DOCUMENT RESUME

ED 242 626 SO 015 533

AUTHOR	Linn, Marcia C.
TITLE	Fostering Equitable Consequences from Computer Learning Environments.
INSTITUTION	California Univ., Berkeley. Lawrence Hall of Science.
SPONS AGENCY	National Inst. of Education (ED), Washington, DC.
PUB DATE	Nov 83
GRANT	400-83-0017
NOTE	33p.; Paper presented at the Annual Midyear Conference of the American Educational Research Association Research on Women and Education Special Interest Group (9th, Tempe, AZ, November 3-5, 1983).
PUB TYPE	Viewpoints (120) -- Speeches/Conference Papers (150)
EDRS PRICE	MF01/PC02 Plus Postage.
DESCRIPTORS	Basic Skills; Cognitive Development; *Cognitive Processes; Computer Assisted Instruction; *Computer Literacy; Computer Oriented Programs; *Computer Science Education; Educational Needs; Educational Opportunities; Educational Practices; Educational Research; Elementary Secondary Education; *Equal Education; Females; Higher Education; Males; Outcomes of Education; *Sex Differences; *Sex Fairness; Skill Development

ABSTRACT

The article discusses two interrelated aspects of computer education: the computer's potential for developing cognitive skills and ways in which the differential participation of males and females in computer experiences may lead to inequitable outcomes. The Assessing the Cognitive Consequences of Computer Environments for Learning Project (ACCCEL) has identified several aspects of computer environments which make it particularly cognitively demanding: the interactive, complex, and challenging nature of the environment; the precise feedback of information; and the possibility for multiple solutions. In addition, higher cognitive skills can be fostered by certain types of educational software and commercial computer games which lend themselves to student adaptation and creativity. However, a gap exists between this educational promise of computers and the reality of their use in the classroom. A number of factors may account for this gap, among them teachers' lack of awareness of computers' potential for fostering cognitive skills, lack of appropriate curriculum materials, and the restriction of computers to programming and logic courses. This gap in turn contributes to the potential for inequitable outcomes. Females are poorly represented in computer courses in high schools and colleges, a fact which is attributed to both content and process of computer instruction. Equitable outcomes will be enhanced if teachers tailor instruction to the needs of the learner, guiding exploration of the computer for female students. (LP)

ED242626

Fostering Equitable Consequences from Computer Learning Environments

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This material is based upon research supported by the National Institute of Education under Grant No. 400-83-0017. Any opinions, findings, and conclusions or recommendations expressed in this publication are those of the author and do not necessarily reflect the views of the National Institute of Education.

Special thanks are due to Nick Burbules, Charles Fisher, Ellen Mandinach and other members of the ACCCEL staff for helpful discussions of these issues.

To appear in Sex Roles, special issue edited by Marlaine Lockheed on "Equity in Computer Education," 1984.

SE 015 533

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Marcia C. Linn

Computers play an increasingly central role in our society. Lack of proficiency in using computers and lack of knowledge about their capabilities can be a barrier to participation in many technologically rich fields as well as for securing jobs in many intellectually and financially rewarding careers. Computer learning environments also have the potential for enhancing many types of cognitive skills that are rarely encountered in other learning situations.

The well-documented differential participation of males and females in computer learning environments could lead to corresponding differences in cognitive attainments and career access. In order to reverse this potential trend the quality of computer education must be improved, especially to ensure that learning environments are tailored to differences among individuals. Most immediately, steps must be taken to ensure equitable participation of males and females in these environments.

This article describes the ways in which computer environments for learning have the potential for fostering cognitive skills for all students. It also characterizes the gap between the potential of computers in education and the reality of their use in classrooms, documents differential participation of males and females in computer

experiences, describes two studies of how males and females respond to computer learning environments, and suggests future actions to foster equitable outcomes from computer learning environments.

