

Methods for Developing Constructivist Learning on the Web

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Constructivism Defined

Constructivism is a theory of learning describing how our minds create knowledge or how student knowledge structures and "...deeper conceptual understanding" come about (Fosnot, 1996, p. 30; Joyce & Weil, 1996). Constructivist activities do not simply provide students with information, expecting them to accept that data as "truth." Constructivist activities ask students to intentionally bring forth their own relevant mental models and attempt to integrate external information within these personal frameworks (Glynn & Duit, 1995; Novak, 1995). To help the learner integrate new ideas with his or her own familiar model, constructivists recommend grounding activities in everyday contexts such as realistic cases, expressing topics to be learned in multiple perspectives, and encouraging student collaboration whereby divergent peer views are reconciled (Jonassen, 1994; Willis, 2000).

Joyce and Weil (1996) contrast constructivist educational practices with traditional practices through the metaphor of a "Frisbee." They point out that the receiver of a Frisbee catches the disc in the same shape and format as when it left the hand of the thrower. Similarly, traditional education attempts to "throw" materials at students with the assumption that they will receive and store this material in a coherent framework identical to that of the instructor or textbook writer. Considerable research into student mental models suggests information may be *delivered* to students in identical formats, but depending on other factors, such as age, underlying knowledge, and experience, information is *interpreted* and understood differently by each individual (Vosniadou, 1994; Wiser, 1995). Educators who support the "delivery" of general information to every student adopt Plato-like arguments

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that knowledge is general, procedural, and universal (Willis, 2000). Constructivist philosophy aligns more closely with Aristotle's view of knowledge as practical, situated in context, and built from concrete experiences rather than external abstractions and theories.

Many classroom activities are simply designed to illustrate or confirm evidence for existing theories (Baxter, 1995). The models and hypotheses tested are those developed by an expert. Discussions, activities, and experiments are carefully designed to lead students to a "correct" response. Learning, however, should bridge from what students already know. If students are not allowed to state and test their own models, hypotheses, ideas, and issues, their understanding may remain partial. Several shortcomings are likely to occur: students accumulate facts that do not fit or connect in any way with their own internal models for concepts; the expert models presented conflict with student models and are ignored; or hybridized and distorted notions of concepts emerge as students attempt to fit expert conceptions with their own (Baxter, 1995). These shortcomings are possible through constructivist activities as well, but the difference is that constructivist activities are specifically designed to move learners beyond misconceptions and distorted models, to make logical connections between what they already know and what is being professed anew. Traditional education assumes that if the learner can repeat an expert model or the instructor's model on a test, he or she understands the issue. In fact, the concept may lack internal coherence and connection to anything the learner already knows.

Preparing for Constructivist Activity

At least two steps must be undertaken to prepare for constructivist activities. First, the instructor must design or work with students to design an authentic, relevant task. The task should provide for motivation and form the impetus for the student to pursue information and revise his or her mental model of a concept. Second, the instructor must promote student intentionality.

Design Authentic, Relevant Tasks

Educators who view learning as a "...behavioral response to physical stimuli" emphasize student acquisition of rules, facts, and information toward a burgeoning knowledge base (Fosnot, 1996, p. 8). Substantial content sets are "covered," and only *after* information is acquired are students asked to apply this information to a case or problem. Constructivist environments, however, always start with a case, problem, ill-defined question, or project, with the expectation that students will learn facts and information *while* they work on the issue or assignment (Duffield & Grabinger, 1997).

Constructivist activities should be situated in authentic contexts to motivate and interest students in learning (Boyle, 1996). According to the goal-based

scenario model, a student interested in trucks should learn to apply math in the context of trucking industry figures; a student interested in dolls should learn to apply math in the context of materials composition for creating plastic figures (Schank, 1992). Authentic tasks might ask students to diagnose and save a patient by researching and collecting information about the symptoms; engineer earthquake-proof structures by collecting evidence about prior building failures (Oliver, 1999); rescue an injured eagle by correctly computing mathematical calculations for travel variables (Cognition and Technology Group at Vanderbilt, 1992); or create a multimedia program to teach students about fractions (Harel & Papert, 1993). Students reflect on the scenarios and must research external concepts or extract embedded concepts in order to solve problems. Students do not simply study concepts apart from any realistic application. Realistic contexts allow students to see how concepts like time and distance are relevant and applicable to real world tasks. Many researchers have presented authentic activity design guidelines, including the use of real-world, ill-defined problems that present multiple, conflicting perspectives and/or interdisciplinary connections (Hannafin, Land, & Oliver, 1999; Herrington, Sparrow, & Herrington, 2000). Collaborative opportunities should be provided for students to define a complex task and its various sub-steps on their own.

Support Intentionality

It is not sufficient for constructivist environments to provide an authentic task. Students must sense some form of ownership in the task if they are to persist and seek a resolution to the situation (Boyle, 1996; Brooks & Brooks, 1993). Most students are familiar with traditional learning environments that tell them explicitly what to do and how to do it. As these students are exposed to constructivist learning environments, they may attempt to adopt more familiar instructivist techniques despite the presence of an open-ended task (i.e., "teacher, just tell me what I need to know"). As Laffey, Tupper, Musser, and Wedman (1998, p. 77) note, "Most students have never taken on a long-term project where the work has not already been essentially scripted by the teacher or curricular material." In their Web-based project support tool, students are provided with open-ended placeholders for project planning. Students set their own goals and objectives, team members plan their responsibilities, and work is allocated to specific periods of time. Hung and Wong (2000) also advocate student project work, suggesting that the creation and evolution of community artifacts by student teams promotes thinking. They designed a Web-based environment based on activity theory, which included project planning and scheduling templates in addition to other

tools. Similarly, Bielaczyc and Collins (1999, p. 286) advocate "emergent goals" or the ability for learners to co-construct group goals based on what they know. Pintrich and Schunk (1996, p. 176) describe advantages of student goal-setting and intentionality:

Students with a goal are apt to experience a sense of self-efficacy for attaining it and engage in activities they believe will lead to attainment: attend to instruction, rehearse information to be remembered, expend effort, and persist. Self-efficacy is substantiated as learners observe goal progress, which conveys they are becoming skillful.

