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ABSTRACT

A study examining the effects of computer animation exercises on cognitive development asked two groups of seventh graders to create computer animations, working from a simple mythic text. The ability of students to create narrative scenarios from this mythic text was analyzed. These scenarios were then recreated in the school computer lab, using Autodesk Multimedia Explorer software. Computer lab sessions were videotaped, and student dialogues tape-recorded in an effort to observe student problem solving techniques. Recurring strategies were observed over the course of the study. Students chose reductionist, literal, or transformational paths in completing their assignments. The importance of transactional dialogue between partners in developing story-l es and solving problems was recorded. Most students exhibited an ability to use the animation program for problem solving. However, in a few students, a relationship between perception and sequencing problems in the cognitive development process was observed. Students exhibiting this combination of developmental problems had difficulty with the manipulation of the computer program. This was contrasted with students who were able to use the program for sophisticated symbol manipulation. The role of computer animation in the language arts curriculum as a tool for the development of student narrative skills was also substantiated. (Contains 27 references.) (Author/TB)

EFFECTS OF COMPUTER ANIMATION EXERCISES ON STUDENT COGNITIVE PROCESSES

BY

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ABSTRACT

This study examines the effects of computer animation exercises on cognitive development among seventh grade language arts students at a suburban middle school in Marin County, California. It draws upon the theories of Piagetian structuralism, and post-Piagetian theories of cognition in detailing a model of semiotic cognitive processes which are apparent in studying the work of student animators. Recent studies in cognitive development were examined which describe important developmental stages in student image processing, transitional thinking , and the understanding of dynamic systems.

Two separate intact groups of students were asked to create computer animations, working from a simple mythic text. The ability of students to create narrative scenarios from this mythic text was analyzed. These scenarios were then recreated in the school computer lab, using Autodesk Multimedia Explorer software. Computer lab sessions were video taped, and student dialogues tape recorded, in an effort to observe student problem solving strategies.

The study investigated the ability of students to create narrative scenarios, and the manner in which they convert these scenarios into animation. Recurring strategies were observed over the course of the study. Students chose reductionist, literal or transformational paths in completing their assignments. The importance of transactional dialogue between partners in developing story-lines and solving problems was recorded. Most students exhibited an ability to use the animation program for problem solving. However, in a few students, a relationship between perception and sequencing problems in the cognitive development process was observed. Students exhibiting this combination of developmental problems had difficulty with the manipulation of the computer program. This was contrasted with students who were able to use the program for sophisticated symbol manipulation.

The role of computer animation in the language arts curriculum as a tool for the development of student narrative skills was also substantiated.

TABLE OF CONTENTS

INTRODUCTION

The question of computer animation in the language arts classroom grows from general questions surrounding issues of curriculum in our technological world. The evolution of the desktop computer from a "smart" typewriter to a powerful graphics generator, coupled with new advances in data compression technology, and linked as well to CD technology, has put into the hands of many seventh graders more graphics capability than the average network television producer of the fifties could command. The implications for the teacher should be apparent. Students will demand to work in media beyond print. If the teacher accedes to these demands, what curriculum will they follow? And, more important, what lenses will a teacher working in computer animation use to inspect the results of a lesson, and evaluate the learning which has taken place? Fortunately, students working with two dimensional computer animation can be assessed by extending rubrics grounded in cognitive theory, without altering the essential justifications of the theories.

The traditional role of the language arts program concerns itself with how children make meaning, through reading and writing. More recently, teachers have added thinking, speaking, and listening to the canon, as skills which can be developed in the classroom. Cross-curricular programs have added art, and drawing to the language arts classroom, and by extension computer graphics. Because computer graphics are new, few teachers have developed a graphics centered curriculum, choosing instead to include a trip to the computer room occasionally for an "enrichment" activity. But when the computer is incorporated into the classroom as a tool for student creativity, and when the creations of the students are directly related to the curricular framework, it becomes paramount for the teacher to understand the computer's role in a student's cognitive development, not just its ability to ease student access into a lesson. As student familiarity with technology increases, and as the technology becomes more sophisticated, the impact of computer graphics upon student cognitive growth will assume much greater importance as a question for the researcher. Students are already using computer animation as a tool for self expression in many schools. These easy to learn programs make excellent curriculum tools, not only because they delight the students, but also because they contribute to student growth and maturity.

While these programs are easy to learn, a great deal of thought goes into the creation of even the simplest computer animation sequence. Computer animation is more complex than the simple paint programs first introduced into the schools. When creating an animation, the student must do more than draw a picture. The artist must create a picture with elements which move, that is, that will incorporate the element of time. This temporal component requires a great deal of planning on the student's part, and triggers thought processes which are akin to the creation of other narratives in their development, although they appeal to the visual senses, rather than the language centers of the brain.

STATEMENT OF THE PROBLEM

Students working in computer animation have an opportunity to develop cognitive skills in the same way that they develop cognition in other situated environments. This paper will discus. the evidence that students working regularly in computer animation experience an observable degree of cognitive growth as a result of their practice. Four questions appear to be salient:

1. How do children seek to make meaning with computer animation?
2. What problems do they encounter while working in the medium?
3. Is there a relationship between problems in perception and purely mechanical problems involving the animation program?
4. How do students attempt to solve problems while working in the medium?

RATIONALE

The classic interpretation of cognitive development stems from Jean Piaget's structuralism. (Piaget, 1967) Long accepted by psychologists as central to any theory of cognitive development, structuralism defines a process through which a child's growth is marked by the creation of mental structures which develop from stage to stage through a process of transformation. Piaget establishes three criteria for the strucuralist model: wholeness, transformation, and self-regulation. The completeness of any given structure allows an observer to classify a particular developmental stage, concrete operational or formal operational, for example, and determine the level which an individual child has attained. Piaget establishes parameters for normal development from stage to stage, and in general, these have been verified through research. (Gardner, 1973) The process of transformation allows the child to progress from stage to stage, as the growing organism interacts with the world. Piaget states that "If the laws of structured wholes depends on their laws of composition, these laws must of their very nature be *structuring*: it is the constant duality of , or bipolarity, of always being simultaneously *structuring* and *structured* that accounts for the success of the notion of law or rule employed by the structuralists." (Piaget, 1967, p.10) This process accounts for his third rule of self-regulation, the homeostatic control which keeps the growing organism in balance as it advances from stage to stage. This structuralist philosophy, once the accepted model for human learning, is currently under revision, and recent articles speak of "post-Piagetian" thinking. Nonetheless, few researchers reject Piaget out of hand, and all acknowledge the substantial contribution his philosophy makes to cognitive science. (Bruner, 1986; Gardner, 1979)

The shift in thinking surrounding the structuralist viewpoint involves a variety of issues, but the most important of these for educators working in computer graphics involves the role of non-linguistic forms of cognition. This paper does not seek to enter the debate regarding the role of language in thought. (Chomsky, 1976; Piatelii-Palmerini, 1980) It does, however, recognize the existence of such a debate and will refer to forms of cognition which are not language centered, but rely instead upon signs and symbols for the expression of complex ideas. Semiotics, the study of signs and their relationship to cognition, has become increasingly important in the debate concerning cognition. Dating from the Genevan linguist Ferdinand de Saussure, 1857-1913, this science examines the differences between formal and informal language, seeking to delineate the relationship between signs, language, and thought. (Gardner, 1973) Charles Peirce, 1839-1914, often cited as the founder of the American school of semiotics, defined sign as icon, index and symbol. (Hoopes, ed., 1991) This classification allows us to distinguish between arbitrary representations of signs, and discover interpretive content within them, creating a hierarchy advancing in abstraction. The role of "interpretant," is essential in Peirce's theory of cognition, for it rejects the arbitrary dual relationship of "sign" and "thing signified," creating a dynamic in which symbols function within a complex system of thought. (Deely, 1990; Sebeok, 1991) Equally important is Peirce's principle of "abduction," whereby ideas are seized, developed deductively, and tested inductively, in a naturally occurring spiral. (Cunningham, 1984; Deely, 1990; Suhor, 1984, 1991) These principles are now enjoying a revival of interest, as we seek to find meaning in a symbol rich electronic environment. Carol Feldman writes that "the new literature on theory of mind embeds the thinking child in a semiotically rich and interpreted world." (Feldman, 1992, p.108) Much of the current debate in cognitive science involves questions surrounding the role of signs in thinking processes.