Potential of Computer Learning Environments for Fostering Cognitive Skill

The Assessing the Cognitive Consequences of Computer Environments for Learning (ACCCEL) project jointly conducted by the Lawrence Hall of Science at the University of California at Berkeley and the Far West Laboratory in San Francisco is examining the potential of computer environments for fostering cognitive understanding. This National Institute of Education funded project has begun to identify the specific features of the computer learning environment which foster higher cognitive skills.

Computer programming activities certainly have the potential for fostering problem solving skills such as those emphasized in several recent reports which have called attention to the deplorable state of science and mathematics education in the United States today. The report of the National Commission on Excellence in Education, "A Nation at Risk" states a pressing need for educational reform to create a "learning society". Similarly the National Science Board in a report entitled "Educating Americans for the 21st Century" has called for the "new basics" or the thinking skills required to cope with rapid technological and scien-

tific advances. Both reports emphasize the need for instruction which fosters problem solving, prepares learners to deal with naturally occurring problems, and encourages students to think critically. Computer learning environments have the potential for imparting some of these important higher cognitive skills. Equitable access to instruction which fosters such skills is, thus, clearly essential.

Computer Learning Environments

The ACCCEL project has identified six features of the computer learning environment which make it particularly cognitively demanding. First, the environment is interactive. The computer can respond quickly and informatively to the learner. Thus, individuals can try several possible repairs for errors in their programs and obtain immediate responses from the computer. In contrast, it often takes days or weeks to get responses to homework. Second, the computer can provide precise feedback e.g. information about where the problem solver has gone wrong. This preciseness is reproducible, providing the same response to all learners. Thus, learners are treated equally, receiving the same response from the computer every time they give the same input. Fourth, the environment for learning computer skills is complex. The computer environment can strain the processing capacity of the learner. Fifth, computers can provide learners with problems which have multiple solutions. Thus, students can write several programs to do the same

task and compare the effectiveness of their programs. Sixth, the computer environment is <u>challenging</u>. Computer learning environments can motivate the learner to solve complex problems which might otherwise be omitted from the curriculum.

<u>Chain of Cognitive Consequences</u>

When the six features of computer learning environments are used fully, the computer environment can eventually foster higher cognitive skills. Initially, students learn the basic elements in a computer environment. Then they learn procedures for combining those elements to solve problems. In so doing they have the potential of cognitive gain. THe ACCCEL project seeks to identify the <u>chain</u> of cognitive consequences necessary to achieve higher cognitive skills.

For example, the programming environment is probably one of the most cognitively demanding computer learning environments currently available. When students learn to program they learn the basic elements such as the language features of the system and they learn procedures for creatively combining those language features into a plan which becomes their program. In addition, when individuals devise plans for programs, inevitably those plans are incomplete or inaccurate. Students also learn procedures for trouble shooting, which involves diagnosing the problems with their programs and devising solutions to those problems. Clearly, program planning and trouble shooting are

higher cognitive skills which make programming demanding. The chain of cognitive consequences from the programming environment includes the language features as well as these higher cognitive skills.

Higher cognitive skills can also be fostered by certain types of educational software. Recently a few pieces of educational software have been developed which emphasize planning and trouble shooting. These pieces of software have elements analogous to certain language features in programming which must be combined in a plan to solve a problem. As in programming, the plan is often faulty and must be debugged. One example of such software is Rocky's Boots from the Learning Company. In Rocky's Boots the basic elements are logic gates: AND gates, OR gates and NOT gates. Students must combine the logic gates and attach them to shape and color sensors in order to build a machine. The machine examines a series of objects, identifies those which should be "kicked" by Rocky's Boot, kicks the shapes it identifies and earns points. Students need to build machines which will kick the correct shapes. When they succeed, they get the maximum amount of points and Rocky, a raccoon, comes out and dances to reward them. As educational software which requires planning and debugging such as Rocky's Boots becomes available, the potential of the computer learning environment to foster higher cognitive skills will be enhanced.

