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AUTHOR	Hogle, Jan G.
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ABSTRACT

Use of educational games to supplement traditional classroom lectures is purported by some researchers to increase interest, motivation, and retention, as well as to improve higher order thinking and reasoning skills. This paper reviews proposed benefits of using games as cognitive tools, and discusses the complexities of assessing those benefits. The paper is divided into three main sections. The first section defines terminology, citing the most commonly used definitions found in the literature. The second section describes proposed benefits of educational games, reviewing issues of motivation, retention, higher order skills, and effects of practice and feedback. The last section discusses several factors which must be considered when attempting to measure these proposed benefits, including issues of learner differences, assessment methods, and implicit knowledge. Five figures present a possible model of the interrelationship between microworlds, simulations, and games, as well as Web screen copies of different games. (Contains 43 references.) (AEF)

Considering Games as Cognitive Tools:

In Search of Effective "Edutainment"

Jan G. Hogle

University of Georgia

Department of Instructional Technology

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Abstract

This paper reviews proposed benefits of using games as cognitive tools, and discusses the complexities of assessing those benefits. Use of educational games to supplement traditional classroom lectures is purported by some researchers to increase interest, motivation, and retention, as well as to improve higher order thinking and reasoning skills. Assessment of the effectiveness of games as cognitive tools is a complex issue, and several variables, such as learner differences, assessment methods, and implicit knowledge, must be considered.

Considering Games as Cognitive Tools: In Search of Effective "Edutainment"

> Play is a very serious matter....It is an expression of our creativity; and creativity is at the very root of our ability to learn, to cope, and to become whatever we may be. (Rogers & Sharapan, 1994, p.1)

Fred Rogers, of the television show "Mr. Rogers' Neighborhood," knows much about children and play. And he seems to be correct when he states that play is serious business; if millions of dollars in sales are a valid indicator, the business of play is thriving. In 1995, educational computer games comprised a significant portion of the rapidly growing "edutainment" market. According to the Software Publishers Association, interactive children's education is one of the fastest growing market segments in the computer industry (Parets, 1995). Educational software is the primary stimulus behind multimedia computer purchases for the home (Hisey, 1995), with sales of $600 million for 1995 (Parets, 1995). Non-computer-based games marketed as having an educational component accounted for more than $200 million in sales in 1994 (Hoover, 1995).

With educational gameware representing hundreds of millions of dollars in sales each year, investors (parents, teachers, students, as well as instructional designers) would be wise to consider the validity of educational gaming. Can one mix a game with a lesson and produce a valuable educational tool? Games marketed as being educational often seem to lack obvious cognitive value, while many educational "toys" are neither fun nor engaging.

The purpose of this paper is to review proposed benefits of using games as cognitive tools, and to discuss the complexities in assessing those benefits. Researchers propose many benefits from the use of educational games, but the issue is complex, and several variables must be considered in assessing their effectiveness (Bredemeier & Greenblat, 1981; Randel, Morris, Wetzel & Whitehill, 1992; Salomon, 1993).

The paper is divided into three main sections. The first section defines terminology, citing the most commonly used definitions found in the literature. The second section describes proposed benefits of educational games, reviewing issues of motivation, retention, higher order skills, and effects of practice and feedback. The last section discusses several factors which must be considered when attempting to measure these proposed benefits, including issues of learner differences, assessment methods, and implicit knowledge.

Definitions

What is a game, anyway?

Games are classified into numerous, often overlapping, categories. A sampling includes: adventure games, simulation games, competition games, cooperation games, programming games, puzzle games, and business management games (Dempsey et al., 1993; Jacobs & Dempsey, 1993). It is common for a game to fit into more than one group.

Generally, to be considered a game an activity must include several basic characteristics. The activity is usually a contest of physical or mental skills and strengths, requiring the participant(s) to follow a specific set of rules in order to attain a goal. Games may involve an element of chance or fantasy. A game involves competition with others, with a computer, or with oneself. Games can be instructional or not, they can be interactive or not, and they can be computer-based or not (Bright & Harvey, 1984; Dempsey et al., 1994; Malone, 1980).

Good games are fun, intrinsically motivating, and offer just the right amount of challenge (Lepper & Malone, 1987; Malone, 1980; Malone, 1983; Malone & Lepper, 1987; Malouf, 1988). Games which succeed in facilitating learning have the additional characteristic of improving skills or knowledge.