Current studies no longer accept a pure Piagetian model which describes cognitive growth in linear terms; the mind progressing from one structure to the next in a rational sequence. Recent trends in the study of cognition tend to reject such purely liner stages, looking at cognitive development as more kaleidoscopic in nature. (Bruner, 1986, 1990; Mussen, 1970; Winograd & Flores, 1986) Such trends presuppose that children possess a developing knowledge of the social world and a sophisticated awareness of other minds. The extent to which children have a developed theory of mind is in debate, although there seems to be agreement that even young children are much less ego-centric then first postulated by Piaget. Much of the new literature on cognitive development emphasizes the importance of learning which is situated in a social environment. Jerome Bruner argues strongly for culturally mediated meaning as central to cognition. He is emphatic about the strength of narrative forms as carriers of meaning, as essential forms of social negotiation. He argues that even children as young as four years of age who may not be able to describe aspects of their culture with confidence, are quite at home with narratives set in that culture. In his words, they already possess a "canon." Moreover, they are quick to create narratives of their own when asked to explain situations which are anticanonical.

Bruner argues for a return to "meaning making" in the study of cognition, decrying the information processing-computational models some scholars put forth. He looks to narrative structures as the center of a powerful folk psychology, and postulates that narratives may very well underlie human grammars, and are the structures from which we derive concepts, including the concept of self. (Bruner, 1986, 1990)

BACKGROUND AND NEED

COMPUTER ANIMATION AS PROCESS

In order to apply these theories to this study, it is necessary to understand exactly what is involved when a student works in computer animation. One begins by asking what happens in the mind when a student creates an animation. When starting a drawing of a figure from scratch, students at first seem very concerned with "getting it right," that is, selecting the correct drawing tools and colors for realism. As they open the shape on the screen, they begin checking with whatever experience they have with figure drawing. Practiced artists work unconsciously and effortlessly; less skilled designers work in fits and restarts. However, since they are not working with pen and paper, but within an environment mediated by the computer, changes come easier through manipulation of the screen. (Crowe, 1988; Sasowsky, 1984) Erasing is pure, and instantaneous, for example. Thus, frustration seldom intervenes. Depending upon the features of the animation program, and the student's familiarity with them, this mediated environment can be very satisfying indeed.

As the students animate a walking figure, they are challenged by experience of how human legs bend and move when walking. The artists must rely upon background knowledge for this information, and in order to create drawings of a figure in motion, may attempt several poses. Once again, the computer helpfully provides guides between frames of animation to ease the path and improve drawing skill. A few quick alterations, some cut and pastes, and the result is a fairly accurate rendition of a figure jogging across the screen. In doing all this, the young student is apt to project a great deal of human information onto the character. Having filled the figure of the runner entirely in red, the artist may see it as a "jogging suit." An impulse to decorate the figure's feet with hi-tech shoe designs may come next. The student becomes involved with the character, and seeks ways to make it more "real," more true to experience, by supplying details from a knowledge of the world.

Until this moment, the artists have been absorbed in a process in which consciousness is focused for the most part upon the "ready to hand" problems of the computer program, and the mouse (Winograd & Flores, 1986), and hand-eye coordination; next upon decisions involving size, color, and proportion. At the same time, they continually need to update their skills at manipulating the computer, looking for solutions to onscreen problems, sometimes drawing on experience, or more frequently, experimenting with the program to find effects they like. Once having created a successful figure, however, the artist moves into a different realm of consciousness.

Because experience tells the student that such figures require a backdrop of in-the-world objects with which to interact, they become engaged in an internal mental dialogue about this character. Where will this person be running, what will he pass, what will he see, who else might be in this world? Once again the students return to memory and experience, trying out conceptual backdrops for the character. Many of these backdrops however, are less than fully realized, appearing mentally as shadowy geometries, polygons that the artists will map onto the two dimensional animation in terms of houses, or trees. At the same time, they begin to analyze the character in terms of motion, and the requisite time requirements for a natural sequence of motion comes under consideration.

COMPUTER ANIMATION AS CONSTRUCTION

All of this thinking requires a continual construction and feedback process similar to that of other acts of creation, but due to the computer's speed, this process occurs at a far more rapid rate than artwork created with paper and pencil. It is for this reason that it is an ideal medium for young children's expression. It also eases the task of the researcher who wishes to observe student thought processes. In observing students in the process of creating a sequence on the computer, one is immediately struck by the back and forth, mind to hand, process of the artist. A student draws, reflects, erases, draws again, confers with a partner, and then continues the process. It is in this process that we see the elements of Piagetian structuralism: wholeness, transformation and self- regulation.

In order to understand how we may view computer animation as structuralist, it may be useful to begin with an actual example of student work. A student has been assigned to draw a sequence which demonstrates a knowledge of life in the Middle Ages. One seventh grade boy, rather typically, decides to show a castle under siege. He begins by creating the necessary geometries and colors which will represent the castle. Depending upon his background, knowledge of actual castle construction, and drawing skill, this can range anywhere from a grey box with turrets, to a model replete with drawbridge, portcullis, gatehouse. parapets, and keep. He then creates figures representing the besiegers. Again, background knowledge and skills determine the outcome of the success, but the process is typical of all students. Becoming more confident, he may add a drawing of a catapult, and if he has time, will actually animate the catapult, hurling a stone against the wall of his castle.

What is important here, is that however far the student progresses in his sequence, when he finishes there will be a wholeness to it, which cannot be segmented in any way, no matter how "far along" the artist has taken it. If only the castle is completed, it assumes the centerpiece role of his conception, and cannot be divided in any manner. If he adds the arrival of the invaders, the castle assumes the role of backdrop in a moment in time. If he causes the stone to hurtle towards the wall, the sequence requires the student to see his drawing in real life terms and to match his experience of the whole battle scene with his artistic impression of it. All of these completed steps must be viewed as a whole piece, with beginning, middle and end, or they are not satisfactory. One cannot divide the sequence, or penetrate its meaning in any form of analysis but holistic.

That animations are transformational seems, on the surface, apparent. The very term implies the giving of life to art, and the ability of the computer to suggest real time motion to the viewer is a significant development in human technology. (Wooley, 1992) But one must decide whether the animation sequence is transformational in Piaget's terms. Here. the researcher is assisted by the temporal nature of animation. The student is always asking, "What happens next" until a completed whole is achieved. When the stone strikes the wall, what will occur? Will it cause the wall to crumble, or will it bounce back, with comic effect? It is this dynamic element which allows the teacher to see the transformational thinking of the student, and to evaluate it.