Links in the Chain of Cognitive Consequences

Entertainment software and educational game software each have the potential for fostering cognitive skills such as the ability to discover and test plans for problem solutions. Although much of this software emphasizes primarily eye-hand coordination, some may foster higher cognitive skill. Since females are less likely than males to use entertainment and game software they may often miss the opportunity to develop skills from computer learning environments which could form a link in the chain of cognitive consequences.

For many of these computer games, students discover or develop problem solving procedures. Current books and articles describe how to plan solutions for games such as Pacman or Jumpman (e.g. Ahl & Staples, 1984). Expert players of games such as Space Invaders can often provide extensive descriptions of their procedures.

These plans are acquired by trial and error, by observing expert players, by reading descriptions and by conceptual analysis of the game. The process of discovering a plan for a complex problem is a higher cognitive skill characteristic of problem solving which can be seen as a link in the chain of cognitive consequences derived from computer environments for learning.

One example of such a plan comes from observing use of

Sea Dragon. In Sea Dragon, the player guides a ship through a maze-like course and shoots at a variety of targets. If the ship either hits the wall of the maze or gets hit by projectiles it returns to an earlier point in the maze and repeats that segment. One student using Sea Dragon initially tried the obvious plan of going as far as he could into the maze, but his score was very low. He observed that his score in the first few minutes was proportionately higher than his score after he had played for a while. The student developed a plan: He went almost to the first barrier in the game and then hit the wall on purpose so that he would be sent back to the beginning of the game. By going through one segment again and again, the student gained a higher score than any of his friends.

Besides developing plans which help them win games, students using computers may change the game or test the limits of the computer. An example of how students can change a game occurred using the Lawrence Hall of Science software entitled What's in Your Lunch? This educational activity asks visitors to indicate the food that they ate for lunch and tells them about the calories, vitamins, minerals, and protein they consumed. Many teenagers, interacting with What's in Your Lunch? have invented a game which could be called "Pig Out." The object of the game is to enter a lunch with the most calories and with the least food value. These students change the learning environment by going beyond the information given.

An example of testing the limits of the environment occurred with Rocky's Boots. In Rocky's Boots, Rocky the raccoon comes out to dance when students build successful machines. This seems to bore many students. One student tried picking Rocky up with the cursor. This worked. The student then went and got the knife used for cutting wires apart in Rocky's Boots and used the knife to "kill Rocky." Another student, chagrined that Rocky would not stay off-screen after being moved away by the cursor but rather returned to dance after the next machine was constructed, tried unsuccessfully to "hide" Rocky many rooms away. By probing the limits of the game students gained understanding of the program which controls the game. The game developer, Warren Robinette, was surprised that students attempted to pick up Rocky. He could not, at first, predict how the program would respond, clearly indicating that students were going beyond the limits envisioned for the game.

Experiences such as those described above form links in the chain of cognitive consequences resulting from computer environments for learning. Successful students discover plans for using entertainment-like computer tasks which go beyond the information given. These plans involve combining known elements of the game in new and innovative ways. Students appear to discover plans for solving these problems using a process similar to that required to discover plans while using geometry proofs, or naturally occurring problems.

Students who develop plans for computer games also could potentially learn something about the nature of computers and the nature of the programs written to guide computers. For example, in identifying peculiarities of software like the ability to pick up Rocky with the cursor, students recognize the structure of the underlying program and may realize that programs can have features which are not made explicit in the instructions.

Students who develop their own plans for games also learn how to make the computer environment more stimulating. These students learn that even fairly uninteresting programs can be modified. They capitalize on the interactive and precise nature of the computer learning environment and change it to suit their own interests. Thus, students learn that computers are potentially interesting even when the actual task they are required to do on the computer may seem dull.

Another effect of interaction with computer entertainment activities concerns the opportunity to gain self esteem. When students develop new plans for using computer games, they tend to get praise or admiration from their peers. In addition, they experience success in getting a high score or solving a particular puzzle. This experience may contribute to their assessment of their own competence in working in a computer learning environment. The development of this competence may well generalize to other computer learning environments of a more academic nature.