Simulations, Microworlds, and Games

Simulations and microworlds are related to games, and at times exhibit enough similarities for these areas to be confused. Simulations and microworlds may overlap with games, or exist in their own realms (see Figure 1).

A simulation usually models a process or mechanism in a simplified "reality" and can be designed so that it differs little from its real-world counterpart. A common example is the use of training simulators for flight training (Randel et al., 1992; Rieber, 1991). Simulation games are used most often by the military and in business education (Dempsey et al., 1993).

An example of an educational simulation game is SimCity, in which the player makes economic decisions to build a computer generated "city." Results of the player's decisions, for good or bad, are displayed over a simulated period of several years (see Figure 2).

Microworld designs are usually more conceptual than simulations. A microworld is also a simplified environment, but one in which learners (usually children) explore or manipulate the logic, rules, or relationships of a modeled concept, as determined by the designer. The computer language, Logo, developed by Seymour Papert at MIT (1980), is perhaps the best known example of a computer microworld (see Figure 3). A microworld is usually thought of in terms of a cognitive tool, rather than a training device (Brehmer & Dorner, 1993; Edwards, 1991; Rieber, 1991).

Cognitive Tools: What is a tool and what makes it cognitive?

A tool is an instrument that a user may operate and manipulate to make a process easier or more productive. It may further be described as cognitive when the tool assists constructive thinking (Pea, 1985). Cognitive tools aid students in performing conceptual operations otherwise beyond their abilities. Learners become better, more independent thinkers when using effective cognitive tools, inasmuch as cognitive tools promote and cultivate higher order thinking skills (Salomon, 1993).

Salomon (1993) lists the four attributes of a cognitive tool as: (a) an implement or device, such as a symbol system, mental strategy or computer program (b) which entails the purpose for which it is designed to serve, (c) serves functions beyond itself, and (d) is distinguished from machines by the need for skillful operation throughout its function.

Cognitive Toys

Cognitive tools can reduce the need for laborious activity and allow students to achieve goals they are already motivated to reach (Malone & Lepper, 1987). But what about goals which students are not motivated to achieve? Games are generally assumed to rouse student interest and motivation, so it should not be surprising that this format is used in an attempt to create less tedious learning environments. Many teachers and researchers use games to supplement or replace traditional instruction, but the educational effectiveness of such approaches has not been well documented (Randel et al., 1992).

Sometimes the design of intrinsically motivating environments requires toys, rather than tools, that challenge learners to use skills they would not otherwise be inclined to use (Malone & Lepper, 1987). Malone and Lepper describe toys as objects that are used for their own sake, but unlike tools, toys are not used as a means to achieve an external goal. While tools are usually made for efficiency and reliability, toys are often made to be challenging and difficult to use. Many activities can be seen as toys or as tools, depending upon the manner in which the activity is approached.

Not all games, toys, microworlds or simulations dubbed "educational" are truly cognitive tools as defined by Pea (1985) or Salomon (1993). However, for the purpose of this paper, the phrase "educational game" will be used to mean a game, simulation, microworld or toy designed to be used as a cognitive tool.

Possible Benefits of Educational Games

Research suggests that gaming in its various forms can motivate and interest learners (Dempsey, Lucassen, Gilley & Rasmussen, 1993; Dempsey, Rasmussen & Lucassen, 1994; Jacobs & Dempsey, 1993; Lepper & Malone, 1987; Malone, 1980, 1983; Malone & Lepper, 1987; Malouf, 1988), increase retention of subject material (Dempsey et al., 1994; Jacobs & Dempsey, 1993; Pierfy, 1977), and improve reasoning skills and higher order thinking (Mayland, 1990; Rieber, in press; Wood & Stewart, 1987).

Stimulating Motivation and Interest

Use of a game format for instruction does not always result in an effective learning environment, as there are several variables involved in creating a successful learning tool. The format should be intrinsically motivating, appropriately challenging, as well as offering elements of curiosity, fantasy and control (Malone, 1980, 1983; Rieber, in press).

