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ABSTRACT

This research compared the performance of ninth grade females and males on flight protocol, with particular attention to interpretation of the graphs of paths of falling bodies, rolling objects, and projectiles. These subjects were chosen because they had received no formal instruction in projectile motion, yet through typical life experience, had encountered the phenomena associated with the concept and therefore could assume to be novices. Flight protocol is composed of a problem sequence presented as a structured protocol during which the subjects individually participate in a clinical interview lasting about one hour. Questions are asked which involve the subjects in making predictions. The predictions are represented as graphs. Their prediction is then compared with the computer representation of the same problem on the monitor. Flight protocol is divided into four phases: intuitive or background knowledge; pattern matching; transformation; and post experimental. The results suggested that there was no significant difference in the performance of ninth grade female and male groups on the flight protocol. Findings suggest teachers should focus on the critical features of graphs rather than surface features, and encourage all students co similar le'/els of competency. (MVL)

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Gender Differences:
Novice Problem Solving Attributes

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Gender Differences:
Novice Problem Solving Attributes

Nobel Laureate and renowned teacher, Richard Feynman said, " Everything we know is only some kind of approximation. Therefore, things must be learned only to be unlearned again, or, more likely, corrected." (Kole, 1982)

Introduction/Background

The under-representation of females in scientific and technical professions is an effect of their attrition in physical science courses in secondary school (Lockheed et al, 1985). There is an ever deepening concern about this problem and a desire on the part of teachers to address it. With the rising importance of the dynamically presented, computer graphics as a mode of representing complex phenomena, it would be valuable to compare performances of females and males in the restructuring of scientific data presented in this manner. If differences are found, then strategies may be designed to address the differences; if no differences are found, then students of both genders may be encouraged to fully participate.

The focus of this investigation resides in the combined approaches of gender differences, misconceptions, mental models, and computers-in-education research.

Studies have continued to show that intuitive understanding of motion is usually erroneous (McCloskey, 1983; Trowbridge & MacKenzie, 1980) and that the misconceptions persist after direct instruction (Resnick, 1987).

Pirkle and Pallrand (1988) have described the persistent retention of erroneous mental models about projectile motion. Pallrand (1988a) found that graduate students in an elementary education program, after viewing a series of computer generated representations and changing their own initially erroneous diagrams of the phenomenon, reverted to an erroneous representation of projectile. Pirkle and Pallrand (1988) and Pirkle (1989) found that ninth grade students were more likely to move from initially erroneous representations to correct representations if: 1) they were also relatively field independent; 2) if their diagrams showed relatively abstract symbols; or, 3) if they were able to decompose, transform and restructure the complex variables into the concept of projectile motion.

Choi and Gennaro (1987) compared the effectiveness of computer simulation with hands-on laboratory activities for teaching the concept of volume displacement in junior high students, and found no difference in learning. Reynolds and Baker (1987) found that presenting information on the computer as opposed to "normal textual presentation" increased the students' "attention allocation and learning" and, in addition, interactive graphical presentations increased the students' attention allocation even further.

Mokros and Tinker (1987) have described their Microcomputer-Based Lab (MBL) curriculum project. The curriculum employs computers interfaced with probes which measure physical phenomena and interpret the measurements graphically. They have asked that further research be done in the area of identification of the early developmental patterns of graph interpretation problems and graphing competencies.

A step forward has been made by Yap and Yeany (1988) in their study that seeks links between the Piagetian cognitive reasoning levels and the integrated process skills, such as graphical representation, as co-developing skill hierarchies.

If computer simulation is to add to the science teacher's repertoire of methodologies, more study needs to be done about student (male and female) cognitive characteristics and the patterns of graph interpretation. Are all students to benefit from undirected use of computer simulations? Which students are more likely to give up the misconceptions they carry?

