INSTRUCTIONAL-DESIGN THEORIES AND MODELS
Volume II

A New Paradigm of Instructional Theory

Edited by

Charles M. Reigeluth
Indiana University

LEA

LAWRENCE ERLBAUM ASSOCIATES, PUBLISHERS

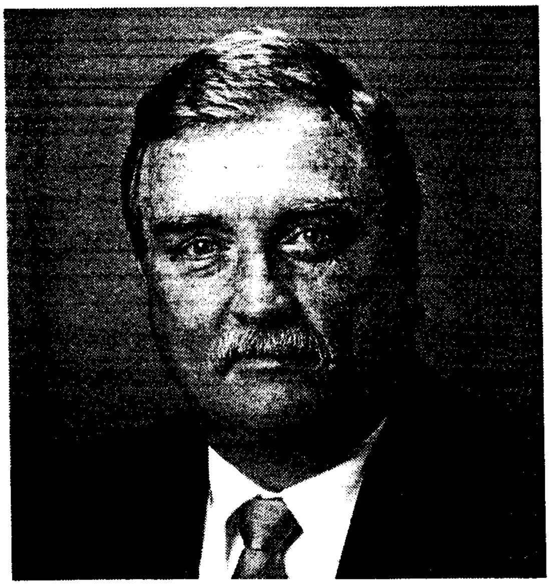
1999 Mahwah, New Jersey London

6 Open Learning Environments: Foundations, Methods, and Models

Michael Hannafin
University of Georgia

Susan Land
The Pennsylvania State University

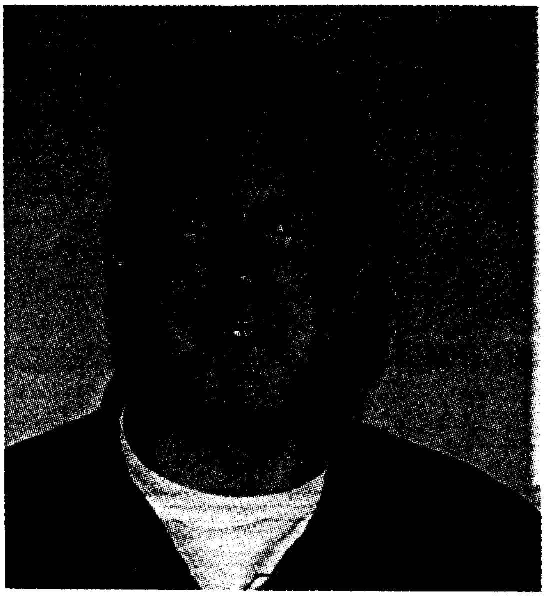
Kevin Oliver
University of Georgia



Michael Hannafin

Michael Hannafin is Professor of Instructional Technology and Director of the Learning and Performance Support Laboratory at the University of Georgia. Previously, he was a member of the Instructional Systems faculty at Florida State University, a visiting professor at the U.S. Air Force Academy, and in faculty positions at Penn State University and the University of Colorado. His research focuses on developing and testing frameworks for the design of technology-enhanced, student-centered learning environments.

Susan Land



Kevin Oliver

Susan Land is Assistant Professor of Instructional Systems at Penn State University. Previously, she worked as a postdoctoral fellow at the University of Georgia's Learning and Performance Support Laboratory and held a faculty position at the University of Oklahoma. Her research focuses on the process of conceptual development with learner-centered technology environments. She earned her doctorate in Instructional Systems from Florida State University.

Kevin Oliver currently works at the University of Georgia's Learning and Performance Support Laboratory, developing multimedia products, conducting teacher-training workshops, and managing grants in K–12 schools. His research interests include problem- and case-based learning, web-based learning tools, and the development of computer-mediated learning environments for K–12 schools. He is a Doctoral Candidate in Instructional Technology at the University of Georgia.

FOREWORD

Goals and preconditions. *This chapter provides a theory for situations where divergent thinking and multiple perspectives are valued over a single "correct" perspective. It is appropriate for heuristics-based learning and for exploring fuzzy, ill-defined, and ill-structured problems.*

Values. *Some of the values upon which this theory is based include:*

- *personal inquiry.*
- *divergent thinking and multiple perspectives.*
- *self-directed learning and learner autonomy with metacognitive support.*
- *mediating learning through individual experience and personal theories.*
- *hands-on, concrete experiences involving realistic, relevant problems.*
- *providing tools and resources to aid the learner's efforts at learning.*

Methods. *These are the major methods this theory offers:*

Enabling contexts (to establish the perspectives taken in the environment).
- *Externally-imposed contexts (specifies specific problems for the learner).*
- *Externally-induced contexts (presents problem context, learner generates the problems to be addressed).*
- *Individually-generated contexts (learner generates both the context and problems).*

Resources (to provide the domain of available information sources)
- *Static (do not change through use).*
- *Dynamic (do change through use).*

Tools (to provide the basic means for manipulating information).
(are not specific methods per se; are used in various ways to represent and manipulate concepts under study)
- *Processing tools (to support learners' cognitive processing).*
  - *Seeking tools (to locate and filter needed resources).*
  - *Collecting tools (to gather resources).*
  - *Organizing tools (to represent relationships among ideas).*
  - *Integrating tools (to link new with existing knowledge).*
  - *Generating tools (to create new things or artifacts to think with).*
- *Manipulation tools (to test the validity of, or to explore, beliefs and theories).*
- *Communication tools (to communicate among learners, teachers, and experts).*
  - *Synchronous communication tools (to support real-time interaction).*

- *Asynchronous communication tools (to support time-shifted communication).*

Scaffolds (to guide and support learning efforts).

- *Domain-specific versus generic scaffolds.*
- *Conceptual scaffolding (guidance on what to consider).*
- *Metacognitive scaffolding (guidance on how to think about the problem under study).*
- *Procedural scaffolding (guidance on how to utilize resources and tools).*
- *Strategic scaffolding (guidance on approaches to solving the problem).*

While this theory does offer some guidelines (conditions under which different methods should be used), much of it is presented here as a taxonomy of methods, where the practitioner needs to figure out when to use each..

***Major contributions**. Addresses a difficult kind of learning with a wide variety of methods and a great deal of flexibility.*

—C.M.R.

Open Learning Environments: Foundations, Methods, and Models

Interest in student-centered learning and learner-centered design has grown dramatically. The emergence of varied teaching–learning frameworks, coupled with technological developments such as the World Wide Web, has made possible approaches that were heretofore impossible, infeasible, or unimaginable.* Open learning environments (OLEs) have proven particularly intriguing. Open learning involves " ... processes wherein the intents and purposes of the individual are uniquely established and pursued";** OLEs " ... support the individual's efforts to understand that which he or she determines to be important" (Hannafin, Hall, Land, & Hill, 1994, p. 48). In this chapter, we provide a brief overview of OLEs, describe their features, and provide examples of open learning designs.

---

* This identifies the emergence of the new paradigm of instructional theory.

** This is the key marker of customization (see chap. 1, p. 18).

OVERVIEW OF OLES

Open-endedness refers to either the learning goal(s), the means through which learning goals are pursued, or both learning goals and means. Learning goals are determined in one of three methods: (a) externally specified by immersing the learner in a particular problem to be solved, such as bringing a virtual satellite into geosynchronous orbit above the equator; (b) externally induced such as by immersing the learner in a problem such as global warming without specifying a particular learning goal or performance task; or (c) generated uniquely, such as by a learner attempting to understand the etiology of a health problem afflicting a family member. In each case, the need to understand is established individually, although the manner in which the goals are framed varies considerably. The individual determines how to proceed based on his or her unique needs, perceptions, and experiences, distinguishes known from unknown, identifies resources available to support learning efforts, and formalizes and tests personal beliefs (Land & Hannafin, 1996).