An activity which is intrinsically motivating is one in which a learner engages in for its own sake, without any external reward or punishment (Malone & Lepper, 1987). Malone and Lepper's research on what they considered "highly motivating" computer games presented a theory of intrinsically motivating instruction. However, as Malone pointed out, his research centered on what made games fun, not necessarily on what made them educational (Jacobs & Dempsey, 1993).

Lepper and Malone's research suggests that activities which engage the interest of the learner allows more time spent on the activity than would be spent otherwise, leading to better learning of the instruction and more sustained interest in future encounters with the instructional content (Lepper & Malone, 1987). Longer time on the task and increased interest could lead to more practice, more automaticity of pattern recognition, more efficient retrieval of concepts, and better use of basic knowledge (Trabasso, 1987).

Gaming elements which often increase motivation include challenge and curiosity. Consistent with the Piagetian process of equilibration (Piaget, 1951), these elements encourage learners to resolve conflict if an answer seems possible and within reach, assuming it is presented in an inherently interesting context (Rieber, in press). Unfortunately, instructional gaming often relies on aspects of sensory curiosity that merely embellish, rather than embody, instructional and metacognitive goals (Jacobs & Dempsey, 1993).

<u>Improving Retention</u>

Retention of the instructional material embedded in educational games is an important issue, one not always considered in gaming research. There is some evidence that game formats may improve retention of what is learned (Dempsey et al., 1993; Jacobs & Dempsey, 1993; Pierfy, 1977), but the most often cited gaming articles which discuss retention are not recent.

Pierfy, in 1977, reviewed twenty two comparative simulation gaming studies and concluded that simulations and games demonstrated greater retention over time than conventional classroom instruction, with students reporting more interest in the game activities. Accumulated findings suggested that students' learning with simulation games was no more effective than with conventional classroom instruction. However, the research also suggested that games appeared to have an advantage when it came to retention of the learned information. In addition, the simulation games appeared to have an advantage over conventional instruction when it came to changing attitudes and holding student interest (Dempsey et al., 1993; Jacobs & Dempsey, 1993; Pierfy, 1977).

<u>Effects of Practice and Feedback</u>

Educational games, especially those that are computer-based, are often designed in a drill and practice format, to the extent that some instructors grimly refer to them as "the old drill and kill." This format may be overused, but development of cognitive skills often requires long hours of practice with consistent feedback and it can be difficult to provide those conditions within a traditional classroom setting. Well designed computer games can be useful for consistent practice. However, games, like any other activity, require an interesting context to prevent students from losing interest and motivation (Wood & Stewart, 1987).

When designing games to provide practice, developers should consider results found when comparing behaviorism and cognitive framework designs. Game designers operating under principles of behaviorism usually create almost error-proof practice, anticipating that total success would be most effective and motivating. Designers working under a cognitive framework, however, have found that practice which evokes misconceptions about newly learned information seems to stimulate learners' interest even more than successful experience (Smith & Ragan, 1993).

Designers should consider ways in which learners might misunderstand lesson content, then design practice experiences which allow learners to discover misconceptions and correct them. Good feedback can be presented in many ways, for example, through text, graphics or sound. However it is used, feedback is an essential element of practice for learners to evaluate their progress against an established game goal (Rieber, in press; Smith & Ragan, 1993).

Improving Higher Order Skills

In addition to providing practice and sustaining learner interest, cognitive benefits of educational gaming are supported by Piaget's learning theory. Game formats provide opportunities for both play and imitation, functions which serve as important accommodation and assimilation strategies that Piaget (1951) considered essential to the equilibration process. Successful play can require extensive critical thinking and problem-solving skills (Rieber, in press).

Simulations and games may improve several types of cognitive learning strategies. These include: organizational strategies (paying attention, self-evaluating, and self-monitoring), affective strategies (anxiety reduction and self-encouragement), memory strategies (grouping, imagery, and structured review), and compensatory strategies (guessing meaning intelligently) (Jacobs & Dempsey, 1993; Oxford & Crookall, 1988).

