self-discovery, and self regulated instruction. His theories are described in the 1980 publication Mindstorms: Children, Computers, and Powerful Ideas. The graphical nature of Logo, its depiction of cause-and effect relationships, and its logical quality made it ideal for creating microworlds or as Paper termed them, “incubators of knowledge.” (Roblyer, 2003).
This paper discusses Constructivism as the epistemology behind Logo, supplies examples of microworlds, and suggests ways teachers can use microworlds in learning contexts to promote active participation, individual knowledge construction, and the resolution of disequilibrium (a conflict between an environmental phenomenon and the learner’s understanding of that phenomenon.)

Constructivism: the Epistemology for Logo

Papert’s view of learning is termed Constructionism; many of its precepts come from Constructivism. Both theories concentrate on students’ abilities to actively build knowledge rather than passively retrieve and store transmitted conceptual data and facts. Constructivism as a learning theory is based on the work of many scholars. Some contributors include John Dewey, Jerome Bruner, Lev Vygostsky, Howard Gardner, and Jean Piaget.

Jean Piaget

Jean Piaget was a world renowned Swiss psychologist who proposed theories about the mind and its inner workings. He studied children and their development in an effort to unlock the mysteries of the mind. His studies led him to formulate a highly influential model of child development and learning. Piaget theorized that developing children build cognitive schema or schemata - internal structures that represent organized knowledge and learner understanding. These organizational frameworks help children understand and respond to experiences in their physical environment. Piaget further reasoned that learners use assimilation and accommodation mechanisms to resolve conflicts in knowledge and understanding. Assimilation allows the learner to append new knowledge into current schema, while accommodation allows the learner to build new schema. Piaget also identified four distinct stages of child development: Sensory-Motor, Representational, Concrete Operations, and Formal Operations.

The Sensory-Motor stage lasts from ages 0-2 years, and it allows the child to build concepts about the world and how it works. These concepts are built through the child’s physical and sensory interactions within the environment.

The Representational state begins at age 2 and lasts until about age 6. In this stage, the child reflects and begins to internalize actions and convert them to iconic images.

The third stage of child development, Concrete Operations covers ages 7 through 11. During this stage, the child develops abstract and symbolic abilities and creates logical structures that explain physical experiences.

The Formal Operations stage begins at about age 12 and lasts through age 15. During this stage, the child’s cognitive abilities (including reasoning) resemble those of adults. The child/learner is active and heavily uses reflection and abstraction. Piaget’s model of child development impacts educational pedagogy in several ways. It suggests that effectively designed curricula is developmentally appropriate, targets student growth, and emphasizes the role of active experience, discovery, and experimentation.

Constructivism relies on experimentation and experience; it is viewed on a continuum divided into several categories: Cognitive, Social, and Radical (Doolittle & Camp, 1999). Each category supports individual knowledge construction through assimilation, accommodation,
adaptation, cognitive ability, and interaction within real world environments. Social negotiation, mediation, relevance, prior knowledge, and self-regulation are also deemed important. Teachers adhering to Constructivists Principles operate in a student-centered environment where they guide learners, encourage diverse ideas and perspectives, and assist learners in the manipulation of objects, ideas, and concepts within the environment. Lessons emphasize problem solving activities, hands-on approaches, and creativity.

Constructivism, Piaget, and Papert

The link between Constructivism, Piaget, and Papert was forged in the late 1950s. During this time, Piaget was studying children and how they begin to understand mathematical concepts. He read Papert’s doctoral dissertation which focused on understanding topology as pure mathematics and found it impressive. He was so impressed that he invited Papert to study with him in Geneva, Switzerland. Papert accepted the invitation and became intensely interested in studying children and the things they could accomplish. Papert later joined the staff at MIT and became a founding member of the AI Lab. He worked with colleagues to develop a programming language (Logo) that allowed children to learn difficult and powerful concepts (i.e., problem decomposition, procedures, list processing, recursion, data structures, geometry, graphics, X-Y Cartesian Coordinate System, multimedia effects, and spatial relationships) through active exploration, experimentation, and manipulation of mathematical structures.

Examples of Microworlds

More commonly used in mathematics and science, microworlds are small, complete subsets of an environment (Rieber, 1991). Non-computerized examples include Cuisenaire rods, mechanical gears, and others. The power, speed, and ability to create realistic graphics quickly make the computer an ideal platform for designers and users of microworlds. Several computer generated examples of microworlds include some simulations, Logo Turtle Geometry, Space Shuttle Commander, Mathsticks, and others.