In addition to goal-setting, students should also be given some voice in such teacher-dominated activities as setting standards and criteria for performance (Airasian & Walsh, 1997; Bielaczyc & Collins, 1999).

A Sample Constructivist Learning Model

Problem-based learning (PBL) has a constructivist framework, because it encourages active construction of knowledge through personal inquiry, the use of problems to form disequilibrium and subsequent accommodating inquiry, as well as social negotiation and work with peers (Savery & Duffy, 1995). PBL began in the 1950s to restructure medical school instruction. PBL has helped break the mold of traditional institutional learning models rigidly framed in segregated disciplines of facts and concepts (Boud, 1985). The main difference between PBL and traditional learning models is that PBL uses a problem as the starting point for learning, while other models use a problem as the culminating activity or assessment for students once facts and concepts have been presented to them (Duffield & Grabinger, 1997). It is through the process of framing and resolving the problem that students develop content knowledge as well as important process skills like critical thinking and analysis. Problem-based learning gives students an opportunity to work with complex knowledge structures as they exist to those employed in actual settings—scientists, doctors, engineers, administrators, educators, etc. In traditional learning environments, content is often sequenced, chunked, divided, and scaffolded beyond all comparison to how it actually exists and must be faced in real settings.

PBL environments involve the following general ideas: the use of learners' pre-existing knowledge; students actively participating in their own learning by helping to plan, organize, and evaluate; an emphasis on interdisciplinary connections, especially in terms of communication skills across subject domains; a focus on the processes of learning; involvement of students in self-assessment and peer-assessment; and students taking on authentic roles as they tackle real-world issues (Boud, 1985; Duffield & Grabinger, 1997).

Barrows (2000, p. viii) refers to PBL as a “genus” with many variable species. His PBL model (1985) is one of many and includes these specific activities: Students are divided into groups; a real problem is presented; the problem is discussed and hypotheses are formed; students identify key issues in the problem; individual group members research specific issues and gather resources; resources are evaluated in groups; and the cycle repeats until students feel the problem has been adequately framed, all issues have been covered, and evidence-based solutions can be justified.

Advantages of constructivist learning environments like PBL include: student acquisition of “retrievable and usable” knowledge and skills that were learned in context and are more capable of long-term transfer, the development of problem-solving and reasoning skills, and the development of “lifelong learning skills” such as metacognitive and strategy knowledge (Duffield & Grabinger, 1997; Myers-Kelson & Distlehorst, 2000; Schmidt & Moust, 2000).

Constructivist Activities Supported by the Web

Constructivist learning should always begin from the student’s point of view or should “...start where the student is” (Nickerson, 1995, p. 9). Yager (1995, p. 40) concurs, “Look for students’ alternative conceptions and design lessons to address any of these conceptions which do not represent those held by scientists.” In the activities described in this section, a constructivist reflection cycle is encouraged: students express their conception of an idea or their mental model, they reflect on the opinions of others or on feedback provided about their ideas, and they revise their initial conception to account for new opinions or feedback (see Figure 1). Land (1995) refers to this constructivist notion of advancing student conceptions as “theories-in-action.”

Reflection allows learners an opportunity to modify misconceptions or improve inadequate understanding (Barab & Duffy, 2000). Reflection can take place in a “practice field” or learning environment that provides opportunities for authentic activity before students enter the world outside school (Barab & Duffy, 2000). Problem-based learning is one example of a “practice field.” Moonen (2000, p. 26) summarizes reflective practice as situations in which “...means and ends [predictions and outcomes] are used iteratively...not assuming prior agreement about ends.” Reflection is recommended for instructional designers of educational materials, but the practice is similarly suitable for students tackling their own fuzzy or uncertain problems. As Willis (2000, p. 11) notes, “A reflective model of practice assumes that many, if not most, important problems in professional practice cannot be well-formed and solved with preformed solutions.” Given this factor, instructors should provide students

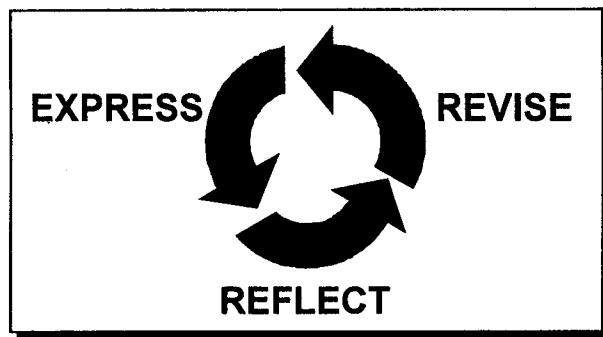


Figure 1. Constructivist reflection cycle.

with tools and “practice-field” activities that promote reflection between what the student knows, thinks, or predicts, and the resulting outcome of that model (e.g., “my assumption was incorrect and must be revised”). Teaching with only well-defined problems, or worse yet, providing all of the solutions, will not allow learners to reflect on and develop their own personal mental model for concepts, nor gain expertise at solving real problems.

Activities that allow for a reflective, constructivist cycle may be divided into two broad categories. The first category, constructing on the conceptions of peers, describes activities whereby each learner expresses what he or she knows, then engages in Web-based activity to merge his or her understanding with that of his or her peers. The second category, constructing on the conceptions of experts, describes activities whereby each learner expresses what he or she knows, then engages in Web-based activity to merge his or her understanding with that of experts or professionals. The Internet or technology in general is not required for either category, but Web-based tools can enable effective, reflective processes.

Constructing on the Conceptions of Peers

Many constructivist lessons involve the use of teams or groups to facilitate discussion of concepts. One student alone can only reflect on what he or she knows, but in collaboration or communication with other students, can be introduced to varying and discrepant points of view with which to consider the merits of his or her own mental model.