Games which incorporate multimedia technologies may improve other aspects of higher order skills. Multimedia is yet a relatively unexplored area, touted as a many-faceted contributor to the development of cognitive skills. As noted by Hisey (1995), educational software is the primary stimulus behind multimedia computer purchases for the home, with games comprising a large component of software considered for purchase. Multimedia games may facilitate learning via structured discovery (Borsook & Higginbone-Wheat, 1992; Fontana, Dede, White & Cates, 1993), improved student motivation (Fontana et al., 1993; Malouf, 1988; Pearson, Folske, Paulson & Burggraf, 1994; Smith, 1992), opportunities for multiple learning styles (Fontana et al., 1993; Smith, 1992; Turner & Dipinto, 1992; Wilson, 1991), navigation of web-like representations of knowledge (Fontana et al., 1993), learner authoring of materials (Gouzouasis, 1994; Turner & Dipinto, 1992), and collaborative inquiry (Borsook & Higginbone-Wheat, 1992; Ellis, 1992; Fontana et al., 1993).

Some simulation games are used to encourage skills in practical reasoning. "Mastermind" and the "Carmen Sandiego" series are two very different examples of games which may not actually teach logic, but offer practice in using it.

Mastermind is a reasoning puzzle, requiring players to guess the position of different symbols, colors, or other game pieces (see Figure

4). Players are given feedback based on guesses, and (with the occasional exception of a lucky guess) must use logic to solve the puzzle. Wood (1987) used Mastermind as a training task in the use of logic, and found a statistically significant decrease in reasoning errors after students practiced with the game.

Games in the Carmen Sandiego series, familiar to many classrooms, are promoted as motivating instructional tools which encourage practice with databases, as well as improvement of problem-solving and higher order thinking skills (Mayland, 1990).

Wiebe and Martin (1994) compared the learning effects of the computer game, "Where in the World is Carmen Sandiego?" (see Figure 5), to a non-computer-based board-style geography game. They found no significant differences in recall of geography facts or attitudes between the teaching methods. The study did not, however, compare the games to traditional classroom instruction.

Issues in Assessing Possible Benefits of Educational Games

The problem with making claims about the benefits a game may offer as a cognitive tool is that its effectiveness often cannot be directly or easily measured. Several variables must be considered, not the least of which is the intended purpose of the game, as well as the context in which it is used.

How does one assess and compare the "goodness" of one tool to another? Is it possible to compare a hammer to a wrench? Certainly the value of a tool must be judged based on its purpose, and its intended effects. Tools are made to serve different purposes, and their effects result from an entire set of circumstances, activities, content, and interpersonal processes taking place in the context in which the tools are used. Cognitive tools must be evaluated according to the activities they stimulate, and the abilities they foster (Salomon, 1979, 1993).

Learner Differences

Important considerations in assessing cognitive tools are the profiles of the learners, including academic ability and personality type (Bredemeier & Greenblat, 1981; Dempsey et al., 1993; Gardner, 1983; Jacobs & Dempsey, 1993; Seginer, 1980). Educational psychologists do not always agree on how to characterize learners' abilities, although traditional academic competence is most commonly associated with verbal and mathematical intelligences (Gardner, 1983). Research has suggested varying degrees of relationship between gaming ability and traditional academic ability, perhaps due to the varying criteria used to determine the level of performance, as well as differences in the type of performance required by different games (Bredemeier & Greenblat, 1981).

In a 1980 study of preadolescent boys in Israel, Seginer attempted to compare gaming ability with traditional academic competence. Seginer's study suggested that gaming ability differs from academic ability in at least three respects: (a) successful gaming strategies may require the ability to perceive relationships rather than command language, (b) cognitive processes involved in gaming may be more independent from self-perceptions of confidence and control, and (c) gaming is not directly affected by social background or status (Dempsey et al., 1994; Jacobs & Dempsey, 1993; Seginer, 1980).

If Seginer's conclusions are correct, our expectations and traditional methods of assessment may need a change of perspective. In particular, gaming may be an effective tool for teaching disadvantaged students whose language skills are not well developed.

Another difficulty in simulation-gaming assessment has been the tendency for researchers to ignore differences among individual students with regard to their personality types, or cognitive styles. Personality types are not a credible subject to some psychologists, but the fact remains that some students learn from games while others do not. Many researchers erroneously treat these individual differences as statistical variance instead of considering their effect on game outcomes (Bredemeier & Greenblat, 1981).