The diagrammed paths of the projectiles and the spacing of the intervals on the diagrams as a function of novice intuitive understanding, pattern matching, transformation and restructuring behavior, have been the subjects of a previous report (Pirkle & Pallrand, 1988). Used as a basis for that investigation was the Flight Protocol developed at Rutgers University. This study extends that line of research.

Purpose

Of interest to this research, therefore, is the comparative performance of ninth grade females and males on the Flight Protocol, with particular attention to interpretation of the graphs of paths of falling, rolling objects, and projectiles.

The hypothesis was formulated:

> There will be no significant difference in the performance of ninth grade females and males on the critical phases of the Flight Protocol. Subjects will be similarly able to analyze the information given in the computer-generated graphs, extract the salient points, and verify or correct their knowledge representations.

The purpose of this investigation is to compare the performance of ninth grade females and males on the critical phases of the Flight Protocol.

Method

Thirty-nine ninth grade students from heterogeneously grouped science classes were administered the Flight Protocol (Pallrand, 1987b). These subjects were chosen because they had received no formal instruction in projectile motion, yet through typical life experience, had encountered the phenomena associated with the concept. They could therefore be assumed to be novices in terms of solving problems associated with projectile motion. There were twenty-two females and seventeen males in the study.

The Flight Protocol is composed of a problem sequence presented as a structured protocol during which the subjects individually participate in a clinical interview lasting about one hour. During the interview, a problem is presented. Questions are asked which involve the subjects in making predictions about what would happen, given a set of variables related to projectile motion in a gravitational field. The predictions are represented as graphs. These graphs are "pictures" of the paths of falling or rolling objects, or projectiles shot from an imaginary cliff. Once the prediction has been made, the computer representation - a graph - is generated, and the subjects can compare their own interpretations with those on the monitor. Thus, the computer, the drawings, and the audible responses all provide feedback to the students in their problem solving activities.

The Flight Protocol consists of a structured problem sequence divided into four phases. The first phase establishes the intuitive or background knowledge of the subject about vertical, horizontal, and projectile motion in a gravitational field. The second phase, "Pattern Matching," asks the subject to predict the path, as seen from the side, of an object shot from a cliff at a velocity of 4, a velocity of 8, and a velocity of 100. At two points in this part of the Protocol, the student is asked to compare the lengths of the paths and the landing time for the projectiles. The third phase, "Transformation," requires the subject to predict the shape of the projectile's path and indicate the speed of its fall, as seen from two additional perspectives: (a) from behind the cliff (View B), and (b) from below the cliff, looking straight up (View C). The subject is asked to describe these views for projectiles at velocities of 4, 8, and 100. The subject is asked to compare the landing time for the projectile as reported from each perspective. The final phase of the Protocol, "Post Experimental," asks the subject to state what he/she understands about the effects of gravity on a falling object and then on a thrown object.

The subjects were tape recorded and the oral responses keyed to the diagrams. These responses were the data collected and interpreted for this study. A code was developed and used to record the responses as successful or unsuccessful.

Specific questions or combinations of questions were identified as critical in the evaluation of the subject's problem solving process. These constituted six tests of the subject's ability to represent projectile motion, verify or correct the representation, and draw conclusions about projectile motion. The six tests were the successful solution to the problems presented in the Results section of this paper.

Results

The following summarizes the results of the comparison of female and male performance on the critical phases of the Flight Protocol.

Pattern Matching

Pattern matching was the activity scored as Test 1. Subjects needed to correctly represent the shape of the path and the tick marks in response to the question about diagramming the path of an object shot at velocity 8. The acceptable representation was one which was a gradually sloping downward curve marked with intervals of increasing size. The mean score of the female group was 0.409; the mean score of the male group was 0.529. The probability that this was due to chance was greater than 5%. A paired *t*-test was performed on the results. The value of *t* was equal to 0.72 (see Appendix Table 3).