Designing collaborative webs. Collaborative webs refer to any Internet-based document created by more than one student in collaboration. Students should not simply read online documents and access links selected by an expert, but rather, they should utilize tools to create their own hypertext or hypermedia documents. Students should be able to interpret which knowledge

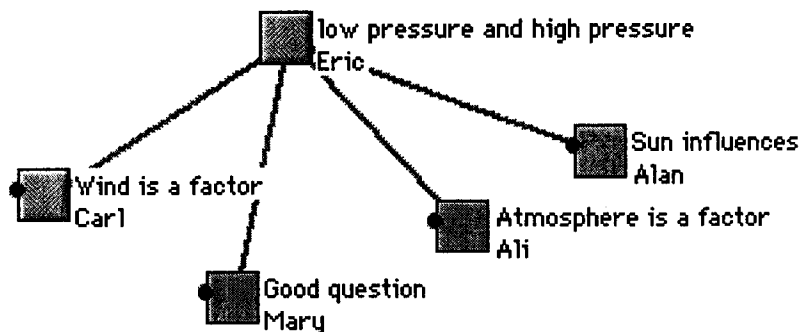
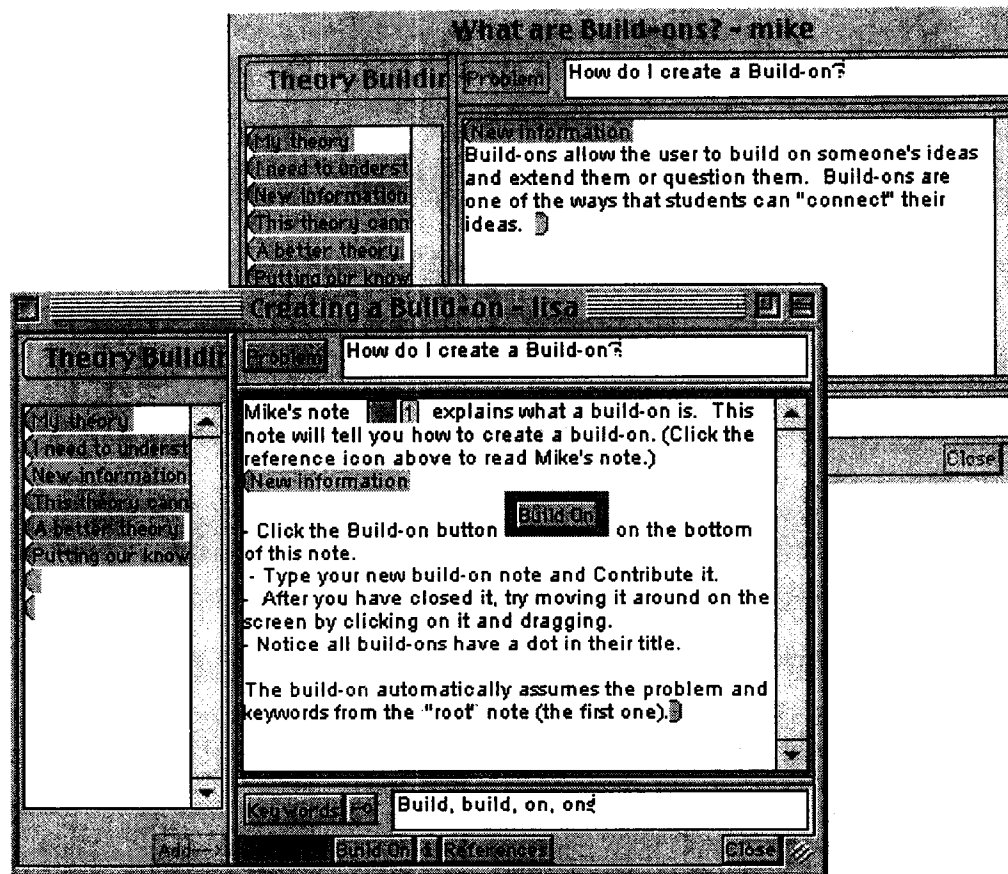


Figure 2. Communal Knowledge Base, Knowledge Forum; screen capture courtesy of Learning in Motion (2000).

components should be linked together, synthesizing the information by themselves (Mayes, Kibby, & Anderson, 1990).

Numerous examples of collaborative webs exist whereby students state what they know, then develop more advanced understanding by connecting their own ideas to those of their peers. These activities may be simple or complex. A simple classroom treatment is to assign or allow students to select a topic around a class

theme (e.g., "diversity"). Each student works individually to research and develop a Web site for their topic. Eventually, students access one another's Web projects and add links to others' pages describing potential linkages, differences, or comparisons to their own work. A more complex classroom treatment would involve tools such as the Computer-Supported Intentional Learning Environment (CSILE), now called Knowledge Forum (Learning in Motion, 2000). CSILE

and the newer Knowledge Forum allow students to create a "communal knowledge base" about a class topic (Bielaczyc & Collins, 1999, p. 277). One feature, known as "build-ons" allows the learners to connect their new notes to existing notes (see Figure 2). Students can also create "rise above" notes to synthesize a collection of notes.

Another tool supporting collaborative webs is called Swiki Swiki (Guzdial, in press). Swiki Swiki allows groups of students to develop a Web site, editing one another's work as they deem suitable.

Collaborative webs may be considered group concept maps, providing a representation of student mental models. Glynn, Duit, and Thiele (1995) suggest that concept maps can allow students to investigate and explicate numerous relationships, including: "hierarchical, exemplifying, attributive, causal, correlational, temporal, additive, and adversative" (e.g., "the information on my page is a cause for the problem you list on your page," "the information on my page is another attribute of the issue described on your page").

Discussing with peers. Peer discussion may be supported by various Internet tools, including e-mail, listservs, bulletin boards, and chat rooms. Some discussion tools such as CaMILE (Guzdial & Turns, 2000) can be "anchored" to a specific Web page, facilitating discussion about a specific topic or resource. If discussions are centered around a question or problem, students can learn by expressing their ideas, opinions, or solutions to others, by critiquing one another's proposed models, and by defending or modifying their initial models.