OLEs may be contrasted with direct instruction. As shown in Table 6.1, direct instruction typically employs clearly articulated external learning objectives. These tend to isolate critical information and concepts, organize to-be-learned concepts into carefully ordered sequences to reflect the presumed hierarchical nature of knowledge, and employ strategies that induce differential allocation of attention and cognitive resources. They feature a great deal of external engineering of both

TABLE 6.1

Distinctions Between Directed and Open-Ended Learning Environments

Directed Learning Environments...	*Open-Ended Learning Environments...*
Break down content hierarchically and teach incrementally toward externally generated objectives	Situate processes associated with problems, contexts, and content with opportunities to manipulate, interpret, and experiment
Simplify detection and mastery of key concepts by isolating and instructing to-be-learned knowledge and skill; "bottom up," basics first	Employ complex, meaningful problems that link content and concepts to everyday experience where "need to know" is naturally generated
Convey knowledge and skills through structured, engineered teaching–learning approaches	Center heuristic approaches around "wholes" exploring higher order concepts, flexible understanding, and multiple perspectives
Mediate learning externally via explicit activities and practice; promote canonical understanding as a goal	Develop understanding individually as learners evaluate their own needs, make decisions, and modify, test, and revise their knowledge.
Activate internal conditions of learning by carefully engineering external conditions	Link cognition and context inextricably
Achieve mastery by focusing on production of "correct" responses, thereby reducing or eliminating errors	Stress the importance of errors in establishing models of understanding; deep understanding evolves from initial, often flawed, beliefs

Note. Adapted from "Student-centered learning and interactive multimedia: Status, issues, and implications," by M. J. Hannafin, J. Hill, and S. Land (1997), *Contemporary Education, 68*, pp. 94–99. Copyright 1997. Adapted with permission.

to-be-learned knowledge and skill as well as the strategies presumed to promote learning (Hannafin, 1995).

In contrast, open environments emphasize the mediating role of the individual in uniquely defining meaning, establishing learning needs, determining learning goals, and engaging in learning activities. Consistent with learner-centered design principles, individual perspectives are used to interpret, assign relevance and meaning, and otherwise influence how given circumstances and contexts are uniquely understood (Hannafin & Land, 1997). Contexts, which vary from instance to instance and learner to learner, define the meaning of, need for, and utility of knowledge and skill. Therefore, it is often not feasible to impose direct-instruction strategies a priori to promote specific understanding or performance.

OLEs employ tools, resources, and activities that augment or extend thinking. They are engineered in the sense that, to varying degrees, affordances are enabled and scaffolds are provided, but they do not typically impose or restrict the content or interpretations of learning sequences. OLEs embed learning activities in contexts that foster thinking. These originate not from abstract descriptions of phenomena, but from personal, practical experiences. Individual efforts to understand are supported via immersion in problems, metacognitive scaffolding, and tools through which available resources can be located and assessed for relevance according to the unique sense-making skills and needs of the learner.

OLEs tend to be especially important in promoting divergent thinking and in situations where multiple perspectives are valued, rather a single "correct" perspective. They are particularly valuable for heuristics-based learning in that they afford opportunities to "play with" concepts in order to interpret patterns rather than to impart only certain desired interpretations. OLEs also tend to be valued for exploring fuzzy, ill-defined, and ill-structured problems. They promote the discovery and manipulation of underlying beliefs and structures rather than impose particular beliefs. Open environments help to promote autonomy* in that they encourage individuals to generate problems and needs, select among various available information sources, and evaluate their judgments.

In contrast, OLEs are less amenable to convergent learning tasks, where different learners need to develop the same knowledge, procedural skills, or interpretations. Since they encourage personal inquiry, it is unlikely that all individuals will encounter information sources, much less interpret them consistently. Likewise, OLEs tend to be less effective for learning of a strict, accountability-based nature or when efficiency in terms of acquisition time is critical.**

---

* Self-regulation is another key marker of the new paradigm (see especially chap. 13 by Corno & Randi).

** This highlights the need for different approaches to instruction for different situations—that no one approach is best for all situations. It also highlights the importance of expanding and reconfiguring much of the industrial-age paradigm, rather than rejecting it.

Foundations And Values

Grounded learning systems reflect alignment among core foundations: psychological, pedagogical, technological, cultural, and pragmatic. Grounding is reflected in the extent to which learning environments manifest the core tenets of each foundation, as well as how consistently these beliefs are reflected across foundations (Hannafin, Hannafin, Land, & Oliver, 1997). Each foundation encompasses diverse perspectives; as root foundations vary, underlying assumptions change accordingly. Behaviorism, for example, is quite different from situated cognition in its assumptions about knowledge and the evolution of understanding; yet, both represent a psychological foundation. Likewise, while pedagogical foundations include a myriad of alternative methods and strategies, teaching learning approaches rooted in behavioral psychology should be different from those rooted in situated cognition (see, for example, Hannafin & Land, 1997).*

Several core values are reflected in OLEs. One such value is the centrality of individual experience in mediating learning. Experience shapes an individual's interpretive perspective: how or if a problem is perceived, the manner in which existing knowledge, skill, and experience are related, and the nature of personal as well as canonical beliefs. OLEs not only recognize personal theories, but they are considered the basis of initial and ongoing formative understanding which can be examined, tested, and revised through inquiry (Land & Hannafin, 1997).

Likewise, OLEs feature experience-based problem-solving activities as means through which understanding and formative theories evolve. Personal understanding evolves through hands-on, concrete experiences involving realistic, relevant problems posed or induced through OLEs. Tools are provided to enable learners to manipulate physical objects or attributes in a problem as well as their own ideas.

Finally, metacognitive support is valued for several reasons. Individuals continually interpret, evaluate, and respond based on ongoing assessments as to which actions are likely to advance their understanding. Individuals make important judgments related to and based on their perceived state of understanding; OLEs both facilitate the spontaneous metacognitive activities of individuals and scaffold metacognitive inquiry processes when not spontaneously initiated.

The confluence among OLE foundations and values illustrated in Fig. 6.1 suggests several design features and strategies. For example, OLEs share psychological and pedagogical values: situated thinking, prior knowledge and experience, metacognitive monitoring, and the progressive testing and refining of understanding (Hannafin et al., 1994). Associated methods emphasize authentic learning contexts, anchored problem-based approaches, construction, manipulation, and scaffolding. OLE technological foundations are manifested in the form of diverse tools (e.g., spreadsheets, graphing programs, web browsers) and resources (e.g.,

* These roots are the underlying descriptive knowledge (learning theory) discussed in chapter 1, pp. 12–13.