Characteristics of learners, such as the preference to work in a group or alone, can affect their experience with a game, especially when the game is designed with a very open structure. The more control a student has over the game, the more likely it will be that a student's personality or style will affect the outcome. Inconsistent findings of research in gaming outcomes may be in part a result of these individual learner characteristics (Bredemeier & Greenblat, 1981).

Potential users or purchasers of educational gameware should consider that any conclusions suggested by research studies about effectiveness of an educational game is relevant to that research group in that group's context. Individuals do have learning preferences. If a learner is not comfortable in a given environment, it cannot be expected that he or she will learn as well there as in an environment which they prefer.

Assessment Methods

Assessment methods and administration are also complex issues which may confuse efforts to measure the value of educational games. A long list of questions have been raised about gaming assessment, and these include, but are not limited to: use of inappropriate measurement instruments, using the same pre- and post-tests with only a short time interval between them, studies not long in duration showing possible Hawthorne effect, bias resulting from evaluating one's own game, and bias introduced during debriefing of subjects after the game (Bredemeier & Greenblat, 1981; Randel et al., 1992; Salomon, 1993).

Measures used to demonstrate the learning effects of a game need careful consideration. Instructional objectives of a game are often not specified, especially in social sciences simulations (Randel et al., 1992). A test for effectiveness needs to match what the game is teaching to avoid misleading results (Salomon, 1993).

Implicit Knowledge: How do we know what is learned?

Finally, the most difficult issue in the assessment of games as cognitive tools is that games may be environments which foster the learning of implicit knowledge. Implicit learning occurs when a subject is not consciously intending to learn, is not aware of what they have learned, and yet they acquire new knowledge (Kihlstrom, 1994). Implicit knowledge is not necessarily reflected in people's ability to answer written questions, since they are not always consciously aware of what they have learned (Berry & Dienes, 1993). Learners often can not describe or readily demonstrate the benefits received from an activity, even when real benefits are achieved (Berry & Dienes, 1993; Kihlstrom, 1994; Reber, 1993). As noted previously when discussing Seginer's work on gaming ability, students in simulation situations often develop and use successful strategies that they cannot verbalize (Seginer, 1980).

Literature on implicit and explicit learning is complex, and other issues confound research findings. Factors such as stress or anxiety may affect explicit directions, positively or negatively. Implicit and explicit learning may be interactional, and complex skills are most likely a combination of these types of knowledge (Reber, 1993). Implicit learning presents a challenge to the researcher, since it must be determined how the learner can demonstrate new knowledge or skills in order to make appropriate assessments.

Conclusions

Educational games may offer a wide variety of benefits. Increases in interest and motivation, as well as improvement of retention and higher order thinking skills are worthwhile goals for an instructional tool.

However, several factors must be considered in the design of an educational game, and in the design of its assessment. Researchers must be careful with their methods, and administer the game as well as the assessment in an appropriate manner. Instructional objectives of the game must be clear, and matched to the assessment tool. Assessments should consider individual personality types and cognitive styles, and carefully consider how the learner can demonstrate what they may have gained from the activity.

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Figure Captions

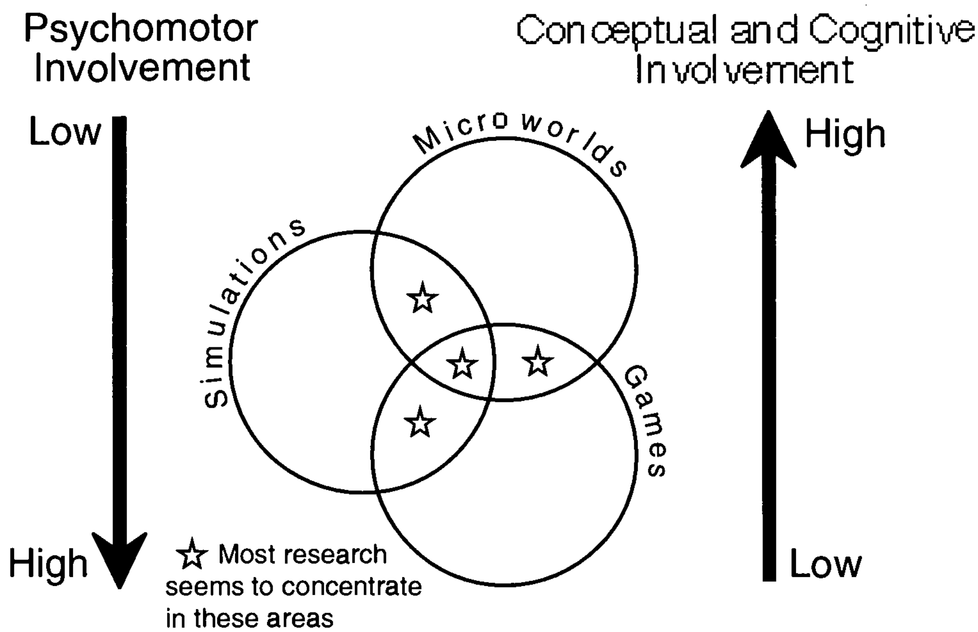
<u>Figure 1.</u> Possible model of interrelationship between microworlds, simulations, and games.