Landing Time of the Projectile

The answer to the question about whether the object shot at velocity 4 or 8 would land first was the part known as Test 2. Subjects were expected to have observed from the representation of the paths of the objects shot at velocity 4 and 8 that the time markings indicated that the objects were in the air for the same length of time. If the subjects answered that they would both land at the same time, then they were credited with a correct response.

The mean score of the female group was 0.364, and the mean score for the male group was 0.471. The difference between was not significant, as the value of *t* was 0.65, indicating the probability of the difference being due to chance was greater than 5% (see Appendix Table 3).

Extrapolation of the Parameter

This test, Test 3, was that part of the sequence that required the subjects to diagram the path of the object shot at velocity 100 and mark the time intervals. The expected response was a curve gradually sloping downward, but proportionately much farther from the vertical axis or *cliff* than the previous two examples. Subjects were to adjust the scale of the intervals which marked the time of descent to indicate the increased horizontal velocity. This could be accomplished either by drawing off the page, by numbering the ticks with a higher magnitude of value, or by verbal qualification. This task was met with little success, as indicated by the scores on Table 3

(Appendix).

The mean for the female group was 0.136. The mean for the male group was 0.000. Knowledge acquisition about projectile motion was met with little success as a result of the pattern matching activities, and the female group continued to perform about the same as the male group. The value of t was 1.78, approaching significance in favor of the female group but still indicating the probability was greater than 5% that the difference was due to chance (see Appendix Table 3).

The Effect of Gravity on Projectile Motion

This part of the Protocol required the subjects to answer a series of questions about their interpretation of the relationships between the paths of the objects shot at velocities 4, 8, and 100. In particular, comparisons were made of the length of time for the object to land at each velocity. Subjects, to be given credit for this part, had to recognize that the object would land at the same time regardless of velocity. The mean score for the female group on this phase, called Test 4, was 0.364; the mean score for the male group was 0.177. The t-value was 1.28, indicating a probability that the difference due to chance was greater than 5% (see Appendix Table 3).

Of interest with this statistic is the consistent success of the female group with both the concept of gravity's effect and the extrapolated path of the object shot at 100. The male group is also showing a consistent deficit in the representation of the path shot at 100 (extrapolation) with the effect of gravity on the objects shot at 4, 8, and 100.

Transformation

After redrawing the object's path, marked with ticks, at velocity 4, the subjects were now required to represent the path from two new perspectives: (a) from behind the cliff, looking forward in the same direction as the shooting cannon, view B, and (b) from a position parallel to the ground below the cliff,looking straight up at the path, view C. Tick marks were to be placed correctly and the path shapes correctly represented. View B was to be a vertical straight line with tick intervals gradually increasing. View C was to be a horizontal straight line with evenly spaced ticks. This constituted Test 5.

The mean score for the female group was 0.273, and the mean score for the male group was 0.412. The *t*-value was 0.88, indicating a probability that the difference due to chance was more than 5% and, therefore, insignificant (see Appendix Table 3).

The Relationship Between the Perspectives A, B, and C

This task, Test 6, required the subjects to compare the length of time it took for the object, seen at perspectives A, B, and C, to land. To receive credit for a correct response, the subject had to recognize that the objects would be perceived to land at the same instant and that the length of the flight would be the same.

The mean score for the female group was 0.091; and the mean score for the male group was 0.118. The *t*-value for these scores was 0.26. The probability this was due to chance was greater than 5% (see Appendix Table 3).

Performance on the Total Test

The total battery, consisting of the critical parts of the Protocol, gave a total possible score of 6. It was decided to determine if there was a significant difference between the female and the male groups on the total scores. It was also decided that, in particular, the Intuitive Knowledge section of the Protocol, the representation of the projectile motion by the subject before viewing the computer, should be accounted for in the overall score. If a subject correctly represented projectile motion in the Intuitive Knowledge section, one point was subtracted from this subject's total score. This occurred in four cases, two females and two males.

The mean adjusted total score was determined for both the female and the male groups. The *t*-value was 0.04 (see Appendix Table 3). This value indicated no significant difference between the groups in their overall performance on the sequence of the problems.