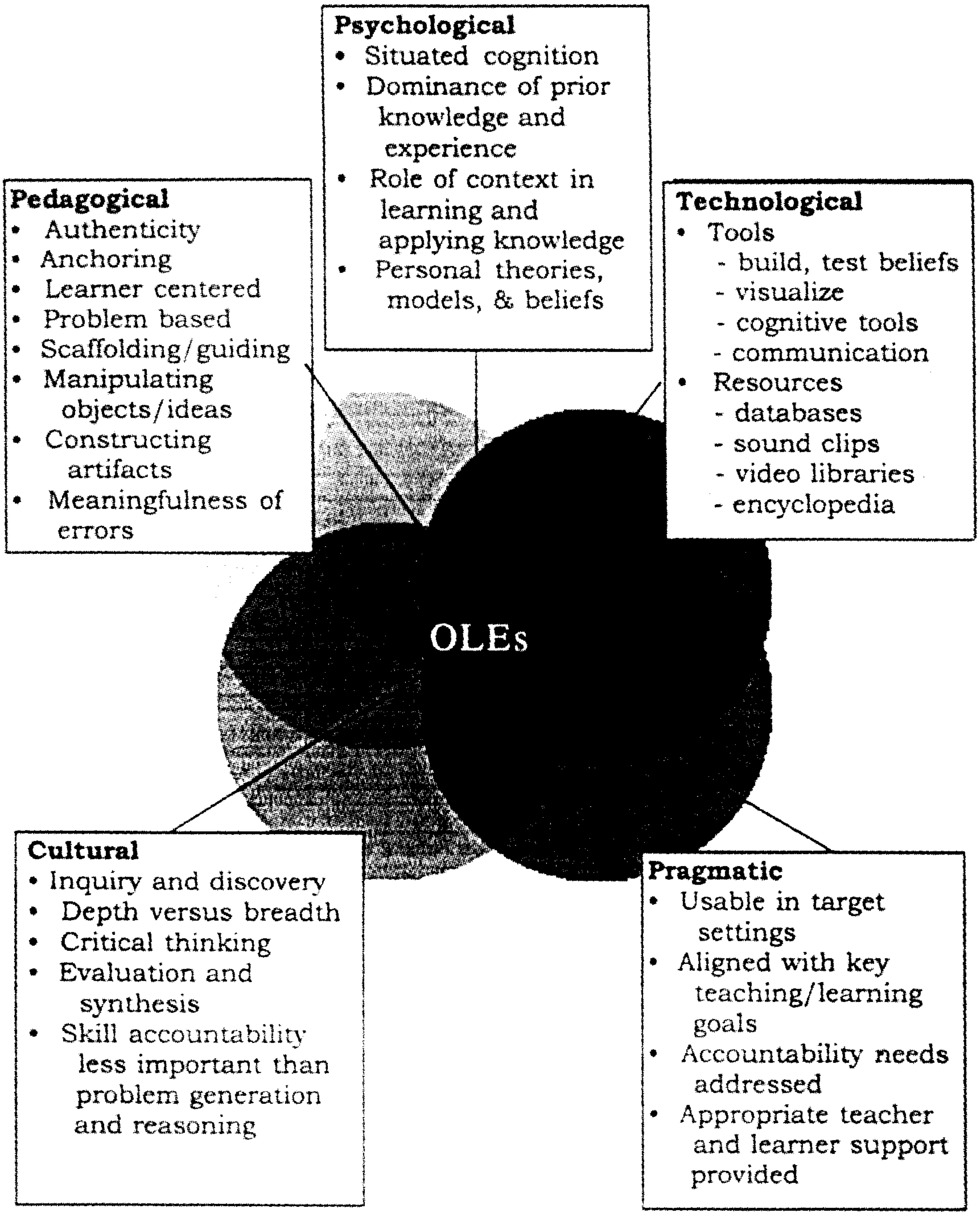


FIG. 6.1. Relationships among OLE foundations and values. (Adapted from "The Foundations and Assumptions of Technology-Enhanced, Student-Centered Learning Environments," by M. J. Hannafin and S. Land, (1977), *Instructional Science, 25*, pp. 167–202. Copyright 1997. Adapted with permission.

on-line databases, image libraries, source documents) that support varied purposes. The approaches "fit" within the inquiry-oriented, critical thinking teaching-learning culture, which emphasizes processes such as inquiry and discovery over compliance and rote memorization; the environment accommodates relevant situational constraints of the settings in which they are deployed.

As s... in Fig. 6.2, OLEs comprise four basic components: enabling contexts, resources, tools, and scaffolds.

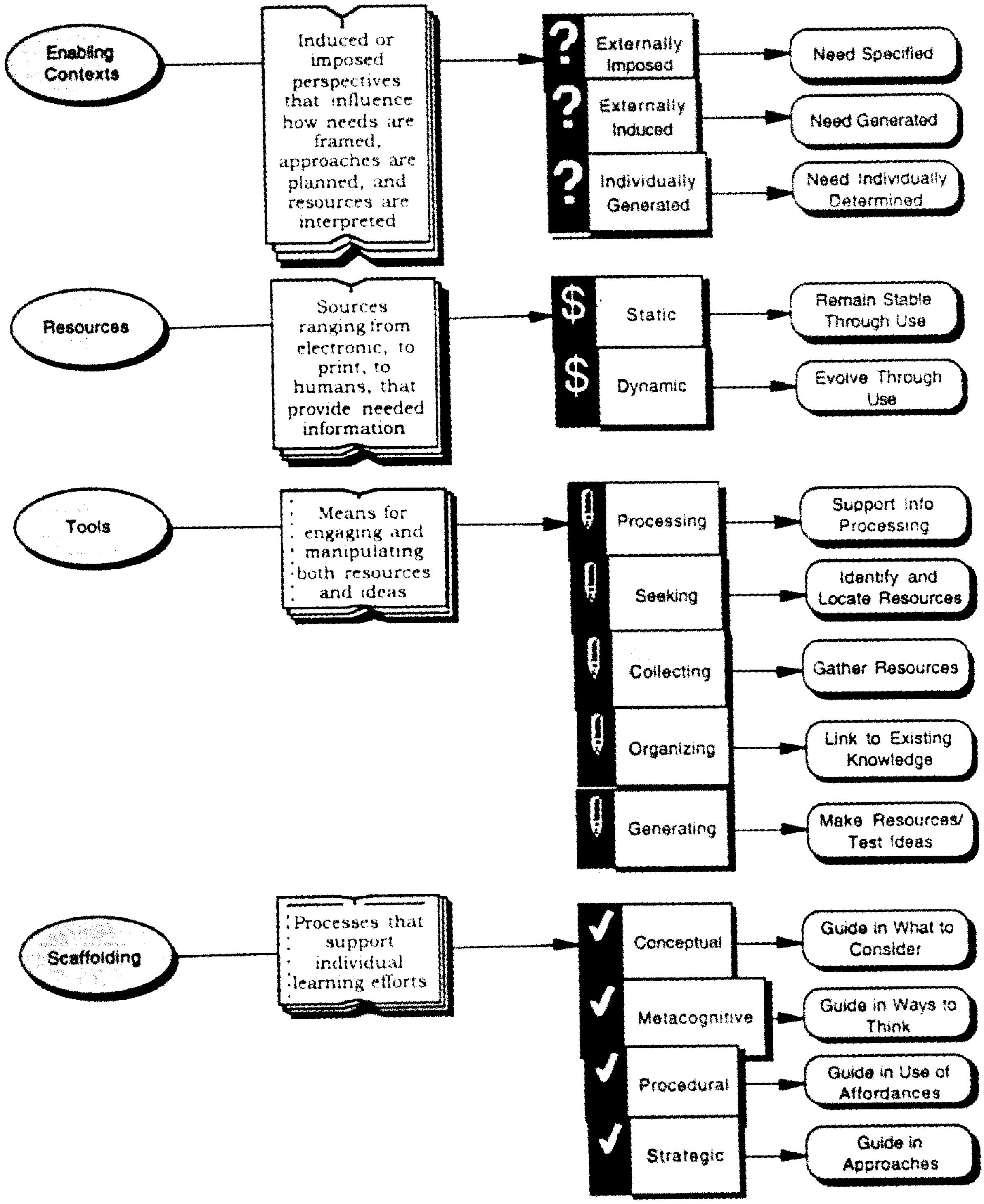


FIG. 6.2. Overview of OLE components and design heuristics.

Enabling Contexts

Enabling contexts are the vehicles through which individuals are oriented to a need or problem and interpretive perspectives are situated. Enabling contexts guide students in recognizing or generating problems to be addressed and framing learning needs. As summarized in Table 6.2, they take three basic forms.* Externally imposed contexts both clarify the expected product of the learner's efforts and implicitly guide strategy selection and deployment. Externally imposed enabling contexts are often presented as explicitly situated problem statements or organizing questions which aid students in referencing relevant aspects of their experience.

Several externally imposed enabling contexts have been reported. The Great Solar System Rescue's (1992) enabling context, for example, places students in a fan-

TABLE 6.2
Examples of OLE Enabling Contexts

Context Type	*Examples*
Externally Imposed	
Context specifies specific problems and/or performance needs, but the means to pursue solutions are at the learner's discretion	Problem solving, the Great Solar System Rescue (1992) Determine the most cost-effective jet transport aircraft, given a host of performance requirements and cost constraints.
Externally Induced	
Scenarios, problems, cases, analogies, or questions are provided and the learner generates the problems to be solved and means to pursue solutions	Anchored instruction, Jasper Woodbury Problem Solving Series (Cognition and Technology Group at Vanderbilt, 1992) Case-based instruction, The Thematic Investigator (Jacobson, Sugimoto, & Archodidou, 1996) Inquiry-based science, Science Vision (Tobin & Dawson, 1992) Scientific thinking, Knowledge Integration Environment (Linn, 1995)
Individually Generated	
Personal interests, issues, concerns, or problems surface that establish unique learning needs and guide strategies employed	As a graduate student, select a topic and frame a specific problem within existing research and theory. A tropical storm is approaching your newly purchased, beachfront property, and you must ascertain appropriate precautionary measures. Due to recent wave of international terrorism in the Middle East, you decide to learn more about the root causes of the Palestinian uprisings.