Oliver (1999) found that students were better able to uncover flaws in their reasoning about engineered designs when they were asked to give a brief presentation and defend their project in light of peer critiques. Numerous computer-based prompts and questions were developed to encourage student reasoning and justification of ideas before class presentations, but these scaffolds were often ignored. During presentations, however, students were able to point out potential weaknesses in one another's design plans, and suggest modifications or additional resources to better inform those designs. Whether Web-based or face-to-face, students may benefit from opportunities to discuss their conceptions with others, justifying those ideas with supporting evidence when possible, or revising their ideas in light of more feasible peer arguments.

In addition to tool-oriented and face-to-face discussions, grouping students into cooperative teams may help them recognize subtle differences between a personal mental model and the models of others. Reconciling differences, then, may encourage students to use evidence to reason, debate, or argue for a specific view (e.g., "I think your idea is valid because I found a reference that indicates..."). Students working

on team tasks will frequently reach a state of conflict that must be compromised in the form of a solution. The solution often represents a "qualitatively different third perspective" combining "two opposing ideas into a coherent, higher-level idea" (Clements & Nastasi, 1992, p. 243). According to the Cognition and Technology Group at Vanderbilt (1992, p. 68), "...cooperative learning and cooperative problem-solving groups enhance opportunities for generative learning....students have the opportunity to form communities of inquiry that allow them to discuss and explain, and hence learn, with understanding."

Discussing with peers and the instructor. The cognitive apprenticeship model of Collins, Brown, and Newman (1990) emphasizes instructor observation of the classroom, modeling for and coaching of students on strategies, and moving students toward a goal through a cyclical process of "successive approximations" on a complex task. Collins *et al.* (1990) describe several cognitive apprenticeship methods, including strategies to help students write better (see Scardamalia & Bereiter, 1985) and heuristics to help students solve problems better through reflection on their thought processes (see Schoenfeld, 1983).

One example of cognitive apprenticeship is reciprocal teaching, designed for students in reading comprehension classes (Brown & Palincsar, 1990). In reciprocal teaching, students formulate questions and make summaries after reading texts to monitor their progress and ensure they understand the material. Students also practice clarifying difficult phrases and words, and they hypothesize about upcoming events in the written work under study. The class mentor or teacher coaches students in these reciprocal teaching strategies by prompting and guiding students to pose questions, summarize, clarify difficult words, and make predictions. The teaching is reciprocal in that students take on the role of mentor as well, prompting their fellow students to follow the strategies. As the students become proficient, the teacher fades his or her coaching and allows the students to lead the process. Web-based cognitive apprenticeship activities are most applicable for distance learning students, as students in the same classroom can communicate face-to-face. Online apprenticeship activities can be supported by synchronous communication tools, allowing each student to "broadcast" their voice to others online. Symposium software (Centra, 2000) is one package that allows student groups to conference online and broadcast audio to others.

Constructing on the Conceptions of Experts

Several constructivist activities allow students to express what they know and merge that personal mental model with the conceptions of experts. In these constructivist activities, individual conceptions should

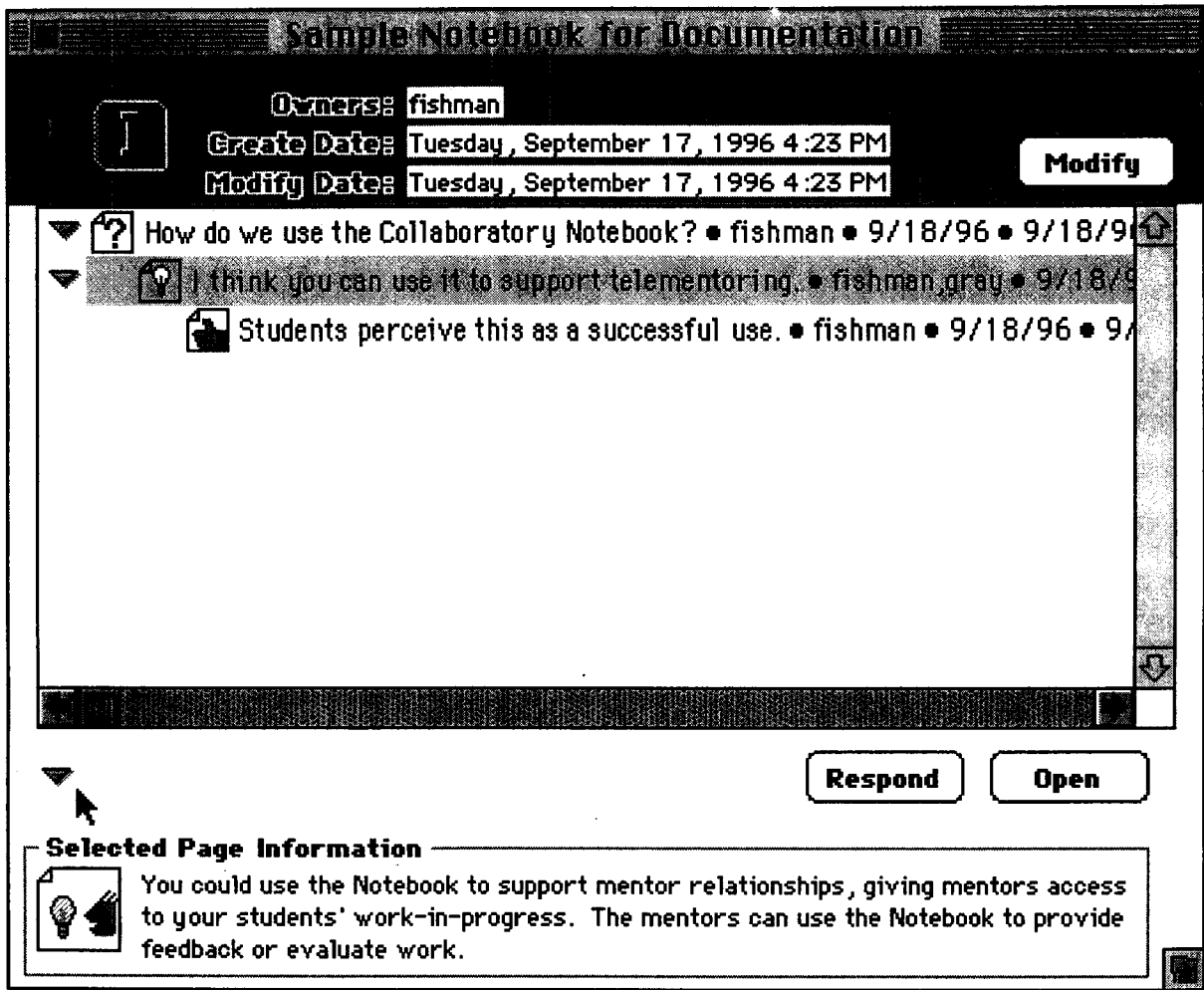


Figure 3. Collaboratory Notebook interface, CoVis; screen capture courtesy of Northwestern University (2000).

be revised. The student can not simply access expert opinions, but must work through the process of reconciling differences between expert models and their own.