The third criteria which Piaget proposes, that of self regulation, is also evident in the thinking of students working in the animation environment. There is a sense of closure to any given sequence, even when it is a part of a larger series of actions which will make up a final sequence, in the same way that a motion picture is only a series of individual shots and sequences edited into a whole, across time. In order to create such a sequence, the student must test, appraise, revise, and re-test until a sequence is completed. This, it would seem, places computer animation within the "immense class of structures which are not strictly logical or mathematical, that is, those transformations which unfold across time." (Piaget, 1967, p.13) Animations are strongly narrative. Many involve some degree of story telling, as the frog becomes a prince; others may simply describe the transformation of material objects, and the castle wall crumbles or the airplane crashes. In addition, there is available to the computer animator an entire class of effects, morphs and tweens, which are purely mathematical and are reversible. A petal may be transformed into a star, by requiring the computer to map all the geometries between the two shapes. Once again, the computer allows a vast array of feedback mechanisms beyond pen and pencil assignments, which allows students to construct meaning as they work.

It is evident that computer animation becomes a useful tool for the teacher analyzing student thinking from a structuralist point of view. In the computer lab, the teacher has an "over-the-shoulder" perspective of his entire class as their thought processes unfold on the screen. This is a perspective not available to the teacher who assigns only writing to the student. Even with well designed process writing, the teacher misses a great deal of the feedback steps with which a student constructs the paper, and with the advent of word processing students who edit as they go never demonstrate their thought processes to the teacher.

COMPUTER ANIMATION AS SEMIOTIC

Animation traditionally makes use of human signs and symbols to convey meaning. This has been true since the earliest animated motion pictures, and is often cited as the reason why Mickey Mouse has universal appeal. What is fascinating is to see how naturally young students working in animation make use of a range of signs to develop ideas on the computer screen. The green triangle on a brown post, for example, is easily interpreted as "evergreen tree" when it appears in the proper context. A more amorphous green shape above the post represents non-evergreen trees. Such constructs are found in other media, and are familiar to all teachers. But once again, the speed at which a computer can copy such shapes, allows students to maintain a running mental analysis in which they reflect upon their concept of "tree." It is important to remember that they are not necessarily improving any particular set of ideas surrounding real trees, unless the teacher is specifically assigning drawings in botany class, but are merely refining their knowledge of the signs for tree, and looking beyond the simplistic dualism of green cloud-like deciduous trees and green triangle evergreen trees. In learning to draw a tree, they may begin to describe branching and leaf systems of more complex tree shapes, which offer a more realistic version which is more satisfying. They will not discard the simpler signs they have begun with, but will maintain these in their repertoire for trees, and use them when occasion warrants. Even adult viewers will accept simple triangle pine trees in an animation of a skier on a mountain slope, and concentrate on the time-action realism of the essential animation elements.

Students, even youngsters, make use of these signs in creating animation, with a spontaneity which frequently surpasses their language skill. For example, in creating a fable set in the middle ages, two young seventh grade girls created a simple sequence entirely composed of recognizable signs, which conveyed the narrative structure without any recourse to language. In this sequence, a castle gate opens, the portcullis rises, the drawbridge drops. From within the castle, a red carpet appears, rolling out across the drawbridge. After a pause, a frog strolls out onto the bridge. That this frog is royalty in disguise is conveyed not only by the crown upon his head, but is actually predetermined by the red carpet, which demands that a dignitary of some sort appear. The frog meets a lady frog, and their joy is apparent, as they cavort around the moat for several laps. They return to the drawbridge, and, as hearts appear above their heads, they engage in a froglike kiss. Hearts appear above their heads, stars appear in the sky, and they are transformed into the necessary prince and princess.

This sequence demonstrates an ease of access to a vast array of signs, and facility in arranging these signs into a unifying whole. It makes use of common fable elements familiar to all school children, but is not limited by any single fable plot. (Thompson, 1989) It suggests an intuitive understanding of object and interpretant important in semiotics. Above all, it has as its primary intention the creation of meaning to be conveyed to the audience, and displays a self assurance that the meaning will be accessible to the viewer. While one should not leap to the conclusion that all thought is sign, or that the entire curriculum should be restructured around a semiotic agenda (Suhor,1984), when working with student-animators one clearly sees that the use of signs to make meaning is a skill common to most students.

REVIEW OF THE LITERATURE

SITUATED COGNITION

Unfortunately, because student drawn animation is new, little research on its effects upon student growth exists. Researchers have tended to investigate the effects upon students viewing animations rather than creating them. (Mayer & Anderson, 1991; Rieber, 1990) The results of these studies are equivocal at best, and lean towards the student mind-as-sponge model of instruction rather than more dynamic models. In studies comparing student understanding of the workings of the bicycle pump, Mayer and Anderson demonstrated that students who viewed animations learned no faster than control groups without the animations. Rieber found similar results with students learning Newtonian laws of motion. In these studies, however, students were asked to learn from animations which were created for them, rather than being asked to create animations demonstrating the concepts which the researchers wished them to attain. It is not particularly surprising that all passive learning systems tend towards equality in terms of concept attainment.

Human perception and knowledge acquisition, however, do seem to favor dynamic systems over static presentations. Michael Mills, researching the use of graphics with a Canadian on-line communication system concluded that "While static graphics schemes are useful, computer animated dynamic graphics -- showing transformations -- can be even more helpful for productive thinking and problem solving." (Mills, 1980, p.33) It should be noted that these researchers are looking for a medium for content delivery, and should recognize that such delivery is dependent upon the quality of the animation. A student will learn no better from a poorly drawn animation, than they would from a poorly written text. One must not search the literature hoping to find dramatic examples involving student learning from computer animations, but must instead piece together a case by applying other discoveries involving learning situations which are creative.

In searching for modes of instruction which foster cognitive growth, recent research has suggested that cognitive growth can be created in situations in which such growth is the essential outcome, and not a by-product of the lesson. Computer multimedia instruction is frequently cited as a vehicle for "situated cognition," involving graphics and language production simultaneously. Proponents of situated learning argue that it automatically creates an environment where thinking is a requirement, as opposed to more passive instructional modes. Animation, which offers the opportunity for creativity, while manipulating content and referring to experience, is an excellent tool for situated instruction.

The goal of the situated mode is to foster movement towards expert status on the part of the learner, rather like an apprentice embarking on the road to mastery of a craft, but with cognitive rather than physical skills. (Collins, 1988) The emphasis is upon real life situations, with problem solving inherent in the process. Students are involved in dynamic learning, with an emphasis not only upon surface meaning, but deep meaning as well (Merrill, 1990; Guey-Fa Chien, 1992).

STUDIES OF COGNITIVE GROWTH

Animation is an illusion created by an artist in which a series of pictures flashes in sequence before the viewer. If the pictures are drawn with enough similarity of background and continuity of movement in the principal characters, the viewer will receive the impression of realistic motion and action. Even a disjointed series of separate images can suggest a whole to the viewer, if the images are constructed around common thematic elements. To be successful, the animator must not only possess some drawing skill, but must also understand those dynamic elements which must be present for a viewer to understand the action. In order to be a successful computer animator the student must be able to bring together the following cognitive elements: drawing skill, an understanding of the workings of the computer program, a sense of action occurring across time, an awareness of the transformation of objects in a dynamic system, and a theory of mind that recognizes audience. This is a great deal to ask of a twelve year old, yet, given some instruction on use of the program, most students are quite comfortable assembling these elements successfully. At th- ame time, students in this age group are not always comfortable with all of these elements at once, and evidence signs of a transitional stage in their thinking.