* This is an example of breaking down a method ("provide an enabling context") into alternative kinds (externally-imposed, externally-induced, and individually-generated enabling contexts).

tasy role (e.g., meteorologist, geologist) in which a space vehicle has crashed on a remote planet. Students are provided clues and challenged to determine on which planet the crash occurred and the precise location of the crash site. The learner's tasks, for the most part, are explicitly delineated. Externally imposed enabling contexts are used widely where knowledge and/or skill accountability requirements are explicitly accepted as well as when concrete progress referents are deemed appropriate or necessary for teachers or students.*

Externally induced contexts introduce the learner to a domain but do not identify specific problems to be addressed. Rather, a domain is encountered in which any number of problems or issues can be generated or studied at the discretion of the learner. Bransford and his colleagues (Cognition and Technology Group at Vanderbilt, 1992)** designed brief video vignettes in *The Jasper Woodbury Problem Solving Series,* featuring a dilemma confronted by the lead character. A situation is introduced in which a problem or problems are apparent. The induced context introduces a circumstance which frames the problems or issues and solicits learner participation. The student interprets the context for meaning, generates subproblems, and devises strategies based on individual interpretations of the enabling context. Jacobson, Sugimoto, and Archodidou's (1996) *Thematic Investigator* employed specific cases of evolutionary biology (e.g., the peppered moth, rabbits in Australia) to provide diverse contexts for the study of complex Darwinian themes. The alternative contexts induced students to "think differently" about scientific concepts that are often complex and ill defined, such as population variety and natural selection. In each of the preceding examples, students are provided perspective-setting or -altering contexts that help to activate relevant prior knowledge, experience, and skill related to the problem and that also help the learner to generate strategies to be potentially deployed.***

In individually-generated enabling contexts, a specific context cannot be designed in advance.**** The learner establishes an enabling context based on needs

---

* Here the theory indicates the situations for which this kind of enabling context (method variable) is likely to be most appropriate. Chapter 1 identified methods and situations as the two major components of an instructional theory (see p. 8).

** See also chapter 9 by Schwartz, Lin, Brophy and Bransford.

*** Here the theory breaks down a method ("provide externally-induced contexts") into *parts* (rather than kinds)—that is, more detailed component methods (as discussed in chap. 1, p. 10)—that are common across situations. However, there certainly are also variations in some component methods across situations, and those variations represent sub-kinds that are recommended for different sub-situations. This illustrates how the complexity of an instructional theory increases geometrically as the theorists attempt to provide more guidance or understanding of the instructional dynamics. See if you can identify additional kinds and parts of methods (and situations for the different kinds) in the remainder of this chapter.

**** This is an important issue for the new paradigm of instructional theory. Sometimes customized instruction cannot be designed in advance. For what aspects of the learning process can and can't an instructional theory offer guidance for such situations? What kinds of support or guidance can an instructional theory offer for such situations? How can technology and/or peers be most effectively used for such situations? This is an extremely important area for additional research and development in the new paradigm of instructional theory.

and circumstances that are unique. For example, a home gardener may wish to determine the cause and treatment of fungus growth in a vegetable patch. A hiker, planning a 3-day trek, may want to better understand how to use various orientation and navigation tools, such as magnetic compasses, landmarks, and sextants. A business executive might need to resolve production deficiencies and inventory control problems. In each case, the individual creates a unique enabling context to frame learning needs. As with induced contexts, the generated context activates relevant knowledge, skill, and experience in order to frame problems and issues and to guide problem-solving strategies.

Resources

Resources are source materials that support learning. Resources range from electronic media (e.g., databases, computer tutorials, video), to print media (e.g., textbooks, original source documents, journal articles), to humans (e.g., experts, parents, teachers, peers). The Web is perhaps the most pervasive repository of available resources. The web enables access, but the potential relevance of the available resources is often difficult for individuals to ascertain (Hill & Hannafin, 1997). While it contains millions of source materials of potential relevance, the utility of web resources for OLEs is often limited due to a lack of clarity of contents, difficulty in accessing or using them, or both. A resource's utility is determined by its relevance to the enabling context and the degree to which it is accessible to the learner. The more relevant a resource is to an individual's learning goals, and the more accessible it is, the greater its utility.

OLEs make extensive use of available resources which provide an extraordinary reserve of source materials across a wide range of OLE applications.* In some cases, available resources are supplemented or augmented with new resources, based on the appropriateness of existing source materials to a given OLE's enabling context. In a simple sense, resources can be either static or dynamic, though increasingly, digital resources reflect both properties.

Static resource contents do not change through use. They may contain information that is stable over time and is not subject to variation, such as photographic images of historical figures. Some resources may only be available through technologies that do not permit their contents to be altered, such as the contents of videodisks, multimedia CD-ROMs, textbooks, and electronic encyclopedias. The *Visible Human* database (National Library of Medicine, 1996) contains thousands of high-resolution photographic slides, graphics, and digital movie clips of the human anatomy, each of which can be used in a theoretically unlimited number of ways. Similar databases have been established by NASA and the National Library

---

* The issue of utilizing available resources versus designing new resources is often an economic decision. But even for situations in which one must utilize available resources, it is helpful to have design criteria for judging the instructional quality of the available resources to help guide either the teacher or the learner in selecting the resources.

of Congress. A learner's interpretations and understanding may evolve considerably through repeated access, but the literal contents of a fixed resource remain unchanged.

In some instances, it is desirable to access resources that change dynamically through time and/or the introduction of new data. This affords the learner the opportunity to repeatedly access the same resource but with different outcomes. For example, dynamic resources such as climatology databases created by the National Weather Service evolve continuously as daily weather data are entered. Dynamic databases can also evolve based on the needs, queries, and intentions of individuals or groups. Smart databases collect data from which they evolve user models to suggest resources. In some systems, users can transform data by adding new entries or annotating existing entries. CSILE (Computer-Supported Intentional Learning Environment), for example, is a social knowledge resource that changes as a function of usage and the ratings of its users (Scardamalia & Bereiter, 1994).

The *Human Body* (Iiyoshi & Hannafin, 1996) provides both static and dynamic resources. *Human Body* is an OLE that contains several thousand multimedia objects, including text, voice narratives, animations, digital movies, and graphic resources. Each resource can be accessed independently or linked according to the ongoing needs of the learner. In addition, individual information can be attached to the resources in the form of personal notes, observations, and elaborations. The core resources remain intact, but dynamic functionality can be attained when users add to, revise, or otherwise customize contents according to the perspectives and needs of individual learners. Likewise, in Honebein's (1996) *Lab Design Project*, students enter a virtual biotechnology research center, identify labs they wish to visit, seek additional details on equipment, and review interviews of the virtual lab inhabitants. These resources are static in their given form, but manipulation is facilitated by providing a pool of research questions and prompting students to generate links among the available resources to address a probing question.

Resources can be identified and selected a priori in cases where enabling contexts are induced externally; judgments as to their potential relevance to the enabling problem or need can be readily made. *Science Vision* resources, for example, include relevant encyclopedia and reference information, on-line domain experts, and libraries of movies and still images (Tobin & Dawson, 1992). Learners are rarely restricted only to the "flagged" resources, but their existence, availability, and potential relevance to the problem context is made apparent. In truly open systems, access is not limited to selected resource pools; the learner can seek and access virtually any resource independent of its designer-perceived relevance to the enabling context. Due to the variable nature of individually created enabling contexts, resource pools cannot be well anticipated. Instead, support for unique enabling contexts is often provided in the form of scaffolding which helps to guide individuals in conceptualizing, seeking, evaluating, and resolving their uniquely defined learning problems and needs.

Tools

Tools provide the overt means through which individuals engage and manipulate both resources and their own ideas. However, tool functions vary according to the OLE's enabling contexts as well as the intents of their users;* the same technological tool can support different functions. Tools do not inherently enhance cognitive activity or skills;** rather, they provide a means through which thinking *can be* enhanced, augmented, and/or extended. Tools provide vehicles for representing and manipulating complex, abstract concepts in tangible, concrete ways. As shown in Table 6.3, three types of tools are commonly used in OLEs: processing tools, manipulation tools, and communication tools.