Arguing for a perspective with gathered materials.

Gall (1995) found the task or process for which learners engaged hypertext resources to be the critical element in defining conceptual understanding. Students given a browsing task performed the lowest, students given a searching task performed better, and students given a connecting task performed the best. The simple provision of online hypermedia resources may aid knowing, but "...the processes used to evolve personal knowledge are as important as the structure of the knowledge itself" (Gall, 1995, p. 130). Students asked to connect knowledge were required to focus on structure daily, and this cognitive engagement

supported greater conceptual understanding. "Connecting" tasks might be problem-based, requiring learners to brainstorm potential causes or relationships for a problem, then selectively research specific information to inform that problem. A "connecting" task might also require students to express a hypothesis, then seek external evidence to support or contradict their initial conception. Several researchers have created online tools that actively lead students to express their conception or model, then sort and connect external knowledge to revise and improve their mental model.

Edelson, Pea, and Gomez (1996) describe the Collaboratory Notebook tool used as part of the CoVis scientific visualization project on the Internet (see Figure 3). The notebook allows learners to store their thoughts and a variety of media in a pre-structured

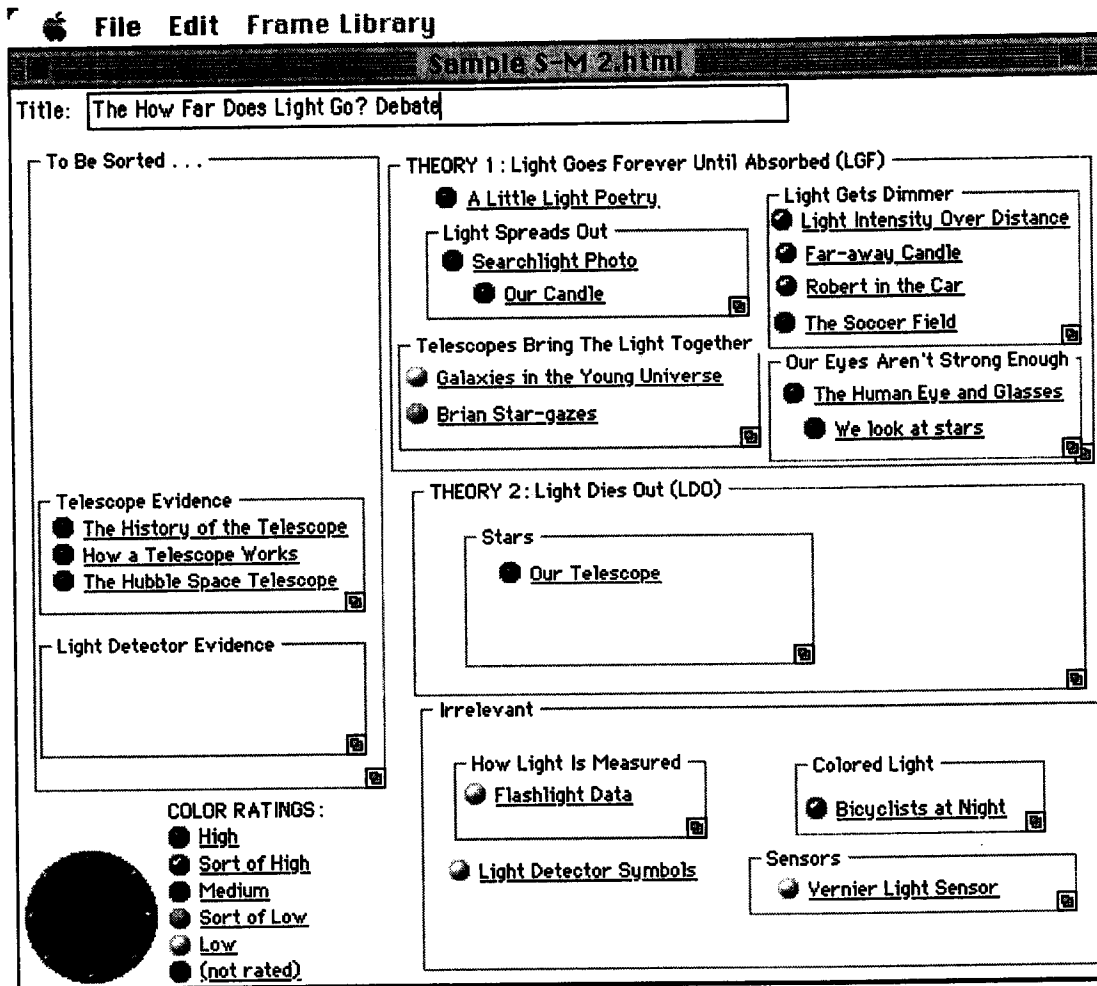


Figure 4. Sensemaker tool; screen capture courtesy of Slotta and Linn (2000).

format that scaffolds an open-ended scientific inquiry process. For example, if a learner studying the seasons were to find a document supporting the circular orbit of the earth about the sun, he or she could record that text in their notebook as evidence for that claim. Counter-evidence can also be recorded along with students' conjectures, supporting the argumentation process.

Also supporting argumentation, Slotta and Linn (2000) describe the Sensemaker tool used as part of their online Knowledge Integration Environment (KIE) (now the Web-Integrated Science Environment or WISE). Sensemaker allows learners to sort and organize web evidence into theory-related categories, visually interpreting which theory is supported by the weight of evidence (see Figure 4).