<u>Figure 2.</u> Screen capture of computer-based simulation game, SimCity.

<u>Figure 3.</u> Screen capture of a Macintosh Logo program, Logo 2.0, one of several versions of Logo available.

<u>Figure 4.</u> Screen capture of a version of the Mastermind puzzle.

<u>Figure 5.</u> Screen capture of a game in the Carmen Sandiego series, "Where in Time is Carmen Sandiego."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Low
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Conceptual and Cognitive Involvement
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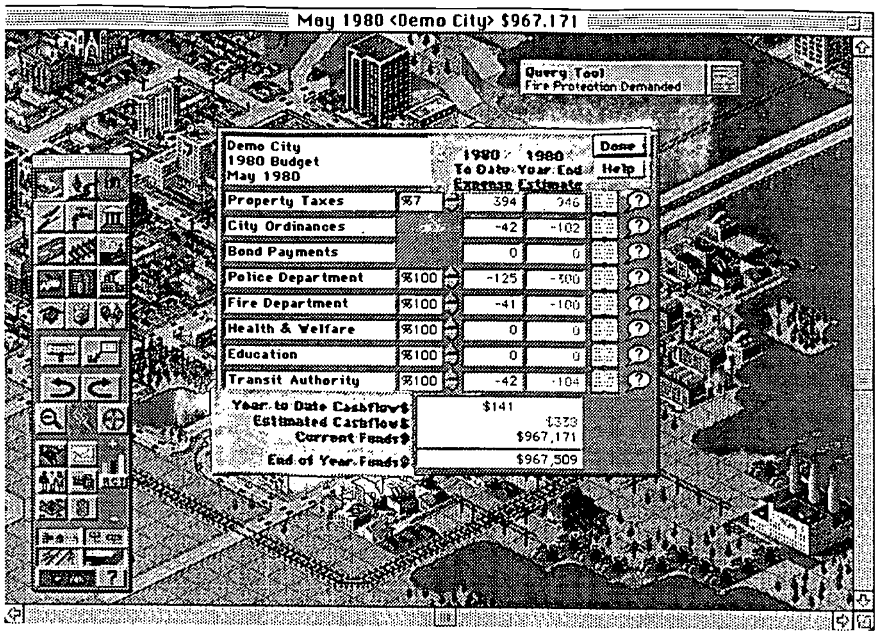