In a recent study published in Child Development (Kosslyn et. al.,1990) , the researchers investigated the developmental nature of children's imagery abilities, looking at both image generation and image maintenance, two important skills for the computer animator. Reminding us at the outset the centrality of imagery in children's thinking process, this study used computer generated images to test imagery abilities across age levels, from five years to twenty-four years of age. The first series of tests measured response time to generated images, measuring both the time requirement and accuracy of subjects recognition. Subjects were asked to memorize upper case block letters drawn in grids; then asked to decide if any particular letter would cover x-marks on an empty grid. Time required to make this decision was assumed to measure imaging capabilities of the subjects. Subjects were tested with both simple and complex forms of the images.

The results demonstrated a decrease in time requirement with increasing age, with a significant jump from the five year old to the older age groups . In addition, there was predictable lengthening of time requirement for the processing of more complex images, in all age groups, although the youngest group did not show as much difference in their manipulation of simple and complex images. This, and the relatively difficult time the young children had with the task itself, led the researchers to discard the data from the five year old set. This allowed a cleaner set of data, and led them to conclude that there is "clear evidence for age differences in image generation." (p.1001) The data showed a significant jump between ages eight and fourteen, and a much smaller mean time gap between the fourteen year olds and the adults, suggesting a transition stage in pre-adolescence.

The researchers used a variation of this technique in their study of image maintenance. Subjects were asked to memorize a computer pattern generated on a grid. Once they had indicated that they had memorized the image, the grid was shown containing two x's. The subjects then responded to whether the x's fell within the area formerly occupied by the memorized pattern. "Heavy load" and "light load" trials were constructed by increasing the complexity of the image, the size of the grid, and the wait time before recall. In this experiment, the researchers concluded that the younger children were equally skilled at holding images as the older subjects, a very different finding from the image generation results. This result they assumed was the result of the role long term memory plays in image generation. They also concluded that different processes are involved in the generation of imagery, and image maintenance. Once again, a significant overall difference in time requirement did appear between the eight and fourteen year old subjects.

The researchers applied variations of this method in order to test image scanning and image rotation as well. These tests also supported the idea of a developmental curve in image processing. Scanning is slower in younger children, as is the ability to manipulate the rotated objects. In general, these results are consistent with the theories of Piaget. However, this set of data indicate the biggest jump is between the two youngest groups and the two oldest groups, whereas classic Piagetian theory predicts more significant differences between five and eight year old subjects then displayed in this study. (Kosslyn et. al., 1993) Most interesting were results with the eight year old group, which included an atypical gender difference in the image generation task. The researchers find it possible that these results reflect a transition to another kind of processing, but do not speculate further at this point.

In general, these results confirm the existence of important developmental stages in image processing for young students. It also postulates the intriguing theory that image processing requires a variety of subsystems which must all develop for successful generation, maintenance and manipulation of images. The idea of a transition stage appearing at age eight is highly suggestive.

A recent study at the University of Chicago (Goldwin-Meadow, Nusbaum, Garber, and Church, 1993) investigated learning strategies of students in transition, and the results of this study contain several important findings. This study looks first at research indicating that novices tend to work piecemeal, placing heavy demands on working memory. Experts chunk information into patterns which reduce the demands on working memory, suggesting a path from strategy following to pattern recognition. Goldwin-Meadow and her colleagues sought to trace this path in a group of fourth grade students (nine and ten year old), who were asked to solve math problems while simultaneously recalling a list of memorized words. Studies have previously indicated that learners in transition tend to utilize more than one solution in problem solving --a previous, well tested strategy, and a newer untested but potentially more useful strategy. When explaining their process, these learners frequently explain only one of these strategies, but convey through their gestures that a second strategy was employed as well. This mismatch was considered significant, and the researchers codified gestures for interpretation, as well as verbal explanations. The results indicated that transitions of this sort involve two different processes: "one process that serves to introduce a new strategy into the learner's repertoire...and a second process that serves to sort out the multiple strategies in the learner's repertoire and arrive at a single correct strategy characteristic of concept mastery." (Goldwyn-Meadow et.al., p.105)

The study supports the theories which indicate that learners moving towards mastery may be impelled to alter their strategies by supplanting unworkable solutions with more useful systems; or through the synthesis of two strategies, both of which, alone, are incorrect. It also indicates that transitional states are demanding, and apt to be short lived. Indeed the tendency would be for learners to regress to less correct but more stable states, unless input and feedback mechanisms are present to impel them to higher levels of understanding.

Studies such as these are critical for building an understanding of the thought processes involved in computer animation. Post-Piagetian thought indicates that cognitive processing may be developmental, but that it is plausible to expect some of the stages to develop in concert, rather than successively. This is particularly true where learners are coming to terms with open, dynamic systems, and where young people may be involved in analytical thinking about dynamic systems while still engaged with Piagetian formal operational thinking. (Chandler & Boutilier, 1992). There is a movement in such studies away from the equation of thought with logic, and the emergence of a theory of information processing.

In Chandler and Boutiler's study, subjects were studied by age group to determine at what level the mastery of an understanding of dynamic systems could be achieved. Beginning with students in grades three and five, continuing with a mid-range in grades seven and nine, and a third group of eleventh grade and post-secondary subjects, the researchers tested concrete, formal and dynamic system thinking processes for each group. The researchers reported that new cognitive events do not necessarily grow from formal operational thought, but may take some form of parallel development. The conclusion is that the understanding of dynamic systems may exhibit a complementarity with formal-operational reasoning, which may be lifelong.

While it may seem a leap from the understanding of thermodynamic systems to the operation of computers, this study seems important for those of us watching youngsters grapple with the dynamics of complex computer programs, where the very tool they seek to use is a dynamic system which must be internalized before any important work can be accomplished. If, in fact, the understanding of dynamic systems such as computer animation requires the passage through the formal-operational stage of development, there would be little point in teaching young students with more than simple drill and practice programs. Though research is still scant, the growing evidence is that very young students can operate dynamic computer programs quite successfully, which would bear out the conclusion that parallel lines of development occur in understanding dynamic systems.

There is a balancing act occurring when a group of seventh graders create computer animation. They are undoubtedly in a developmental transition stage, possibly in several such stages, involving transitioning from novice to expert in computer operation, from static to dynamic image conceptualization, from concrete to formal operational thinking, from the understanding of static systems to the exploration of dynamic systems. What keeps this balancing act stable is a canon of signs and symbols, and the power of narrative form. The measurement of their success as animators, and their growth as thinkers will be the extent to which they can keep all these transitional states in equilibrium. Proper balance will yield the equilibration which produces new structures; discordance and discomfort will produce no growth or regression. With all this in mind, it should be possible to observe a group of students in the computer lab, and determine the areas in which the students show signs of transition, and the areas which show stability. This, in turn, should provide data whereby we can observe cognitive processes.

METHOD

These questions were approached through an ethnographic method in which the researcher is at once participant and observer. The classroom is a human society, a very special organization, existing in the larger organizational structure of the school. In a small middle school like the one involved in this study, the informational loop is highly inclusive. Kids talk to each other in class and out; and one of their favorite topics is what they are doing each day. It would be impossible to keep the subjects from discussing the study as it progressed. Indeed, when the first group of students left the classroom, the incoming students first question was "Will we be doing the leader story too?" This is actually all to the good. If meaning is constructed out of a social process, then promoting the process can do no harm, and the degree to which this process occurs may actually come to light during the study.