Processing Tools

Processing tools support the functions typically associated with information-processing models of human cognition (Iiyoshi & Hannafin, 1996).*** Seeking

TABLE 6.3
OLE Tools and Examples

Tool Type	*Examples*
Processing Tools	Enable and facilitate the cognitive processing tasks associated with open-ended learning.
• seeking	Keyword searches, search engines, indexes
• collecting	Text copying and pasting, file transferring, image grabbing
• organizing	Brainstorming, outlining, flow charting
• integrating	Knowledge representation tools, annotation links, elaborations
• generating	Graphic programs, programming languages
Manipulation Tools	Enable learner to change contents, values, and/or parameters in order to verify, test, extend understanding.
	Plugging in ranges of values into spreadsheet to examine effects
	Programming functions into graphing calculators to visualize effects graphically
Communication Tools	Provide learners, teachers, and experts a means to promote discourse, share ideas, review work, ask questions, and collaborate.
• asynchronous	Messaging centers, e-mail, listservs, video and audio streaming.
• synchronous	Telephone, telementoring, groupware, video conferencing.

* So "enabling context" is a situation variable that influences the selection of tools (a method variable).

** In this sense, tools are not inherently methods of instruction. The way they are used, however, can be a method.

*** Notice the similarity between the following processing tools and Mayer's SOI Model (chap. 7).

tools, for example, support detection and selection of relevant information by helping learners to locate and filter needed resources. Various seeking tools exist, ranging from keyword searches, to topical indexes, to the semantic search engines available on the Web. Each tool supports the user's efforts to search available resources to locate information likely to be relevant to his or her individual learning needs.

Collection tools allow learners to gather resources or pieces of resources for their own purposes. They support learning by aiding in the amassing of potentially important information which can be used to simplify subsequent access, support study in closer detail, or collect subsets of resources appropriate to individual learning needs. Collection tools enable the learner to perform diverse tasks, such as to "grab" text documents or selected text, store copies of graphical images, and create directories of selected Web-site URLs (addresses on the Web).

Organization tools assist learners in representing relationships among ideas. The Highly Interactive Computing Group's Model-It supports learners as they progressively establish and revise their conceptual understanding. Model-It provides a graphical tool with which individuals can create and test qualitative models of scientific understanding (Jackson, Stratford, Krajcik, & Soloway, 1995a). General-purpose organization tools such as Inspiration™ aid the learner in organizing and annotating concept maps depicting complex relationships.

Integration tools help learners to link new with existing knowledge. CONSTRUE, for example, is an Internet shell used to develop dynamic, knowledge-building environments (Lebow, Wager, Marks, & Gilbert, 1996). A typical CONSTRUE environment comprises a variety of options for searching and linking an extensive database of manuscripts and articles. Users can search across documents according to their specifications, and annotate their reactions and interpretations as a permanent resource. The linking and constructing functions assist in both organizing ideas from a variety of perspectives and integrating them with personal knowledge.

Generation tools enable learners to create things. Generation tools have been developed across a wide range of learning environments. Hay, Guzdial, Jackson, Boyle, and Soloway (1994) created the MediaText computer program to simplify the creation of multimedia compositions. Iiyoshi and Hannafin (1996) described a series of tools with which individuals could create their own multimedia lessons using both fixed resources and resources the users develop. Harel and Papert (1991) studied students' generative tool uses of Logo, a high-level and easy-to-use programming language, to develop software designs for teaching peers about fractions. Microworlds Project Builder (1993) can be used to generate objects using given shells as well as to create new shells for use by one or more individuals.*

* Note that what we have here is primarily a taxonomy of tools; little guidance is offered as to when to use each. This may be due largely to the complexity of that level of detail of guidance and the space limitations for each chapter of this volume.

Manipulation Tools

Manipulation tools are used to test the validity of, or explore the explanatory power of, beliefs and theories. Vosniadou (1992) noted that in order to promote restructuring of mental models, learners must first be given the opportunity to become aware of their existing beliefs. Rieber (1993) created a microworld within which learners could manipulate Newtonian physics concepts such as mass and velocity while attempting to dock a virtual spacecraft. These manipulations were functionally similar to the Space Shuttle thrust engines used to adjust forward speed, pitch, and yaw. Lewis, Stern, and Linn (1993) described a tool that enables learners to speculate about, then manipulate, the thermodynamic properties of objects. For instance, an individual may believe that increasing the surface area of an object invariably results in additional heat loss independent of insulation properties. Object properties can be altered to test the assumptions and veracity of these beliefs. RasMol (Raster Molecules) is an Internet-based learning environment used to create and display the structure of DNA, proteins, and small molecules (Sayle, 1996). Several RasMol shells can be downloaded and manipulated by learners. Molecules can be displayed as wireframe graphics, cylinder stick bonds, space-filling spheres, macromolecular ribbons, hydrogen bonds, or dot surfaces. These representations may be colored or shaded, and the molecules may be rotated and sized to increase the depth and vividness of the images manipulated.

Communication Tools

Communication tools support efforts to initiate or sustain exchanges among learners, teachers, and experts. They have become especially important in Internet and Web-based OLEs. Communication tools engage participants synchronously or asynchronously depending on their availability, cost, and the nature of the enabling context.

Synchronous communication tools support real-time interaction among participants. For example, telephones are widely available, low-cost tools that support live voice communication among two or more participants. In cases where collaboration is induced through the enabling context, telephone tools may be readily available. However, voice communication is limited to sound, rendering the sharing of other resources via alternate media impossible. Two-way live video teleconferencing, on the other hand, enables both voice and image sharing, thereby increasing the learner's available toolkit; however, it is not widely accessible and can be costly in terms of technology demands and hook-up charges.

Asynchronous communication tools, in contrast, enable communication that is time shifted. They allow for extensive exchanging of ideas and/or resources, but do not rely on the simultaneous availability of all participants. Listservs, for example, provide a vehicle for common discourse among learners and teachers, but do not require their immediate presence.

Examples of synchronous and asynchronous communication tools in practice are widespread. Blieske (1996) involved students in collaboration in the design of floor plans for a new home. Students asynchronously shared their design with other schools, collaborated on the merits of various approaches, and then attempted to build each others' designs. Other projects involved students in different classrooms collaborating in writing different acts for a play (Schubert, 1997a) and writing stories for submission to on-line newsletters for publication (Schubert, 1997b).

Scaffolds

Scaffolding is the process through which learning efforts are supported while engaging an OLE (Jackson, Stratford, Krajcik, & Soloway, 1995b; Linn, 1995). Scaffolding can be differentiated by mechanisms and functions. Mechanisms emphasize the methods through which scaffolding is provided, while functions emphasize the purposes served.

TABLE 6.4
OLE Scaffolding Classifications

Scaffold Types and Functions	*Related Methods & Mechanisms*
Conceptual	
Guides learner in what to consider; considerations when problem task is defined	Recommending the use of certain tools at particular stages of problem solving Providing students with explicit hints and prompts as needed (Vygotskian scaffolding, intelligent tutoring) Providing structure maps and content trees
Metacognitive	
Guides how to think during learning: ways to think about a problem under study and/or possible strategies to consider; initial role in finding and framing problems, and ongoing role during resolution	Suggesting students plan ahead, evaluate progress, and determine needs Modeling cognitive strategies and self-regulatory processes Proposing self-regulating milestones and related monitoring
Procedural	
Guides how to utilize the available OLE features; ongoing "help" and advice on feature functions and uses	Tutoring on system functions and features Providing "balloon" or "pop-up" help to define and explain system properties
Strategic	
Guides in analyzing and approaching learning tasks or problem; provided initially as macrostrategy or ongoing as needs or requests arise	Enabling intelligent responses to system use, suggesting alternative methods or procedures Providing start-up questions to be considered Providing advice from experts

Individuals attempt to resolve either a situated problem or a personal learning need reflected in the enabling context. As shown in Table 6.4, OLE scaffolding complexity varies according to the locus of the problem(s) posed and the demands posed in the enabling context.* Scaffolding approaches, therefore, vary accordingly. When enabling contexts and problems are supplied, scaffolding can be closely linked to the domain under study; when enabling contexts are individually generated, scaffolding of a generic nature is generally provided. OLE scaffolding may or may not be faded out as facility is attained. In externally imposed or induced contexts, for example, scaffolding may be faded out since the nature of system needs and learner use can be reasonably established beforehand. For individual uses, where the nature of use and learner needs cannot be established in advance, scaffolding typically remains available but its usage becomes less frequent as the learner's facility increases.