Implications for Problem Solving

Although there is little evidence that students acquire problem solving skills in one environment which they can use for other problems (e.g. Linn, in press), the computer environment may ultimately help foster general problem solving skills. First, the computer environment provides many opportunities to develop and test plans. The interactive nature of computer learning allows students to quickly discover whether their plans work. In contrast, many school environments are slow to inform students about the accuracy of their plans. Second, the computer environment provides precise information which may help students modify and improve their plans. The exact effect of a given plan can be observed and may provide clues about which changes would make it work more effectively. Third, the computer environment provides multiple opportunities to develop plans in different subject matter areas. The experience of discovering plans for solving problems in many different subject matter environments may ultimately contribute to a more general understanding of planning. Repeated experiences and practice with planning may help students separate general planning procedures from problem specific procedures.

Researchers refer to general problem solving skills as meta-reasoning skills. These are skills which guide identification of plans for solving problems. The computer environment allows students to devise plans for a range of

problems, thereby allowing students to develop and test meta-reasoning skills. One reason that students rarely appear to develop meta-reasoning may be that it is difficult to separate the subject-matter dependent aspect from the subject-matter independent aspect (Linn, in press). By practicing in many computer learning environments, students may gain these skills. If experience in these environments is inequitably distributed, those who participate may be better prepared for subsequent learning in computer environments.

The Gap between Promise and Reality in Computer Learning Environments

Despite their potential utility, there is a severe gap between the promise of computers in education and the reality of their use in classrooms (Linn & Fischer, 1983; Linn & Stein, 1984). This gap contributes to the difficulty of fostering higher cognitive skills and of achieving equitable outcomes from these environments. Although even some informal computer learning experiences can potentially foster higher cognitive skill as described above, many students either fail to gain exposure to these environments or fail to benefit from them. To increase the effectiveness of classroom computer learning programs, this gap must be narrowed.

There are a number of reasons for the gap between promise and reality in classroom computer learning environments. First, researchers and educators have not yet identified the

full potential of the computer for fostering cognitive skills. Second, curriculum materials have not been developed to take full advantage even of the identified potential of the computer. Third, curriculum materials which foster cognitive skills tend to be in the subject matter area of programming, or logic, rather then, say, history or biology. Fourth, due to lack of effective curricular materials, many teachers must develop their own activities with few resources and limited support from their districts. Fifth, teacher professional development programs have either not been developed or have not been effectively utilized in preparing teachers for incorporating computers in their programs. Sixth, researchers and educators have not fully identified how computer learning experiences can be tailored to the needs of a diverse student body.

The gap between the potential of computers in education and the reality of their use is compounded by a lack of school-based planning for computer education (Linn & Fisher, 1983). Planning for computer education can be frustrating, given the problems mentioned above. Some districts choose to follow a "buy now, plan later" approach, deploying limited resources primarily for hardware, neglecting planning, software, and teacher professional development. As argued elsewhere, allocating resources to planning may ultimately result in substantial benefit to schools (Linn & Fisher, 1983). Unfortunately, the limited available resources for computer education sometimes force schools to curtail

necessary activities such as planning in order to make minimum hardware purchases.

As a result of this situation, few computer-based courses effectively foster the higher cognitive skills which could be taught. For example, much programming instruction teaches the language features but not the planning required to put those features together. Although a few students learn higher cognitive skills autonomously, the remainder probably fail to gain these skills if they are not emphasized in instruction.

The gap between promise and reality in computer education contributes to the potential for inequitable outcomes because only a relatively few students are served effectively. Good teaching can potentially benefit the least prepared students more than others. Furthermore, students with limited previous experience with computers and interest in computer use are more likely to attempt and complete a well-taught class than a poorly taught class.