In these examples, students are allowed to make an initial expression of understanding, then continually revise that conception as new information is encountered. Such activity can be supported with

complex tools as described, or rather simple activities whereby students collect and cite online evidence to defend a perspective.

Constructing a perspective to teach others. A fundamental difference exists between *constructivist* activities that expose students to pre-structured cases, problems, and scenarios, and *constructionist* activities through which students design and structure their own cases, computer programs, and representations (Jonassen, Myers, & McKillop, 1996; Salomon, Perkins, & Globerson, 1991). Jonassen and Reeves (1996) note that students think best when they are allowed to represent what they know with software like HTML text editors and spreadsheets. Perkins (1986) indicates that learners should be asked to produce new models to exercise and apply the ideas they are learning.

Harel and Papert (1993) conducted research on students learning and using Logo programming software to teach other students about fractions.

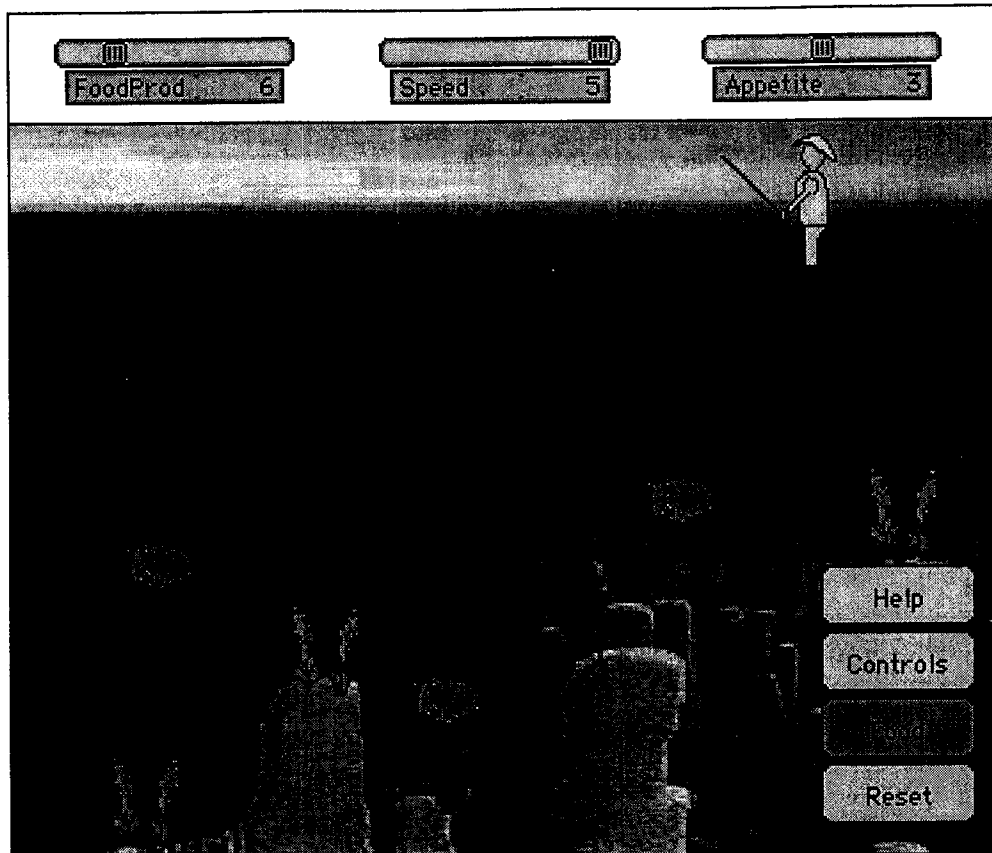


Figure 5. Microworlds Pro student project interface; screen capture courtesy of LCSi (1998).

Initially, students were stumped and rigid in their thinking about fractions as numbers or parts of a whole. Eventually, through the open-ended design activities, students were led to understand everyday objects can be used to represent fractions: clocks, measuring cups, and airplanes.

Microworlds Pro (LCSI, 1998) is a knowledge generation tool based on the Logo programming language. The software is used to develop problem solving and creative thinking skills in students. To develop the interactive fish ecosystem in Figure 5, students had to study and program relationships between relevant background variables using Microworlds Pro (e.g., food production, fish speed, and appetite). The environments created by students can be viewed on the Internet with a free plug-in, then discussed, critiqued, or used by peers.

Design projects frequently involve student teams. Hung and Wong (2000, p. 34) relate activity theory to collaborative student projects, suggesting "...activity is a form of doing directed at an object," such as a Web

page or group document. Activity is mediated by available tools and should be negotiated by the team or community. Students should be allowed to balance any structured project requirements or limitations with more reflective personal concerns, interests, or models (Moonen, 2000). A rapid-prototyping approach may take place in which students develop a series of "half-products" that are tested by experts and adapted through negotiation to fit both end-user and student-designer needs (i.e., quality educational material and quality educational experience) (p. 30).

Collaborating with experts. Another popular constructivist strategy involves pairing students with online experts or professionals to participate in real-world inquiry projects. Internet-based programs are offered by such groups as Student and Scientist Partnerships (TERC, 1998), the Jason project (Jason Foundation for Education, 2000), and Classroom Connect (2000). In traditional math and science classrooms, students may conduct basic experiments and calculations (e.g., measuring and interpreting

rainfall). In collaborative classrooms, students still collect data, but they also report and share their findings with other classes online. Students can then access a global database of information, discuss observations with peers and professionals, and seek trends and patterns. Providing students with access to more problem-related information may help them develop a better understanding of real issues.

The GLOBE program is perhaps the most publicized student-scientist partnership, involving hundreds of schools in scientific data collection and archival via Web forms. Means and Coleman (2000) describe SRI International's evaluation of the GLOBE program, reporting that students in GLOBE classrooms are not only motivated by helping scientists measure and interpret the world's climate, water, biology, and geology, but also learning to interpret large data sets by forming hypotheses or explanations for anomalous findings. The program is also suggested to improve student learning by providing multiple representations of the same data: physical or hands-on during data collection, numerical during data reporting and analysis, and visual during analysis and interpretation of charts, tables, or graphic satellite images.