The approach, of course, has the usual defects, the most obvious being that the teacher and researcher are one in the same. The teacher role, after all, is to help students solve problems encountered in the course of their work. For him to continue that role while observing strategies for problem solving, may at first seem odd. However, the teacher cannot be everywhere at once, and most problems are solved independently of him. In addition, most problems solved by the teacher in the computer lab are technical, involving the running of the equipment, such as how to save files. Few of these problems involve cognition as it is being defined in this study.

In order to assist the teacher-researcher, tape recordings and video tapes were made of students at work, in order to supplement his own observational skills. While this equipment added a new distraction for the students, the novelty quickly wore off, and the tapes yielded valuable data for later assessment. In addition, selected students were interviewed in order to discover their perception of the processes involved.

POPULATION

The study looked at two intact seventh grade language arts classes at a suburban middle school. These two groups were experienced in computer animation, having made a trip to the school lab to complete animation assignments on an average of once a week for six months. In a questionnaire administered prior to beginning the study, both groups described themselves as comfortable with computers in general, most of the students having experience dating back at least four years. Students reported that they enjoyed computer animation and most rated themselves as fair to good in animation skill.

Group A: Group A consisted of thirty one students in a heterogeneously mixed population. Of the thirty one in the class, eleven are identified by the school as Chapter One in either mathematics or language skills, scoring below the 35th percentile in either of these areas on the previous year's California Test of Basic Skills. One student participates in the school resource program for students with identified cognitive problems. Two students are identified by the school as "at risk" for poor behavior and low academic performance. The students are generally a lively group of learners, cheerful and energetic. They tend to be extremely social, talkative and interactive in a variety of ways. For some students, this tendency to socialize interferes with their ability to focus on a given assignment. Such "background" interference can occur at any time in the course of a class period, and much of the teacher's time is occupied in steering students back on task. In extreme cases, students may be removed from the classroom for the duration of the period.

Group B: Group B consisted of twenty nine students in a homogeneously grouped class, including eleven students identified by test scores as "Gifted and Talented." The group is generally concerned about academic success, and tends to be highly competitive. Many of the students have been together as a select group since fourth grade, and tend to think of themselves as an elite. As with group A, the students are energetic, active learners. They too are extremely social. Unlike Group A, however, the students tend to be able to compartmentalize their social problems while working on a given task, and not allow themselves to be distracted. When social problems do occur in the class, a few words from the teacher usually corrects the problem It is rare that a student in removed from the group, although occasionally a student will ask to see a counselor if a social need is pressing. For this reason, the teacher is able to spend less time in directing behavior, and more time in problem solving with students.

SETTING

The study was conducted during the normal class schedule. Students met in the language arts classroom to receive their assignment and discuss it. Trips to the computer lab were then arranged so that the students could complete their animations. For the purposes of the study, the number of trips to the lab was increased from two in a two week period to five.

The classroom is arranged with two blocks of desks, divided so that the groups are facing each other. This arrangement promotes interaction between the students. The teacher directs the class from a position near the "front" by the white board while giving assignments, but is generally moving around the room thereafter.

The computer lab is self contained, and available to all teachers on a weekly sign-up basis. The hardware consists of twenty PC workstations, in a mixture of Intel 286 and 386 configurations. All twenty workstations are loaded with the animator program from "Multimedia Explorer" by Autodesk. While generally reliable, the hardware and software suffer occasional malfunctions, and student work is lost. Such glitches, however, are not sufficient to disrupt a given project, and are accepted by teachers and students as "part of the game." The computers are arranged in an open "U", and all screens are visible to all students. Talking is allowed during computer sessions, and the atmosphere is relaxed and social. During the sessions, the background noise level may fluctuate from quiet working tones to lively student chatter. When the tone becomes discordant, the teacher will ask for a more business-like demeanor. If the students are not responsive, he may then reprimand the group, or lecture individuals to restore the mood. Deliberately disruptive or defiant behavior is discouraged and students are expected to be on task.

The lab is open to visitors, and because computer animation is still somewhat unique in the curriculum, there are apt to be other adults in the room besides the instructor. Usually these visitors are other teachers, interested in viewing the proceedings with an eye towards adapting the method for their own classroom. Not infrequently, other visitors to the school will be invited to observe a class at work in the lab. This occurred on day three of this study, when three separate delegations watched Group A at work. Such visits afford the students an extra opportunity to talk about their work with adults other than the teacher.

PROCEDURE

The exercise selected for the students was an assignment in interpretation. The students were first given a short questionnaire which discussed their computer background, and their experience with computer animation. At this time, they were told that the next computer assignment they were to attempt would be studied by their teacher as part of his master's research . A short discussion on the novelty of computer animation in the classroom took place, and the students were told that the purpose was partially to ascertain whether animations could be substituted for essays in the language arts class. The lesson was then introduced.

The teacher told the students that they would next begin a unit in poetry, and that much of their work would involve interpretation. The students were invited to offer a definition of the word "interpretation." When several acceptable definitions were forthcoming, the teacher listed them on the board and commented upon them.

The students next were given an assignment sheet titled "Animation Problem One." This sheet contained the following prompt:

> A leader is faced with great danger. He seeks the advice of the wisest person in the land and receives the following advice: "Courage and love will solve your problem."

The teacher then directed the class to begin to imagine how they would interpret this scenario in animation. They were given seven minutes to complete the following questions:

1. How would you imagine the leader?
2. What do you think is the danger?
3. What can the leader do to solve the situation?

Students then were invited to share their ideas with a partner. After a short five minute discussion, the students were directed to complete a fourth question: "What new ideas did your partner have?"

The next step involved storyboarding the animations. Each student was given thirty minutes to complete a short sketch of the stages for his or her animations. Students were allowed to work with partners if they desired, and several exercised this option.

Both groups were given identical prompts. In Group A, however, a student objected that the wording was "sexist" and so gender bias was relaxed regarding the role of the leader. Once students had completed work on their storyboards, the teacher asked to have the worksheets handed in. From these worksheets, three scenarios from each group were selected at random and the authors interviewed. The students were asked to explain their proposed sequences . In addition they were quizzed as to the viability of completing their scenarios in the scheduled lab time.

Four lab sessions were scheduled, alternating Tuesday and Thursday afternoon sessions over a two week period. This was later amended to five sessions at the request of the school principal, in order to accommodate visitors. Thus, a Friday morning session was added to the schedule. Lab times were normal fifty minute class periods. Students were given individual new data disks, and asked to save each day's session under a separate file name -- "Day1," Day2" etc. to show each session's progress. A small battery tape recorder and the school video camera were introduced into the setting. These were used to record dialogue between working partners, or to observe decision making processes as evinced by the students manipulation of the program.

All data disks were collected and reviewed by the teacher at the end of each session. Hardware problems were corrected as they arose. The teaching-learning exchange between students and teacher continued in " a normal fashion" despite the fact that all involved were aware there was a study going on.

RESULTS

It should first be noted that both populations were extremely computer literate, most having worked with computers in school for at least four years. Several students had been allowed to work with the family computer since age four. All reported enjoying computer animation, although most rated themselves as only fair to good in skill level. The fact that it might be unusual for seventh graders to be working in this medium did not strike them as impressive, although they were vaguely aware that not every school uses computer graphics for classroom assignments. Many expressed a preference for graphics for self expression, as opposed to words, and the remainder rated the two media as equal in preference.