Participation of Males and Females in Computer Learning Environments

More males than females participate in computer learning environments. Furthermore, females are poorly represented in courses which have the greatest potential for higher cognitive skill development. In California, females comprise 42% of the 51,481 participants in high school

instruction which involves computers; when they do participate, females are 86% of the students in word processing courses and only 37% of the students in programming courses. Thus, females participate more frequently in courses which are less likely to foster higher cognitive skills.

The participation of males and females in informal computer learning environments is similarly skewed. Only 26% of the 2693 students registering for computer courses at the Lawrence Hall of Science over the last three years were females. Females comprised only 19% of the students in Intermediate BASIC compared to 34% of the students in an introductory course called "Micros for Micros." The situation at computer camps, according to Hess and Muira (1983), echoes that found at the Lawrence Hall of Science: about 30% of the students enrolling in the computer camps are females. Similarly, Hess and Muira report that families are more likely to purchase computers for males than for females and to spend more money on computer purchases for male children than for female children.

The trend continues through college, females are less likely to earn degrees in computer science than are males. In 1981 females earned 32.5% of the bachelor's degrees and 23% of the masters' degrees in computer science (Vetter, 1983). At the University of California at Berkeley currently about 37% of the computer science majors are females. Thus, female participation at the college level in

cognitively demanding computer learning environments corresponds to participation at lower grade levels.

Inequitable participation in computer learning environments by socio-economic status (SES) is also evident in survey data. Schools of low SES which are predominantly white are about half as likely as high SES schools to have microcomputers (Becker, 1983). Similarly, schools with predominantly minority populations are about half as likely to have computers as are predominantly white high SES schools. Low SES and minority schools, thus, offer less participation in computer learning environments. Presumably the pattern of differential participation between males and females continues to prevail in these environments, meaning that low SES women are very unlikely to get exposure to computer learning environments.

It is evident that the inequitable participation in computer learning environments has the potential of increasing the individual differences among children. Students exposed to computer learning environments have the opportunity of gaining higher cognitive skills not available to their peers.

Three consequences of inequitable participation in computer learning environments deserve mention. First, societal productivity may be hampered because individuals are not trained to their full potential. Employees may be forced to hire under-qualified workers because the most talented

students were not trained. Second, individual satisfaction may be curtailed because potential job-related success and financial benefits are not achieved. Careers in computer-related fields tend to have high salaries (Vetter, 1983) and can offer professional satisfaction. Lack of equitable access to training makes these benefits unavailable to some deserving learners. Third, the underrepresentation of females in computer-related fields may inhibit the influence of the female perspective described by Gilligan (1983). This perspective could potentially respond to concerns that computer environments dehumanize society.

Factors contributing to differential participation in computer learning environments

Hypotheses to explain the differential participation of males and females in computer learning environments emphasize both content and process features. Content features include the reliance on mathematics and science-related information in much computer software and the use of violent themes in many computer games. Process features include the precise, interactive nature of the environment.

Content features

Much has been written about how the content features of computer environments discourage participation of females (e.g. Lockheed and Frakt, in press; Sheingold, Kane and Endreweit, 1983). For example, Lepper & Malone (1983) have

shown that the violent themes of many entertainment-oriented computer games tend to appeal to males more than females. Computer companies target their advertising to males (who comprise 98% of the purchasers of computers) thereby characterizing computing as a male domain. Lepper (in press) notes that mathematics and science content characterize much of the available educational software. Since scientific problem solving is perceived as a male domain, it may not be an objective of females to master that environment. In addition, societal expectations tend to encourage males but not females to participate in scientific activities.

Changing the content features of a computer learning environment can influence participation. For example, Burger (1982) investigated the effect of science content versus art content on the participation of males and females in computer learning. He compared software which taught controlling variables using scientific content to software which taught controlling variables using artistic content. Both programs emphasized the same fundamental concept. He found that males were much more likely than females to interact with the scientific content program but that males and females were equally likely to interact with the artistic content program. When participation of males and females was equal, the cognitive outcomes for the groups did not differ.