Conceptual Scaffolding

Conceptual scaffolding is provided when the problem under study is defined, that is, for externally imposed or induced enabling contexts. When problem parameters and domains are established externally, it is possible to anticipate methods that are sensitive to the demands of the area under study. Known and widespread science misconceptions, for example, provide a powerful foundation for predicting likely conceptual difficulties and embedding support accordingly. Conceptual scaffolding can be designed to help learners reason through complex or fuzzy problems, as well as for concepts where known misconceptions are prevalent. Hints can guide the learner to available resources, or tool manipulations might be suggested where understanding is typically problematic.

Conceptual scaffolding, then, guides learners regarding *what to consider.* At times, this is accomplished by identifying key conceptual knowledge related to a problem or creating structures that make conceptual organization readily apparent. These structures can be made available through a variety of mechanisms, ranging from the graphical depiction of relationships among concepts, to outlines featuring ordinate–subordinate relationships, to information and hints provided by experts.

In OLEs, conceptual scaffolding provides problem-relevant perspectives related to the concepts under study, not explicit direction as to which resources are considered best. The *Jasper* environment, for example, supplies video clips wherein the thinking of the main characters is presented using think-aloud dubbing. The soundtrack does not isolate the specific concepts or cause–effect relationships, but instead provides examples of things that might be considered.

Metacognitive Scaffolding

Metacognitive scaffolding supports the underlying processes associated with individual learning management. It provides guidance in how to think during learning.

* Note the method and situation variables here, albeit on a very general level of description. More detailed guidelines are offered in the next sentences, but there is still room for much more guidance.

Metacognitive scaffolding can be either domain specific, such as where enabling contexts are externally induced, or more generic where the enabling context is not known in advance. Linn's (1995) Knowledge Integration Environment (KIE), for example, provides metacognitive support for externally induced problems as learners attempt to formulate models of scientific phenomena. The processes of scaffolded inquiry help students to consider how or if to initiate, compare, and revise their representations.

Metacognitive scaffolding might also remind learners to reflect on the goal(s) or prompt them to relate a given resource or tool manipulation outcome to the problem or need at hand. When a problem context is known, such as KIE's "How far does light travel?", scaffolded inquiry can be designed to emphasize specific ways to think about the problem under study (e.g., "Would it take more time, less time, or the same amount of time to see light from a candle or a flashlight shown from across a lake?"). In contrast, the scaffolding for generic model-building, though uniform in task, represents a wide array of phenomena to be modeled with very different components and weights. In such a case, the scaffolding focuses on the *processes* of creating models, including finding ways to link models with prior knowledge and experience, linking representational models to current understanding, and enabling learners to manipulate ideas through modeling tools (Jackson, Stratford, Krajcik, & Soloway, 1995b).

Procedural Scaffolding

Procedural scaffolding emphasizes how to utilize available resources and tools. It orients to system features and functions, and otherwise aids the learner while navigating an OLE. For example, some learners become disoriented in OLEs. Procedural scaffolding is frequently provided to clarify how to return to a desired location, how to "flag" or "bookmark" locations or resources for subsequent review, or how to deploy given tools. The *Human Body* (Iiyoshi & Hannafin, 1996), for example, provides several resources and tools with distinct functions. Since the cognitive load associated with remembering all procedures for each tool and resource can be overwhelming, on-demand procedural demonstrations are available. Learners need not develop facility with all procedures until they have established, on an individual basis, the need for a given tool or resource.

Strategic Scaffolding

Strategic scaffolding emphasizes alternative approaches that might prove helpful. It supports analysis, planning, strategy, and tactical decisions during open-ended learning. It focuses on approaches for identifying and selecting needed information, evaluating available resources, and relating new knowledge to existing knowledge and experience. The Great Solar System Rescue (1992), for example, offers a range of alternatives to approach the problem at hand, providing varied degrees of direction. Probe questions can provide an explicit strategic clue for those needing a place to begin, while also helping to trigger a series of related strategies for those who are immersed in, but have not yet reconciled, a problem.

Another type of strategic scaffolding involves alerting the learner to available tools and resources that might prove helpful under given circumstances, and providing guidance in their use. Some OLEs, for example, provide on-demand pools of related questions to consider while evaluating a problem, as well as hints as to which tools and resources might contain the needed information (Litchfield & Mattson, 1989). Expert advice regarding approaches that might be helpful in an OLE can also be embedded.

Finally, strategic scaffolding may take the form of response-sensitive guidance at key decision points. For example, individuals might select a number of resources and "feel comfortable" with their understanding of concepts associated with gravity. Once an intention to exit the environment is indicated, they might be advised to test their understanding. They can make a prediction based on the perceived relationship between or among variables and test the prediction using manipulation tools.

OLES IN PRACTICE: ERGOMOTION

Overview

ErgoMotion is one in a series of interactive multimedia units in the *Science Vision* program. It emphasizes student-centered investigation of the laws of physics and their influence on everyday life (Tobin & Dawson, 1992). *ErgoMotion* is consistent with constructivist epistemology; provides tools with which participants can seek, sort, collect, organize, integrate, and generate knowledge; utilizes a host of multimedia resources; and scaffolds inquiry-based learning to promote understanding based on evolving interpretations (Litchfield & Mattson, 1989).

ErgoMotion combines computer-generated graphics, simulations, video, and print-based materials. Students learn about physics concepts, in part, through the design of a virtual roller coaster. They are given opportunities to select and evaluate various resources related to the underlying concepts, query on-line experts for information or advice, study several physics principles (i.e., energy conversion and acceleration) related to roller coasters, and create and test alternative roller coaster designs.

Enabling Context

ErgoMotion provides externally induced macro- and microcontexts. Macrolevel contexts serve to broaden the frame for understanding as well as to encourage the pursuit of personal interests at more comprehensive levels. The macrocontext for *ErgoMotion* is the learning of physics principles associated with the design of a roller coaster. Learners are oriented to the system with a roller coaster movie accompanied by dubbed-over questions about what makes it interesting and fun.

A variety of perspectives and concepts, designed to encourage learner-centered explorations and interpretations, is provided. Initially, an enabling context is externally induced through a video vignette depicting teenagers boarding a roller coaster; participants observe a brief ride through the eyes of the teenagers. They are then asked to design a roller coaster that is both thrilling and safe using physics principles which, though available in various forms in the environment, are not explicitly cued. Like the *Jasper* series, a problem is introduced which helps to frame the exploration of physics content as well as the complexity of roller coaster design. The nature of the problem vignette stimulates learners to identify hypotheses and plausible explanations and utilize a variety of resources and tools to address the problem.

Similar to microworlds, microcontexts represent skills and concepts within a specific range. They introduce problems that are somewhat narrow in scope and definition, but are open-ended in terms of how they can be addressed. During the coaster challenge, for instance, specific extension problems are externally imposed (e.g., set the size of the hills so that the coaster will come to a rest in the first valley). Three progressively difficult challenges are available which support learners in extending their understanding while demonstrating sophisticated awareness of complex concepts and principles. These problems can only be solved if the student has attained understanding of combinations of related concepts (e.g., friction, mass, horsepower). There is an explicit task to be undertaken, with a specific desired outcome.

Available Resources

Static Resources. *ErgoMotion* features a variety of static resources that provide diverse multimedia examples and explanations of the concepts under study. For instance, learners may view video clips and demonstrations from the "videopedia," an alphabetized listing of physics terms (e.g., Newton's Laws, velocity, friction) which is accessible at all times. Physics information is also available in the form of on-line consultants who explain physics concepts from the perspective of a physicist, motorcyclist, police officer, or roller coaster designer. These resources remain stable throughout and across student referencing, but both the initial inclination to access them and the context for interpretation vary with each individual.