This may account for their interest in completing the assignment. It does not, however, account for the ease with which they translated the simple mythical prompt into a fully developed narrative scenario. The students immediately generated a character who could fulfill the central role of leader, and after a short discussion were able to fit this character into a plot involving a wise person and some sort of dire emergency. There was very little duplication of theme or setting and no duplication of plot; that is, while several stories were set in the Middle Ages, the casts of characters varied widely, and the central problem -- whether dragon, sleeping beauty, or evil sorceror was always unique. All were able to assemble the elements of Kenneth Burkes "pentad" of an Actor, an Action, a Goal, a Scene and an Instrument -- plus Trouble. (Bruner, 1990) While several of the narratives were derivative in some fashion, none were out and out plagiaristic. Students frequently made use of well worn plots: the daughter who would marry the jester; the dragon besieging the castle; but did not recreate a scene from "Robin Hood, " or attempt to draw the "Wizard of Oz."

In interviews, students were quite at ease in discussing how they would tell their story. These discussions always began with the leader, a description of who he or she might be, and then proceeded to the trouble he found himself in. The students were quite comfortable with the phrase "courage and love" as appropriate advice for any particular dilemma, whether it be the threatened nuclear power plant, the unhappy princess, the blackmailed president, or the invading army. The following is typical of the oral descriptions of the narrative design:

> There's a king and he has a brown hair and a beard, and he's kinda fat; and he's got a daughter that wants to marry the court jester: and the king 's ah, afraid that like, all the other kings in the area are going to make fun of him and he doesn't want his daughter to be unhappy -- because it's the joker you know? And so um he's going to make the joker go and find a dragon, and bring him back to prove he has courage and if he can do it then the daughter can marry the fool guy and then um, and that's it.

This plot may be contrasted with the following oral report:

> This is all about a leader and he's taking some hikers through some, like, mountains, maybe the Himalayas or something, and they have to get across the mountain, and the problem is they come to an abominable snowman and it's more like King Kong, and they have to get past it. And they have to solve the problem by, instead of being like, forceful you know, with guns and everything, he has to be gentle. And he's trying and he has to have the courage because in past experiences the monster's eaten his other people. And what I was going to do, I was going to have first scene, them walking up the mountain hiking, and then the second scene they're coming to the lair, and the third scene they're inside the lair and you see the monster and everything, and the fourth scene he thinks about what the wiser man told him and then, you know, he thinks about it, and the way to get the monster and he talks to the monster and tries to calm it and everything in the fifth scene, and in the sixth scene, they leave, and in a future time - you know -- he doesn't harm them but he may harm others. And that's pretty much it.

All of these narratives were whole structures by the end of the the class period in which the lesson was assigned. No one objected that there was not enough time to complete the assignment. No one complained that they "couldn't think of an ending." In the short random interviews, all students expressed confidence that they could complete an animation of their idea in the four class periods originally scheduled. It is important to emphasize how comfortable the entry into the assignment was for the students. The creation of a text from which to work was accomplished by every student. All seemed to be well stocked with a variety of tales, waiting for the prompt to bring them forth. A student who missed the original assignment asked for a briefing in the computer lab the next day, so that she could catch up. After a look at the handout she said, "Oh you want us to tell this story? I get it." She then went immediately to the computer and began creating a cast of characters for a plot involving a gang leader, racial tension, etc. The ability to think in narrative form did not appear as a problem.

Translating these complex narratives into animations, however, in the short time frame allowed, did pose problems. By the end of the first session many students were worried about "not getting done." Others had already settled upon a reductionist strategy where a part of their scenario, the leader on horseback entering a castle, for example, could stand for the whole. Students with a strong literal interpretation of the myth were quite concerned, as were students involved in detailed background drawing. These concerns were most strongly voiced among students whose animation technique did not extend to sophisticated control of the program itself. Artists who tried to force their stories through dozens of single frame pictures were more concerned about finishing then students who finished their sequences in chunks, for later assembly. Students who understood the basic relationship between an animation "cel" and a background were also less concerned about time, even when they recognized that the time allowed was insufficient to finish. These students seemed confident that having assembled all the requisite elements of their stories, they could finish at another date, if they were allowed.

Three distinct strategies evolved in the creation of the animations: reductionist, literal, and transformational. The reductionist strategies involved creating a scene from the narrative which could be representative of the whole. In these sequences, the artists focused upon the introduction of character, a knight on horseback, a princess tumbling down stairs, a young black girl asleep in her bed, and so on. Several of these sequences were well drawn and showed control of the animation program. Others were more childlike in execution and involved static scenes without motion. Many of the reductionist sequences involved partners at the computer. This might suggest that the time involved to negotiate with partners slowed the drawing process. It might also suggest that the continual rehearsal of the narration with a partner made completion of the whole for a new audience less compelling.

Other reductionist strategies consisted of stripping the plot to a single action sequence, such as a castle siege, or a stabbing scene. These scenes made use of strong animation technique, even when abandoning the leader-trouble- courage and love myth. These students however, always had a ready response as to how their sequence fit the required scenario, when quizzed by the teacher, and referred to scenes left undrawn which would, if assembled, complete the whole assignment. These students were unconcerned with the time element, and asked only to be left alone to work on technique. Some who were concerned about possible teacher evaluation added one or more of the mythic elements to their action, to satisfy the requirement, but these additions were not the focal point of their work.

Students with a strong literal interpretation created scenarios which followed a tightly constructed "beginning to end" strategy, in which the leader was introduced, the trouble arrived, the wise person was sought, the trouble confronted, and so on. Most of these students worked in an extreme linear fashion, adding black frames to the end of completed work for additional drawing space, rather than saving scenes for later assembly. Frequently, these artists introduced text elements to further their story telling, including writing dialogue on the screen or scrolling plot summaries between visual scenes. These artists were quite concerned with finishing, asking if they would be allowed to return to the animation "when the study was done." Animation technique varied in this group, with many students falling back on words when graphics elements were too difficult to assemble. In telling the story, many of these dramas lacked interaction or transformational elements: the leader appeared, heard the advice, and won the day without apparent causal links between the advice and the solution.

A third group of interpretations made use of transformational elements in the creation of their stories. By far the most complex, these animations wove graphic elements, characters, plot devices, symbols, and text cues into satisying wholes which demonstrated an understanding of complex problems and solutions on the part of the artists. These artists were most concerned with using the courage and love advice to solve the problem, and created scenarios in which the leader gained an understanding which enabled him to act. Compromise frequently played a role in these scenarios, and agreement between hostile forces figured in the denouement. Many of these animations were assembled from separately created scenes, and made e of cels and backgrounds that were created independently. In assembling the scenes the artists used transition effects -- fades and wipes - in a cinematic fashion, for dramatic effect. In addition to understanding time elements, these artists utilized symbols for story telling, and allowed simple semiotic devices to stand in for more elaborate animation. The storytelling strategies used in these animations were at once sophisticated and simplified in order to save drawing time. As a result, these animations progressed at a much more rapid pace, and one group of artists offered to alter their plot if it were important to finish on time. Interplay between forces, human and natural were common thematic elements in these scenarios.

ANALYSIS OF DATA: TRANSACTION

Several students in each group chose to work as partners. This is common in computer lab settings, where the ratio of students to work stations is not one to one. In this particular study such partnerships were helpful in analyzing the processes involved in creation of animations. Several of the partnerships were tape recorded. It was discovered that the partners engaged in a continual dialogue involving negotiation and problem solving, as they sought to create a scene which would be satisfactory to both partners. This constant negotiation belied the usual model of the "cooperative group" in which a harmonious interchange of ideas is thought to take place. As revealed by tape recorded conversations, even the friendliest of pairs haggled over decisions involving everything from choice of backdrop color to animation technique. In the following example, two young ladies discuss how to create their scene:

S:First we draw -- oh, easy, easy.