Micro worlds
Simulations
Games
☆ Most research seems to concentrate in these areas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-102
Bond Payments
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Education
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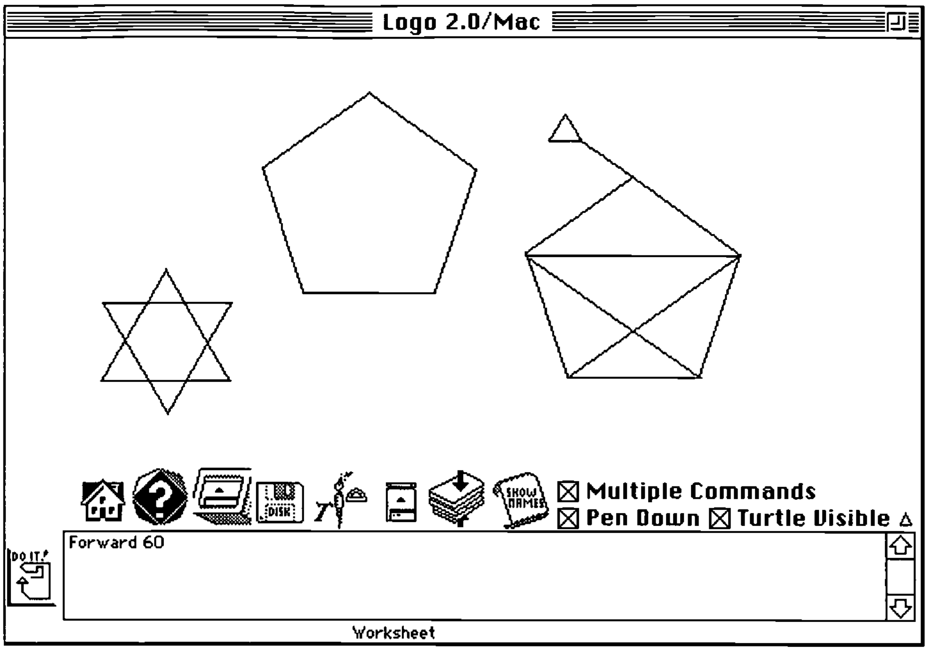
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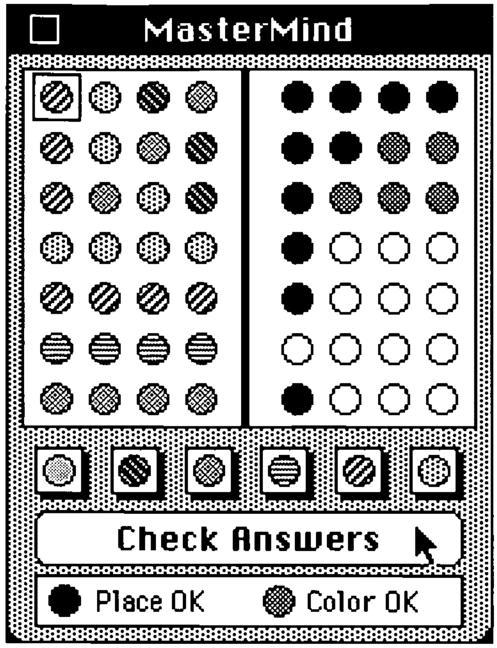
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Place OK
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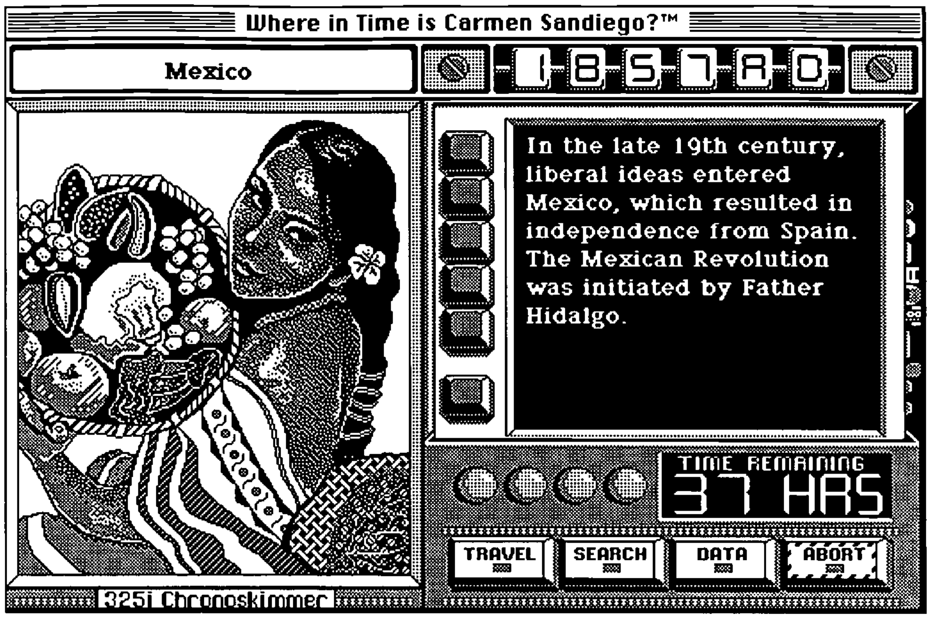
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