Dynamic Resources. *ErgoMotion* also utilizes resources that are static in initial form but become dynamic based on decisions made by the learner. This is available to enable the student to examine changes in the status of the coaster as different forces are changed. For instance, students collect numeric data on coaster performance based on parameters set in the user-specified designs. As they set the mass of the coaster, curve radius, and hill size, numeric data are generated as to the speed of the coaster, its potential and kinetic energy, acceleration, and g-forces at various points along the track. In effect, new data are generated through user experimentation, which provide resources to support student-centered problem solving. Fig. 6.3 illustrates how resource data, available as data points along the coaster track, vary dynamically as a function of learner-supplied parameters.

Available Tools

Seeking tools are provided in the form of keyword searches and indexes to simplify the task of locating desired information. The program also provides a tool that enables students to mark sections for subsequent review, as well as a tool that allows them to generate original presentations using *ErgoMotion* resources. As shown in Fig. 6.4, one *ErgoMotion* manipulation tool enables learners to define roller coaster parameters and simulate their effects at an experimentation site. These tools allow learners to generate coaster designs or theories and test their viability. For instance, tools can be used to manipulate available design parameters: size of three different hills (three options each), the motor size and mass of the coaster cars (three options each), and the radius of a horizontal curve (small, medium, and large). Parameters are set by simply selecting icons to identify which parameter will be tested.

After setting parameters, learners can simulate a coaster run. The manipulation and simulation tools support both the modeling of the learner's beliefs about how roller coasters function and the real-time simulation of the effects of those beliefs and models. The tools provide a means to *test* ideas and theories, *collect* data on the observed results of decisions, and *integrate* personal beliefs with data that support or contradict them.

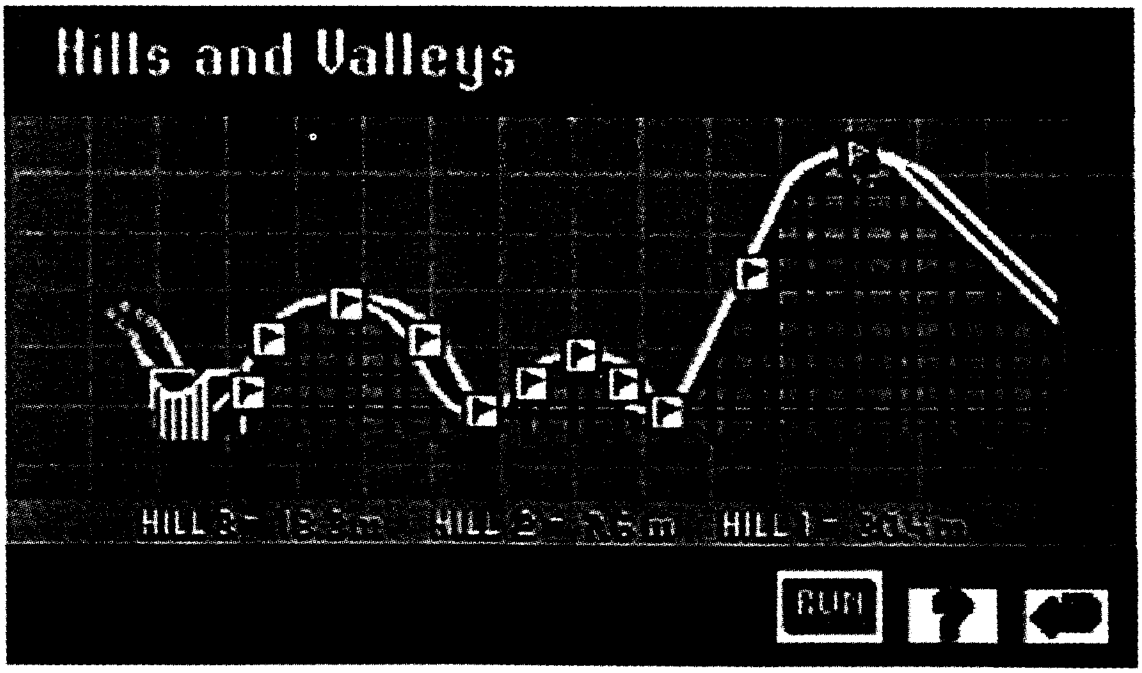


FIG 6.3. Dynamic resource for identifying data points along the coaster track.

FIG 6.4. Coaster experimentation site with parameter manipulation tools.

Scaffolding

Procedural scaffolding is provided in the form of a background video tour of the environment accompanied by a demonstration of the system. It introduces learners to the available resources and tools as well as methods for their use. A pull-down menu listing available text resources is also provided. Text files are provided mainly to assist learners in guiding their own explorations, determining where to collect and record data, and generating project ideas.

Conceptual and metacognitive scaffolds include facilitation guidance such as the questions illustrated in Fig. 6.5. These scaffolds provide a set of approaches that *could be* used should assistance be sought in initiating or continuing efforts. *ErgoMotion* also provides divergent questions regarding hills and valleys, energy loading, and the influence of curve radii on coaster performance. Students may investigate one or more questions to gain conceptual understanding of the underlying principles or design task, or may use the probe questions to guide them in the management of their plans and actions.

Additional conceptual scaffolding is provided in the form of opinions and perspectives on given problem areas. For instance, a question such as "What factors affect banking speed?" is posed, and alternative responses are provided. Learners are prompted to evaluate the opinions of the on-line authorities, identify those with which they agree or disagree, and collect evidence to support or refute their positions. Additional conceptual scaffolding is provided in the form of a radio talk show activity, where competing expert opinions are tendered in response to roller coaster design and performance.

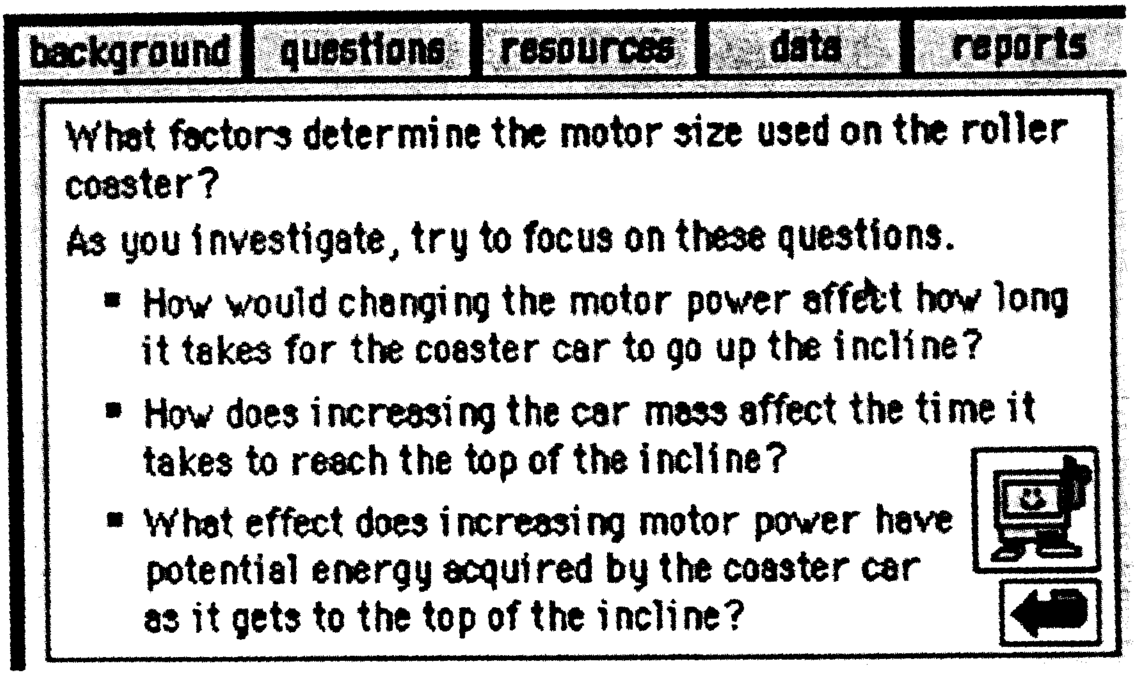


FIG 6.5. Conceptual scaffolding in the form of guiding questions.

Finally, *ErgoMotion* provides a reports file that contains strategic suggestions for creating artifacts to illustrate what was learned (e.g., concept maps, media clip presentations, games). Another strategic scaffold contains questions to be considered and lists resources available to support students in investigating the key questions. The data file, another text resource, suggests locations in the accompanying student workbook to record data collected at the coaster site.