Testing experimental models. A recurring issue in addressing complex problems is the inability to consider a range of potentially valid models before selecting a path to a conclusion (Johnson-Laird, 1990). Using tools that allow for rapid prototyping of many models, learners can manage and manipulate more models than short-term memories typically allow (Wild, 1996). Small-scale microworlds and large-scale simulations, for example, encourage students to generate various models consistent with their evolving understanding. These manipulation tools allow students to test personal theories, receive immediate feedback, contemplate discrepancies in their hypothesized versus resulting outcome, then reformulate and test a new model accounting for the difference. Incorrect models are eventually shaped toward more canonical models. Manipulation tools are not inherently constructivist if they only demonstrate a phenomena and have no internal mechanisms for students to make decisions or alter the initial state (Snir, Smith, & Grosslight, 1995). Simulations that do not allow the student to begin from their ideas and restructure them through trial and error are not constructivist, for they only represent someone else's understanding.

Snir and Smith (1995) describe activities where students conceptualized their mental models of weight and density on paper, then using a simple computer-based simulation, were able to test these ideas. Some students who simply drew scientific models were led to generate rules explaining complex scientific phenomena (e.g., weight and density). When simulations or microworlds were used, however, nearly all students were able to generate rules to explain the

data (e.g., the rate at which an object sinks depends more on its density than its weight). Snir and Smith (1995) suggest classroom and lab work be used to introduce phenomena, with computer and microworld work used for students to clarify their ideas.

Jackson-Metcalf, Krajcik, and Soloway (2000) describe the *Model-It* manipulation tool (see Figure 6). Students must first identify variables that factor into equations (e.g., contaminants influencing water quality in local creeks). Each variable or factor is defined by minimum and maximum units. Using pull-down menus, students hypothesize about relationships between variables (e.g., as factor one increases/decreases, factor two will remain the same/change). Simulations are ran to test students' models, then students use an organization tool to chart relationships. Considerable scaffolding has been built into the latest version of the tool, providing students with: supportive scaffolding in the form of procedural guidance and instructions for a task, reflective scaffolding in the form of metacognitive guidance to facilitate student thinking about an inquiry, and intrinsic scaffolding in the form of system features that minimize task complexity. Building models was shown to help students articulate and extend their understanding, while testing models was shown to help students refine their initial models. The inclusion of a concept or "factor map" feature, allowed students to visually represent their models and transition to more expert-like conceptions (p. 98).

While the listed examples were not distributed via the Internet, emerging software tools such as Coursebuilder and Shockwave Flash (Macromedia, 2000) enable experts to design and deliver similar simulation and microworld environments on the Web. Further, the Web can be used to provide online resources or data sets from experts that are used by students to develop their own simulations for testing personal models (e.g., ocean temperatures and resultant weather patterns, interest rates, and stock prices).

Summary and Conclusion

Two categories of constructivist activity supported by the Web have been presented. Students may construct advanced mental models by (1) cooperating with peers, and/or (2) connecting personal conceptions with expert conceptions. While the Internet is not required for such constructivist activity, online environments that allow learners to perform many active tasks can make constructivist activity more efficient and manageable in traditional classrooms confined by space, resources, and time. Without online tools, activities that ask learners to communicate, locate and organize external resources, collaborate on shared projects, and/or develop and share new materials can be limited.

Popular online environments for higher education include CourseInfo (Blackboard, 2000) and WebCT

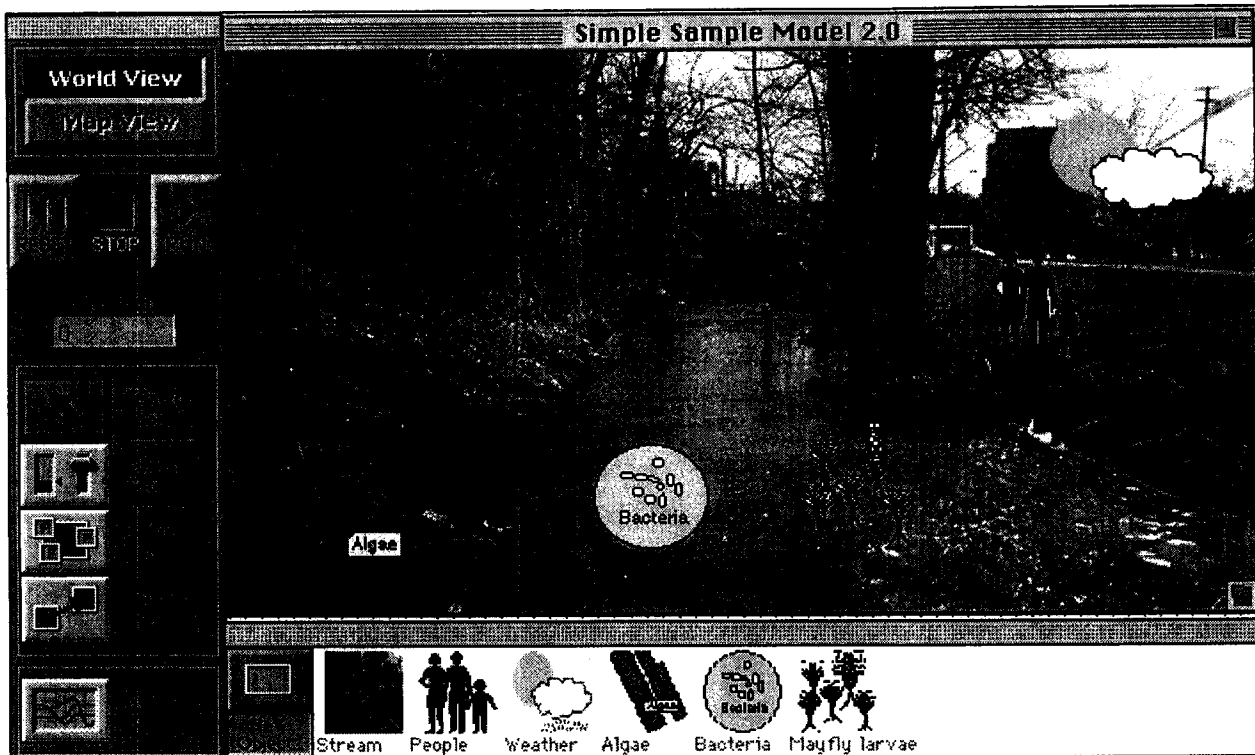


Figure 6. Model-It interface; screen capture courtesy of Regents of the University of Michigan (2000).