Some Simulations

Simulations are a form of Computer-Based Instruction that allows users to alter variables and observe cause-and-effect relationships. Simulations that replicate real life scenarios (flight simulators) without permitting users to experience different outcomes or understand underlying conceptual models are not considered microworlds (Rieber, 1991). In order to be a microworld, a simulation must permit debugging, help learners understand the conceptual model for knowledge, house useful ideas that can be connected to other learning, encourage experimental learning, contain simple domain knowledge recognized by an expert within the domain, and represent a complete subset of a domain (Hogle, 1995).

Logo Turtle Geometry

Logo Turtle Geometry allows users to experiment with geometric concepts by manipulating a turtle that follows user commands. The turtle can be used to learn the X-Y Coordinate System or draw elaborate graphics using circles, rectangles, and squares. Users can create procedures and decompose spatial and logical problems into smaller, more manageable entities. Students manipulate the turtle by giving it directions, changing its shape and position,
and thinking about the objects they create and change. Interaction with the turtle produces feedback which encourages reflection and assists learners as they resolve the natural conflicts that arise as they interact in the Logo Environment.

Space Shuttle Commander

Space Shuttle Commander was designed for elementary and middle school students; it gives students instruction on Newton’s Laws of Motion (Hogle, 1995) by combining tutorials in flight lessons with simulated space shuttle missions based on Newton’s Laws. It combines an instructional hierarchy of tasks with exploration and self-discovery. It requires some teacher guidance and support to channel the incidental learning that occurs as a result of exploration and student discovery.

Mathsticks

Mathsticks is a microworld designed to help students appreciate number patterns as functional relationships (Hoyles, Noss & Adamson, 2002). It allows students to use special – purpose tools (i.e., dot, jumpl, match, hmatch, rmatch, etc…) to assemble sequences of objects on the screen and directly manipulate them. User actions are linked with graphical representations and feedback immediately supplied. Students create objects that match those given. In the process, they learn structural details, relationships between objects, and instances of classes. The creators of Mathsticks found that student learning was related to the interaction between learner actions and the mathematical relationships encapsulated within the microworld (Hoyles, Noss & Adamson, 2002).

Some additional examples of microworlds include Green Globs and TGEO. Both are used to allow students to gain knowledge of mathematical models, enhance problem solving ability, and support student debugging and mental model formation. To view web-based examples of microworlds, review the following urls:

http://www.coe.missouri.edu/~jonassen/courses/mindtool/MicroworldExamples.html,

Promoting Active Student Learning with the Logo Microworld

Students can actively participate in developing their own knowledge structures with Logo. They can use the turtle to study geometric principles, the X-Y Cartesian Coordinate System, and algebraic equations. A student who knows a few Logo Primitives (commands) can make an on screen turtle change its position, move to precise coordinates, and create elaborate shapes and designs. By actively interacting with the turtle, students learn spatial and numerical relationships that can be transferred to other problems.

Students can experiment with powerful programming concepts (i.e., problem decomposition, list processing, recursion, data structures) in the Logo Microworld. It is possible for students to learn to decompose problems into manageable segments through planning. They can use their plans to construct programs (made of procedures) that can solve problems, help them examine relationships, and strengthen their debugging skills. Planning and decomposition
are important problem solving activities that can be transferred to any domain, not just
programming.

List processing, recursion, and data structures are complex programming concepts that
can be explored in Logo. Concatenating, locating the beginning and end of lists, studying
mechanisms for copying and referencing procedures in memory, and manipulating and storing
data in trees, lists, and arrays are important skills for programmers. Correctly mastering and
implementing these foundational programming concepts allows those creating programs to
efficiently use computing resources and write better programs.

Logo permits students to actively create presentations that disseminate their findings, and
communicate their ideas. Objects in student presentations can be animated, graphically
displayed, and combined with text and sound. Transitions can be applied to give the presentation
aesthetic appeal and make it cohesive.

Summary

Microworlds are small, interactive, and programmable models of real world
environments that can create engaging and appealing environments for student learning based on
Constructivist Principles: active participation, individual knowledge construction, resolution of
disequilibrium, discovery, and meaningful learning contexts. Instructors should investigate the
possibility of using a microworld to facilitate active discovery, creative expression, and problem
solving.

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