J: I know but --

S: First we draw a knight and he's riding to the war...

J: The War?

S: Well wherever he's riding.

J: Where he's going to fight a battle next-

S: Yeah, and the next morning he's going to be fighting --

J: Yeah over the girl but shouldn't the girl--

S: No, the girl is like a -- no, it's like the girl is totally against --

S: You get your frames after you have your thing so its all through --

J: All right. Fry it. F-R- Y. I get frames first? I get grey?

S: Yeah. You get grey.

J: That one right there? Yeah.

S: Yeah. Fill it. No.

J: I want to get it darker.

S: No-o-o. There's like navy, and grey ya know.

J: Ok Ok Ok Ok.

These transactional dialogues occurred wherever there were partners. Most of the tone alternated between serious working tones and a friendly banter involving critical support of the partnership. This dialogue was constant, with one partner working quickly with the mouse while the other checked and double checked each move. While never acrimonious, the exchanges always kept a high level of tension as both girls competed to get their ideas represented in the scene. These were not petty points, such as the color of costumes or the types of background objects to use, but deep arguments over mood and meaning. Generally the myth was left unstated but these discussions obviously grew from their mutual understanding of the text. Social concerns continued to be addressed as well.

S: Go and see if there's another color.

J: I like that one.

S: Just -- shut up. Do this one.

J: That one. No that one's going to be --no let's see-- too late --

S: Do that so we can see in the little window.

J: No I like mine better.

S: Oh choose this one, this one's misty...

J: This one's better cause it's dark...

S: Do you want to do, like, uh like one layer of fog...Yes.

J: No.

S: Yes.

J: No.

S: Yes!

J: Ok Ok Ok Ok.

The dialogue serves to further the development of their plot, while at the same time tracking the animation program and solving problems with it. This continual transaction involves thought that is at once imaginative and heuristic.

S: It's misty...romantic... misty... Oh never mind cause then it's going to be a war...

J: Yeh, then it's morning.

S: Look what you did. (Laughs)

J: Oh.

S: Fill over it. Yes.

J: OK. Should I draw the castle?

S: No see it's -- after the castle ,we'll show --

J: Yeh . OK. Now go to frames?

S: Yeh . Do you want to make fifteen frames?

J: Fifty? Fifteen?

S: Do you want to make fifteen frames, -- yeh that's it --Make fifteen frames going into the castle, cause I mean when it's running you know --

J: Do you want to go in there?

S: When you go in there you make new frames.

J: How many should I get?

S: We'll have to change the background. I think.

J: Yeh, well we can change the place. We could just make them all this and then we could change

S: Yeh. Oh, um fifteen. But I think it'll take less.

J: Oh, um...

S: It'll take less --To get in...

J: Well here its -- we could take away frames.

S: That's true. OK.

J: Should I draw little stars?

Other dialogues caught this same flavor of transaction between partners as they worked through the process of creation. Different strategies of control were adopted, as well, with some partners taking turns drawing, while others chose to specialize, with one artist using the mouse and one "co-pilot" who tracked the needs of the program and suggested material for the artist to draw. Another example, again between girls, should suffice to capture the spirit of these exchanges:

C: OK, make the cape.

L: I don't know how to make a cape!

C: Well like...

L: He'll ride 'em cowboy! (laughs)

C: That looks good. Yes!

L: My god... it looks like a backpack.

C: No..

L: It looks like a backpack!

C: No, it doesn't.

L: It's not Eddie Bauer. Period.

C: I don't care.He needs food ya know.

L: I don't know. Want me to fill it?

C: No. A little more. Good job.

L: Ok, what about...

C: What did you do -- Did you use zoom?

L: That looks really lame.

C: No, it looks fresh, it looks totally...

L: It does not look good. Fry it.

C: (Unintelligable.)

L: My god.

C: That looks so cool.

L:That does not look like a cape.

C: It does. It 'll be blowing in the wind. He'll be standing --- nice and tall...

L: Good. OK. Uh oh.

C: Chest stuck out...

L: OK . Good. Oh!

C: Saying " I am the mighty warrior."

L: Oh! Oh! Oooh!

C: I didn't mean to be sick.

L: Is that your fantasy?

C: Shut up. (Laughs.)

(Unintelligible)

L: OK. We need to save...

C: Jesse got braces again.

L: What?

C: Jesse got braces again.

L: She didn't have' em last year did she?

C: She had 'em in like --elementary school.

L: OK. Day what?

C: Day Four.

It should be noted that exchanges between boys did not differ significantly in either tone or content from those of the girls. "Getting it right," i.e realism, competed with computer problems and semiotic content as partners worked out agreements in strategies.

ANALYSIS OF DATA: HEURISTICS

The tape recordings of partnerships revealed a constant negotiation, one involving both the creation of meaning and the solution of problems, but it was not always necessary to listen to student explanations or eavesdrop on conversation to observe cognitive processing. In analyzing video tapes of individuals working alone on the computer, this same combination of imagination and heuristic was observed. One young man in the process of creating an elaborate adventure, involving a hero, a dam, an earthquake, and a nuclear power plant could be observed creating an effect that would convey the earthquake to the viewer. In order to create the effect, he attempted several methods of offsetting the screen image so that his landscape would appear to shake. This required three different attempts before finding the one which appeared the most "realistic" to him. This he adjusted before finally rendering a pass that he wished to keep. After a playback or two, he turned to his neighbor, and was heard to ask, "John, does this look like an earthquake to you?" Receiving an affirmative reply, he saved his section, then turned to the problem of moving his character down the hill, and away from a cascade of water.

While creating the animations, the students were observed to be continually working at several levels of simultaneous decision making and problem solving. Simple decisions of color choice, or backdrop setting were balanced against difficult problems involving animation effects and plot development. Where motion was chosen to further story elements, various levels of sophistication could be observed in student understanding of time elements. Some used time to further the dramatic effect, with an airplane leaving just ahead of a wall of water or a monster creeping up on unsuspecting explorers. Others showed less dramatic understanding, but still manipulated characters from scene to scene in a convincing fashion. A third group showed no awareness of time elements, frequently avoiding the use of motion, or creating simultaneous events on the screen that would be impossible in the real world, but were not contradictory to the artists. One pair of girls complained that an adult had criticized their scene because "the drawbridge hit the horse on the head." In adult perspective, of course, the simultaneous arrival of horse and drawbridge at the same spot would signify a collision. But the girls did not perceive any contradiction in the simultaneous occupation of the same location in space and time by two different objects. In another scenario, an Indian chief travels to seek the wise man for advice. On his journey the sun passes overhead from left to right, and day changes to night. On his return, the sun also makes a return trip, from right to left, literally returning to the place from which it had issued. This anomalous cosmology was completely ignored by the artists rendering the scene, and their neighbors who watched it.

In observing the wide range of activity in this project, one particular problem seems worthy of attention. In a few cases, some students with simple perspective perception had greater difficulty working with the animation program then other students, including those students who also were limited to flat, two dimensional perspective. These were students who drew their initial scene from a top view perspective, with, for example, a character in bed. Once this scene was created, the artists were unable to progress, even after saving this scene and creating a character for the role of leader on another screen. Invariably , the combination of a cel in profile, and a top view background set up a perspectival dilemma that the animators could not solve. Because the program is most easily manipulated from a single perspective, the animators in this group remained in limbo, unable to advance their plots. Other artists solved this problem by sequencing scenes, so that their animation contained more than one perspective, even if the drawings lacked depth. But the former group seemed unable to arrive at this solution, finally pasting the profile figures into the top view floor plan despite the contradiction in perspective. These students made no attempt to manipulate the cel across time or to indicate any action.