Thus, the content features of some computer environ-

ments evidently tend to dissuade females from participating. Changing content features can help. At times, such changes will influence the nature of the outcome. For example, in the Burger (1982) study, if students needed to learn the variables in the scientific condition, males would have an advantage not remedied by changing the subject matter content of the program (e.g. Linn, 1983). Changing the content features of a computer environment may not be sufficient to achieve equitable participation of males and females.

Process features

The Assessing the Cognitive Consequences for Computer Environments for Learning Project has conducted two studies examining the processes which characterize responses of males and females to cognitively demanding programming-like software. Mandinach and Corno (1984) have studied the Wumpus task. Burbules and Reese (1983) have studied the Rocky's Boots task.

These studies involved environments which require the higher cognitive skills of planning and trouble shooting as described above, and thus, take advantage of the potential cognitive consequences from computer learning. These environments require problem solving processes common in other types of scientific problem solving. Students must learn a fairly constraint-laden system and then manipulate the language features of the system to solve the problems. In solving mechanics problems in physics for example, one

learns some concepts, some formulas for combining those concepts, and then one is required to plan combinations of the concepts in order to solve complex problems (e.g. Larkin, McDermott, Simon, and Simon, 1981). Some computer learning environments have important similarities with scientific problem solving environments. As mentioned above, it is precisely the close resemblance of these learning environments to mathematics and science problem solving environments that may contribute to the lack of participation of females.

Wumpus

Wumpus is a computer based strategy game. In Wumpus the problem solver searches through twenty rooms each connected to three other rooms. There are multiple paths to each room. The player must locate the room which has the Wumpus in it and shoot the Wumpus with an arrow. If the player enters a room with the Wumpus in it or with a pit in it, the player will be killed. If the player enters a room with bats in it (s)he will be picked up by the bats and moved to a different room which could be a room with a pit in it. The player receives hints about the adjacent rooms. If there is a pit in any adjacent room the hint is "I feel a draft." If there are bats in any adjacent rooms the hint is "I hear flapping." If there is a Wumpus within two rooms of the room the hint is "I smell a Wumpus." The player must travel from room to room picking up hints until there is enough informa-

tion to figure out where the *Wumpus* is. Then the player can try to shoot the *Wumpus* with an arrow. *Wumpus* is a game of both strategy and luck. Even the best strategy does not always prevent the player from being killed. Sometimes the best strategy is to enter a room even though it might have bats in it. At other times, the best strategy is to gather more information. Successful *Wumpus* players need to combine caution with a willingness to take risks. At the beginning of the game caution is important. After the game has been played for a while, it may sometimes be necessary to take a risk in order to gain more information. At that point a judicious risk is the best strategy. Learners who succeed at the game discover when they should take risks and when they should gather more information. Learners who take unnecessary risks tend to get killed in the early parts of the game. Those who are extremely cautious, tend to make redundant moves. At least in some implementations, a student could stay alive by moving back and forth between two safe rooms almost forever.

In the *Wumpus* study, 48 (24 male and 24 female) volunteer junior high students participated in four instructional sessions and then received post-tests. Students were assigned to either an activation condition or a modeling condition. In both conditions, students were encouraged to record the rooms they visited to reduce the memory load needed to keep track of what was going on. In the activation condition, a discovery learning mode prevailed. Students

interacted with *Wumpus* with little intervention from the experimenter. In the modeling condition, students were given explicit instructions. Students were encouraged to be cautious, to consider whether known risks ought to be taken, and to seek alternative solutions. The students were encouraged to find another path rather than exploring rooms which might have bats or pits. As will be clear below, although these instructions were helpful, there are drawbacks in encouraging aution without also encouraging students to take necessary risks. The *Wumpus* study included careful observation of processes students used to interact with the computer, recording of verbalizations, recording of students predictions concerning the success of their next move, and administration of attribution measures. The study is reported in greater detail in Mandinach and Corno (1984).