IMPLICATIONS AND CONCLUSIONS

Alignment among the theoretical foundations and available features is the cornerstone of OLE methods and practices. This chapter has attempted to identify and elaborate the core values, goals, components, and methods of OLEs. This has proven difficult to accomplish in a single chapter. Thus, we have attempted to emphasize fundamental, core-level underpinnings and methods of OLEs, while directing readers to a host of publications and software wherein greater detail is available.

We believe strongly in the importance and utility of OLEs for both current educational practice and emerging resource-based teaching and learning approaches. This is a reflection of our biases toward learner-centered environments. Yet, we do not summarily discount the potential value or viability of competing perspectives. Clearly, there are many ways to learn. Many practical factors must be weighed, and many methods are available that are consistent with both theories of learning and the circumstances within which learning is supported, expected, or required. Indeed, grounded design argues principally for the alignment among the core foundations we described in this chapter, not for the inherent superiority of one approach over others (Hannafin, Hannafin, Land, & Oliver, 1997).*

However, we recognize a need to optimize available resources rather than continually redeveloping and rehosting them. Literally billions of resources in diverse media have been produced during the past two millennia. Growth in both technology and information will only accelerate in the future. This poses a serious dilemma: How can we not only make existing resources more available to support learning, but accommodate future developments in each? It seems unlikely that we will be able to maintain pace using resource-embedded designs.

We need greater utility from the resources we have and those that will emerge in the future. We need systems that utilize resources more flexibly, extensively, and efficiently. We need to accommodate diverse goals and needs involving identical (or similar) resources rather than redeveloping the same resources. The growth of both information and technology require that scaleable models be advanced, along with designs that permit ready access, updating, and inclusion of growing bodies of resources.**

At the same time, learning systems must do more than afford better, dynamic access to rapidly emerging information systems. We need to advance a design technology that optimizes rather than minimizes the reasoning capabilities of learners and that exploits these capabilities to support individual goals and needs. OLEs attempt to address these needs by inducing (or supporting) frames for study, making resources available, providing tools to support and encourage analysis and interpretation, and guiding learners in accomplishing their goals or addressing their needs.

REFERENCES

Blieske, M. (1996). *Collaborative design project for the Internet* [On-line]. Available: gopher://gopher.schoolnet.ca:419/00/grassroots/projects/final.reports/elementary/collaborative

Cognition and Technology Group at Vanderbilt. (1992). The Jasper experiment: An exploration of issues in learning and instructional design. *Educational Technology Research & Development, 40*(1), 65–80.

Great Solar System Rescue [Computer software]. (1992). Watertown, MA: Tom Snyder Productions.

Hannafin, M. J. (1995). Open-ended learning environments: Foundations, assumptions, and implications for automated design. In R. Tennyson (Ed.), *Perspectives on automating instructional design* (pp. 101–129). New York: Springer-Verlag.

Hannafin, M. J., Hall, C., Land, S., & Hill, J. (1994). Learning in open environments: Assumptions, methods, and implications. *Educational Technology, 34*(8), 48–55.

Hannafin, M. J., Hannafin, K. M., Land, S., & Oliver, K. (1997). Grounded practice in the design of learning systems. *Educational Technology Research and Development, 45*(3), 101–117.

Hannafin, M. J., Hill, J., & Land, S. (1997). Student-centered learning and interactive multimedia: Status, issues, and implications. *Contemporary Education, 68*(2), 94–99.

---

* This is an enlightened view that seems to me an essential feature of the new paradigm of instructional theory.

** These last two paragraphs raise many issues that are a consequence of the information age and have great implications for an information-age paradigm of instruction. They are issues that cry out for serious pondering and discussion.

Hannafin, M. J., & Land, S. (1997). The foundations and assumptions of technology-enhanced, student-centered learning environments. *Instructional Science, 25*, 167–202.

Harel, I., & Papert, S. (1991). Software design as a learning environment. In I. Harel & S. Papert (Eds.), *Constructionism* (pp. 41–84). Norwood, NJ: Ablex.

Hay, K. E., Guzdial, M., Jackson, S., Boyle, R. A., & Soloway, E. (1994). Students as multimedia composers. *Computers and Education, 23*, 301–317.

Hill, J., & Hannafin, M. J. (1997). Cognitive strategies and learning from the World-Wide Web. *Educational Technology Research and Development, 45*,(4), 37–64.

Honebein, P. C. (1996). Seven goals for the design of constructivist learning environments. In B. G. Wilson (Ed.), *Constructivist learning environments* (pp. 11–24). Englewood Cliffs, NJ: Educational Technology Publications.

Iiyoshi, T., & Hannafin, M. (1996, February). *Cognitive tools for learning from hypermedia: Empowering learners.* Paper presented at the annual meeting of the Association for Educational Communications and Technology National Convention, Indianapolis, IN.

Jackson, S., Stratford, S. J., Krajcik, J., & Soloway, E. (1995a). Model-It: A case study of learner-centered design software for supporting model building. *Paper presented at the Working Conference on Technology Applications in the Science Classroom.* Columbus, OH: National Center for Science Teaching and Learning, The Ohio State University.

Jackson, S., Stratford, S. J., Krajcik, J., & Soloway, E. (1995b, April). *Making system dynamics modeling accessible to pre-college science students.* Paper presented at the annual meeting of the American Educational Research Association, San Francisco, CA.

Jacobson, M. J., Sugimoto, A., & Archodidou, A. (1996). Evolution, hypermedia learning environments, and conceptual change: A preliminary report. In D. C. Edelson & E. A. Domeshek (Eds.), *Proceedings of ICLS '96* (pp. 151–158). Charlottesville, VA: Association for the Advancement of Computing in Education.

Land, S. M., & Hannafin, M. J. (1996). A conceptual framework for the development of theories-in-action with open-ended learning environments. *Educational Technology Research & Development, 44*(3), 37–53.

Land, S. M., & Hannafin, M. J. (1997). Patterns of understanding with open-ended learning environments: A qualitative study. *Educational Technology Research & Development, 45*(2), 47–73.

Lebow, D., Wager, W., Marks, P., & Gilbert, N. (1996, June). *Construe: Software for Collaborative Learning over the World Wide Web.* Paper presented at the AET Collaboration in Distance Education Conference, Tallahassee, FL.

Linn, M. (1995). Designing computer learning environments for engineering and computer science: The Scaffolded Knowledge Integration Framework. *Journal of Science Education and Technology, 4*(2), 103–126

Lewis, E., Stern, J., & Linn, M. (1993). The effect of computer simulations on introductory thermodynamics understanding. *Educational Technology, 33*(1), 45–58.

Litchfield, B., & Mattson, S. (1989). The IMS Project: An inquiry-based multimedia science curriculum. *Journal of Computers in Mathematics and Science Teaching, 9*(1), 37–43.

Microworlds Project Builder (Version 1.02) [Computer program]. (1993). Highgate Springs, VT: Logo Computer Systems.

National Library of Medicine. (1996). *Visible human project.* Bethesda, MD: Office of Public Information.

Rieber, L. P. (1993). A pragmatic view of instructional technology. In K. Tobin (Ed.), *The practice of constructivism in science education* (pp. 193–212). Hillsdale, NJ: Lawrence Erlbaum Associates.

Sayle, R. (1996). RasMor [Computer program]. Edinburgh, Scotland: University of Edinburgh.

Scardamalia, M., & Bereiter, C. (1994). Computer support for knowledge-building communities. *The Journal of the Learning Sciences, 3*, 265–283.

Schubert, N. (1997a). *Playwriting in the round* [Online]. Available: http://www1.minn.net:80/~schubert/Play.html

Schubert, N. (1997b). *Signs of spring* [Online]. Available: http://www1.minn.net:80/~schubert/spring.html

Tobin, K., & Dawson, G. (1992). Constraints to curriculum reform: Teachers and the myths of schooling. *Educational Technology Research & Development, 40*(1), 64–92.

Vosniadou, S. (1992). Knowledge acquisition and conceptual change. *Applied Psychology: An International Review, 41*(4), 347–357.