ANALYSIS OF DATA: SEMIOTICS

As expected, student manipulation of imagery to convey meaning was clever and apt. Symbols were frequently utilized in appropriate situations, either for identification or interpretation depending upon the demands of the action. Although students would not be expected to understand Peirce's distinction between icon, index and symbol (Bruner, 1990) the cross section of data disks reveals frequent representations of each, in carefully thought out situations. Many of the more complex story lines make use of all three, and a few reveal thinking in terms of entire symbol systems. An example from one sequence may serve to demonstrate how convincingly these young artists can use their symbol vocabulary:

In this sequence, the President of the United States is informed in a letter that in order to avoid a war, he must bomb the country of "Taxco." The decision he must make is complicated by the fact that his beloved daughter lives in Taxco. Unable to decide, he retires to his bed "to sleep on it." As he sleeps in his ornate bedroom, beside a framed picture of his daughter, a series of dream images appears above his head, including the letter, a map of the nation, the photograph of his daughter and at last, a hooded figure who gives him the "Courage and Love" advice. This short series of frames poses the entire problem for the viewer, without recourse to lengthy textual additions, and gives new meaning to the stock "Courage and Love" phrase by confronting the President with a dilemma between love of country and love of family. The character of the daughter is introduced in the bedside photograph, recurs in the dream, and at last appears in the finale amid the rubble of bombed out Taxco, alive and well, justifying the brave

President's decision. This manipulation of the symbol penetates deeply into an understanding of its purpose, and its ability to convey meaning to an audience. Most remarkable is the fact that the symbol was not an outgrowth of an involved design process, but appeared "on the fly" as the students negotiated their story. Other useful images -- the president's desk, his bookcase, the furnishings of his bedroom, a soldier's cemetery -- were also "discovered" during the process, recalling Peirce's principle of "abduction. "

CONCLUSIONS

There are several points which this study brings to light. The first of these is the manner in which computer animation stimulates young students to develop narrations without recourse to text, working instead from a canon of semiotic structures. Next, the role of the animation program in simultaneously developing both imagination and problem solving skills needs a more intensive study, pointing as it does to the cognitive processing of the student in transition. Finally, the problems encountered by students with poorly developed perceptual and sequencing skills in manipulating the program demonstrates possible areas of inquiry for researchers wishing to understand human interactions with dynamic computer programs.

In analyzing the work of these student animators, one is impressed with their apprehension of a text, the rapid assimilation of a simple mythical scenario into material for deeper meaning making. Interpretation was no problem for these students; rather, they were prepared with dozens of interpretations. Even the most reductionist sequences grew from the courage-love ideal which the myth required, and demonstrated a sense of narrative. This ability to assemble a narrative interpretation was most evident in the more accomplished efforts, among students who could manipulate the program, draw well with a mouse, and were able to structure their work into logical chunks for assembly, but all students seemed able to develop and maintain the logic of a complete story structure. This was ascertained in interviews with some of the less accomplished artists, who all had ready explanations for how their sequence fit the demands of the larger pattern.

This mastery of narrative freed the students for work on technical problems with the computer animation. The majority of student questions involved complex movements requiring technical knowledge , how to flip a cel, for example, rather than questions involving story line or content. At the same time, the strength of the mental image of the story line provided the students with a sense of direction , a "what to do next" that kept them on task and moving from problem to problem. This may account for the ease with which most students learn the animation program. This sense of direction only failed among students with demonstrable problems in both perspective and sequencing, who had difficulty in manipulating the program in concert with their mental image of the action.

The animation program provides a unique environment for the development of cognitive skill. At once imaginative and heuristic, this environment appeals to the student's delight with action, all the while providing immediate feedback which allows the artist to advance through a series of problem solving levels, each requiring more elegant solutions. This environment, situated in the active, social realm of a middle school computer lab appeals to the child's innate ability to create narrative structures, and offers new methods for student explication of texts, in an image rich world beyond print.

SOURCES

Bruner, Jerome. (1990). Acts of meaning. Camb idge, MA: Harvard University Press.

Bruner, Jerome. (1986). Actual minds, possible worlds. Cambridge, MA: Harvard University Press.

Chandler, Michael and Boutilier, Robert. (1992). The developmem of dynamic system reasoning. *Human Development*. 35. 121-37.

Chomsky, Noam. (1976). Language and mind. San Diego: Harcourt. Brace, Jovanovich.

Collins, Allan. (1988). Cognitive apprenticeship and instructional technology. Cambridge, MA: BBN Labs, Inc.

Crowe, Bruce. A. (1988). Computers in the secondary artcurriculum: painting a picture of effective teaching. Lexington: Mid-South Educational Research Associaction.

Deely, John. (1990). Basics of semiotics . Bloomington and Indianapolis: Indiana University Press

Guey-Fa Chien. (1992, August) . Situated learning, metaphors, and computer-based learning environments. *Educational Technology*. p. 12

Gardner, Howard. (1979, July). Encounter at Royaumont. *Psychology Today*. p. 14

Gardner, Howard. (1973). The quest for mind. New York: Alfred Knopf.

Goldwin-Meadow, Susan, Nusbaum, Howard, Garber, Philip, and Church, R. Breckenridge. (1993). Transitions in learning : evidence for simultaneously activated strategies *Journal of Experimental Psychology*. 1. 92-107.

Hoopes, James. (ed.) . (1991) . Peirce on signs. Chapel Hill: University of North Carolina Press.

Kosslyn, Stephen, Margolis, Jonathon, Barret, Anna, Goldknopf, Emily, and Daly, Philip. (1990). Age differences in imagery abilities. *Child Development*. 65. 995-1010.

Mayer, Richard E. and Anderson, Richard B. (1991). Animations need narrations: an experimental test of a dual-coding hypothesis. *Journal of Educational Psychology.* 84. (3) . 484-90.

Merrill, M. David. (1990, Dec.) . IDZ and constructivist theory. *Educational Technology.* 30 . 22-30.

Mills, Michael. (1980). A study of the human response to pictorial representations on Telidon. Montreal University: Telidon Research no. 3.

Mussen, Paul. (ed.). (1970). Manual of child psycholgy. Third Edition. New York: John Wiley & Sons.

Piaget, Jean. (1967). Structuralism. NewYork: Basic Books.

Piattelli-Palmerini, Massimo. (ed.) . (1980) . Language and learning: the debate between Jean Piaget and Noam Chomsky. Cambridge, MA: Harvard University Press.

Rieber, Lloyd. (1990). Animation in computer based instruction. *Educational Technology.* 38. 77-86.

Sasowsky, A. B. (1989). The computer and the art teacher. *School Arts.*

Sebeok, Thomas A. (1991) . Semiotics in the United States. Bloomington and Indianapolis: Indiana University Press.

Suhor, Charles. (1991). Semiotics and the English Language Arts. Bloomington: ERIC Clearinghouse on Reading and Communication Skills.

Suhor, Charles. (1984 , July). Towards a semiotics based curriculum. *Journal of Curriculum Studies.* 16. (3). 247-57.

Thompson, William Irwin. (1989). Imaginary landscape: making worlds of myth and science. New York: St. Martin's Press.

Winograd, Terry and Flores, Fernando. (1986). Understanding computers and cognition. Reading, MA: Addison- Wesley.

Wooley, Benjamin. (1992). Virtual worlds. Oxford: Blackwell.