Rocky's Boots

The *Rocky's Boots* study involved the participation of 7 volunteer junior high aged students in 5 40-minute sessions with *Rocky's Boots*. Since having students talk about their problem solving while solving problems tends to create an information overload for the problem solver, students were observed and then asked to comment on their performance. Before students tried out machines for example, they were asked to predict whether the machine would work and to comment on the processes that they used for constructing the machine. This was an exploratory study. Verbal protocols

were tape recorded and the experimenters took notes on the performance of individual students. Results from the study are indicative of trends but cannot be viewed as statistically significant since there were only four male and three female participants.

Four consistent differences in the processes used by males and females emerged in these two studies. Each of these differences could be attributed to the previously documented differential experience in computer learning environments between males and females.

Going Beyond the Information Given

Boys were more likely than girls, when participating in these computer learning environments, to go beyond the information given in the learning environment. as described above, students using Rocky's Boots had a tendency to pick up Rocky and carry him around. Boys were far more likely than girls to go beyond the information given in picking up Rocky and in testing other limits of the Rocky's Boots game. For example, boys were more likely than girls to experiment with stopping and starting the machines or with making modifications to the machines while they were running.

In Wumpus, males were also more likely than females to go beyond the information given, as illustrated by response to the modeling condition. Females improved in response to the modeling condition for the first three sessions and then

performed considerably less well in the fourth session. Females' decline in performance in the fourth session can be specifically attributed to their increasing tendency to make redundant moves rather than to take necessary risks. Females appeared to be conscientiously following the instructions to proceed with caution by making redundant moves. In contrast, the males seemed to be able to go beyond the information in the modeling instructions and to assume necessary risks at appropriate times.

Students who go beyond the information given learn why the rules work, if indeed the rules do work. It seems reasonable to assume that individuals need to have some understanding of the learning environment before they are ready to go beyond the information given. These differential responses to Wumpus may reflect previous differential experiences with other constraint-laden learning environments. Ultimately in constraint-laden environments, it is necessary to take risks in order to find out what is going on. Females may be less willing to take risks than males (e.g. de Benedictis, Delucchi, Harris, Linn, and Stage, in press).

Expectations About Performance

Males are more realistic than females in predicting their own success and failure in computer learning environments. In Rocky's Boots, males were more likely than females to accurately predict whether their machines would

work after they had constructed them. Furthermore, when males failed to make accurate predictions about the success or failure of their machines, they tended to be optimistic. Males tended to predict that their machines would work when in fact their machines did not work. In contrast, when females failed to accurately predict whether or not their machines would work, they tended to be pessimistic. Females tended to predict that their machines would not work. In responding to Rocky's Boots, females were far more likely than males to make verbal comments, such as "I'm stupid, I don't understand this," or "I don't know anything about computers; I'll never be able to do this," or "I can't do this." Thus, females were less accurate in predicting their success in the environment and in general, expected that they would not do very well. Both the lack of accuracy and the pessimism on the part of females in the Rocky's Boots environment may reflect lack of experience with this sort of an environment.

In Wumpus, similar results were found. Boys were more realistic than girls in predicting success in the game. Sixty-four percent of the time boys accurately predicted the outcome of their game compared to fifty-three percent of the time for girls. Consistent with the findings for Rocky's Boots, girls were inaccurate and pessimistic twenty-three percent of the time, whereas boys were inaccurate and pessimistic only thirteen percent of the time. Each group was optimistic but inaccurate about fifteen percent of the time

and between seven and ten percent of the time each group was unable to predict the outcome of the game.

Females were less successful on Wumpus and they, in general, had less previous experience with environments similar to Wumpus. Thus, males' more realistic expectations about their success and failure in both Wumpus and Rocky's Boots may well reflect greater experience with these sorts of environments.