(WebCT, 2000). These tool suites or course management systems provide for some degree of communication and collaboration with such tools as e-mail, bulletin boards, chat rooms, and electronic group file sharing. The systems are somewhat limited, however, in supporting a full-range of student activity (see Table 1). Most course management systems do not allow students to write goals or plan tactics, seek external information, organize information, integrate information, or generate and share new information with classmates. Constructivist activity is somewhat impaired, and in the worst cases, online environments are used solely to present or deliver information to learners (e.g., "read this handout, take the quiz"). Such instructivist activity arguably adds no real value to student learning, and does not justify the purchase or maintenance of expensive new online tool systems. Students are simply given the expert conception of some event, issue, or topic, rather than reflecting on what they know and engaging in activities to develop their own understanding. Salomon (2000) suggests the domestication of new technologies to teach in standard or ongoing, traditional modes results in a technological paradox:

A most powerful and innovative technology is taken and is domesticated such that it does more or less what its predecessors have done, only it does it a bit faster and a bit nicer. Consequently, nothing really happens, which comes to prove what skeptics have argued all along and what misguided research tends to show: Technology makes no difference in learning. But of course it cannot make a difference since it has been domesticated to be totally subservient to the ongoing practices.

Jonassen (2000) fittingly cautions educators to beware of traditional uses of technology that seek only to transmit or control a message. He further cautions professors not to be "duped" into placing course materials online without good pedagogical reason, as such post-modern teaching serves only to "commoditize" education and to decrease the instructor's value (p. 23). Too many popular course environments seem to endorse such models of online teaching, with faculty simply "delivering" materials, rather than students processing information to inform authentic inquiry or activity. Willis and Wright (2000, p. 15) also recommend the expansion of instructional design "...beyond direct instruction to include the creation of student-centered learning environments, as

Table 1. Modified taxonomy of constructivist tasks and support tools for Web-based activity.

Constructivist Tasks Ask Learners to Express, Reflect, and Revise Internal Conceptions	Tools Support Active Student Processing of Web-Based Resources
plan appropriate tactics, establish personal or group goals	action or goal manager; for example, see student Web-based project-planning templates (Hung & Wong, 2000) and strategic task advisors (White & Frederiksen, 2000)
discuss or debate internal conceptions, state idea or issue and receive feedback	e-mail, listservs, bulletin boards, video conferencing; for example, see CSILE project (Scardamalia & Bereiter, 1996) and CaMILE discussion tool (Guzdial & Turns, 2000)
seek and collect external information	search engines, bookmarking, cut & paste, digital drop boxes for sharing files with group or project team; see VisIT tool (Levin & Kauwell, 1999) for collecting and generating diagrammatic displays of Web searches, GLOBE Web forms for archival and analysis of scientific data (Means & Coleman, 2000)
organize external information into internally coherent frameworks, develop categories (note, this category is a necessary addition to simply seeking/collecting data)	software to construct tables, charts, diagrams, timelines, concept maps; ability to organize hyperlinks into categories; for example, see Sensemaker (Slotta & Linn, 2000)
integrate or merge external information with internal conceptions	note-taking, annotating resources, questioning experts via e-mail; for example, see Mildred (Slotta & Linn, 2000) and VisIt tools (Levin & Kauwell, 1999) that allow students to write or attach personal notes to Web resources
generate new information; constructionism	HTML text editors, Web page generators, collaborative Web editing, video editors, word processors; for example, see Swiki Swiki (Guzdial, in press)
manipulate external information and variables to test and revise internal hypotheses or models	simulations, microworlds; for example, see 4M:Chem (Kozma, 2000) and Model-It tools (Jackson-Metcalf, Krajcik, & Soloway, 2000) for student development and simulated testing of personal models

well as resources that learners can use...a step in the right direction."

Table 1 presents a modified taxonomy of constructivist tasks and requisite Web tools helpful in supporting them (Oliver & Hannafin, in press). As instructors consider the purchase of new tool systems for their institutions, it will be helpful to closely analyze supported features. If constructivist activity is deemed appropriate and nurturing for the development of mental models, priority should be given to online tools and tasks that support student processes. □

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- A Knowledge Object and Mental Model Approach to a Physics Lesson. By M. David Merrill.
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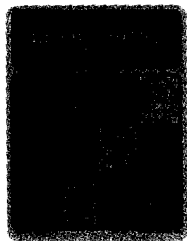
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CONTENTS

Articles

- 5 Methods for Developing Constructivist Learning on the Web
Kevin M. Oliver
- 19 Socially Responsible Educational Technology Research
Thomas C. Reeves
- 29 The Case for Design:
Creating a Culture of Intention
Harold G. Nelson and Erik Stolterman
- 36 Learning Objectives from the Perspective of the Experienced Cognition Framework
Ikseon Choi and David H. Jonassen
- 41 Constructivism in Online Learning:
A View from the Science Faculty
Pascal de Caprariis
- 46 A Strategy for Effective Change in Instructional Behavior:
Staff Development That Works
Dennis H. Sorge and James D. Russell
- 49 The Impact of Technology on Educational Equivalency:
Capabilities Based Educational Equivalency Units
Ryan Watkins and Charles Schlosser
- 55 Faculty Strategies for Distance Teaching
Melodee Landis
- 58 Collaborative Online Course Development:
Converting Correspondence Courses to the Web
Cheryl White
- 61 Toward an Information and Instructional Technology Research Framework for Learning and Instruction
David W. L. Hung and Philip S. K. Wong