Discussion and Implications for Teaching

The results confirm the hypothesis that there is no significant difference in the performance of ninth grade female and male groups on the Flight Protocol. The females in the study were somewhat better (but not significantly) than the males on the tasks requiring extrapolation of the data during the Pattern

Matching phase of the task. The males in the study were somewhat better (but not significantly) than the females on the tasks requiring transformation and restructuring of the data.

This finding is provides evidence in support of the notion that females and males should both be provided with experiences that reinforce their competencies in interpreting graphs.

The implications of this study are that the teacher should:

1) focus the students' attention on the details of a graphical representation to encourage the students to recognize the the critical features rather than surface features of a problem;

2) expect to encourage all students in ninth grade, girls and boys, to construct and interpret graphs with similar levels of competency.

A limit of the finding is that minority students were not a part of the study. Minority subjects would be of interest to future investigations.

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Appendix

Tables 1 through 3

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Table 1.

Performance on the Critical Phases of the Flight Protocol by Females

Subject		Tests 1	2	3	4	5	6	Total adjusted score
2	F	0	0	0	0	0	0	0
3	F	0	1	0	1	1	0	3
6	F	0	0	0	0	0	0	0
7	F	1	0	0	0	0	0	1
8	F	0	1	0	0	0	0	1
9	F	0	0	0	0	0	0	0
10	F	0	0	0	0	0	0	0
11	F	1	1	0	1	0	0	3
13	F	0	1	0	1	0	0	2
16	F	1	0	0	0	0	0	1
17	F	0	0	0	0	0	0	0
18	F	0	0	0	0	0	0	0
23	F	1	1	0	0	0	0	2
25	F	1	0	0	1	1	1	4
26	F	0	0	0	0	0	0	0
29	F	1	0	0	0	1	0	2
30	F	1	1	1	1	1	0	5
31	F	0	0	0	0	0	0	0
34	F	0	1	1	1	0	0	3
36	F	1	0	0	1	1	0	2
37	F	0	0	0	0	0	0	0
38	F	1	1	1	1	1	1	5

Note. Total Adjusted Mean Score = 1.545.

Table 2

Performance on the Critical Phases of the Flight Protocol by Males

Subject	Gender	Tests 1	2	3	4	5	6	Total adjusted score
1	M	0	1	0	0	0	0	1
4	M	1	0	0	0	0	0	1
5	M	0	1	0	0	1	0	1
12	M	1	0	0	0	0	1	2
14	M	0	1	0	0	1	0	1
15	M	0	0	0	0	0	0	0
19	M	1	0	0	0	0	0	1
20	M	1	0	0	0	0	0	1
21	M	1	1	0	0	0	0	2
22	M	1	0	0	0	0	0	1
24	M	0	1	0	0	0	0	1
27	M	1	0	0	0	1	0	2
28	M	0	0	0	0	0	0	0
32	M	1	1	0	0	1	0	3
33	M	0	1	0	1	1	1	4
35	M	0	0	0	1	1	0	2
39	M	1	1	0	1	1	0	3

Note. Total Adjusted Mean Score = 1.529.

Table 3

Performance on Flight Protocol by Female and Male Groups: t-Test Findings

Test	Gender	N	M	SD	t
1	F	22	0.409	0.503	0.72*
1	M	17	0.529	0.515	
2	F	22	0.364	0.492	0.65*
2	M	17	0.471	0.515	
3	F	22	0.136	0.351	1.78*
3	M	17	0.000	0.000	
4	F	22	0.364	0.492	1.28*
4	M	17	0.177	0.407	
5	F	22	0.273	0.456	0.88*
5	M	17	0.412	0.507	
6	F	22	0.091	0.294	0.26*
6	M	17	0.118	0.332	
Total score	F	22	1.545	1.491	0.04*
	M	17	1.529	1.068	

*p .05.