Attributions of Success and Failure

In making attributions for success and failure in computer learning environments, boys have a clearer understanding of their own role in the situation than do girls. Boys are more likely to attribute success and failure to the presence of lack of an appropriate strategy for the problem, while girls are more likely to attribute success and failure to their own ability. In Rocky's Boots, boys were more likely than girls to explain the specific reasons why the machine had failed and to attribute the failure of the machine to the lack of a specific strategy. Girls were more likely to attribute failure of the machine to personal lack of competence.

In Wumpus, questionnaire responses and observations of attribution patterns were available. Both boys and girls responded to a questionnaire about their attributions of success and failure in computer learning experiences. On

the questionnaire, boys were more likely than girls to attribute success or failure to using a "good" strategy while girls attributed success and failure to general ability and to task difficulty. While playing Wumpus, forty percent of the boys and only eighteen percent of the girls made attributions about their success. Boys demonstrated their increased understanding of the environment by attributing their success first to task difficulty and then to strategy. In contrast, girls attributed most of their success to luck and failed to consider the role of strategy. Task difficulty is certainly a component of luck, however, girls tended to lump task difficulty and other components of luck together, while boys differentiated these features of the situation.

Thus, in attributions for success and failure in computer learning environments, boys seem to seek explanations for their performance while girls seem to seek excuses. This situation could stem from boys greater experience with computer learning environments and other similar environments.

Help seeking

Girls were more likely than boys to seek help in computer learning environments. In Wumpus, and in Rocky's Boots, the girls were more likely than the boys to ask the experimenters for assistance and to ask for approval of their actions. Differential help seeking could reflect

differential experience with the computer learning environment (girls may need more help). It could also reflect differential expectations about the knowledge level of the experimenters. Perhaps girls are more likely than boys to believe that experimenters and other people in positions of authority have information which they can use.

In summary, a variety of evidence concerning the processes used by males and females in computer environments suggests that females are earlier on the learning curve, as a group, than males. Of course, these group differences are not characteristic of each individual male and female. In both the <u>Rocky's Boots</u> and the <u>Wumpus</u> study, there were exceptional females who scored as well as or better than all the males. As a group however, females used processes which reflected less experience and less facility in interacting with the environment.

Conclusions

The inequitable participation of males and females in computer learning environments may well contribute to differential achievement of the problem solving skills which have been labeled the "new basics" by the National Science Board when calling for reform in mathematics and science education.

Differential participation of males and females in even relatively cognitively undemanding learning environments such as computer entertainment games can potentially

contribute to differential response in other environments. Females may be dissuaded from participation in entertainment or recreational computer learning because they find the content features of many computer games unappealing. Differential response to the content of computer entertainment games may contribute to differential success in cognitively demanding computer learning environments because these games may foster skills which become part of the chain of cognitive consequences from computer leaning environments. Cognitively demanding computer learning environments such as Rocky's Boots and programming have the potential to foster higher cognitive skills. Females may come to these environments with less relevant experience than males and may, therefore, require more effective instruction to benefit equally.

All students benefit from effective instruction. Females may have a greater opportunity than males of benefiting from effective instruction in computer learning environments because they are more likely to need and to seek help. Females may need more instruction about how to take advantage of these environments. Otherwise they may continue to make excuses rather than to seek explanations, and to follow the instructions rather than to test the limits of the environment. Thus, equity in computer learning can be enhanced by narrowing the gap between the promise of computers in education and the reality of their use in classrooms.

Since males and females do respond differently to computer learning environments, equitable outcomes for the sexes will be enhanced if teachers tailor instruction to the needs of each learner. Females more than males may respond to explicit instruction. As noted for Wumpus, however, females appear to be more likely than males to follow instructions completely--even when following the instructions becomes counter-productive. Thus, explicit instructions must be carefully designed. Alternatively, since females lack previous experience with computer learning environments, they may benefit from guided exploration which encourages them to experiment with going beyond the information given rather than from explicit instruction. Research is needed to clarify how best to tailor computer learning environments to the needs of males and females.

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