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ABSTRACT

This study examined learning by individuals and groups in a computer environment. Individual interactivity as a function of group size was investigated by focusing on various modes of interaction available to students while they completed activities using a computer. The activities, which involved manipulation of pictures of batteries, bulbs, and wires on the computer screen to perform simple experiments with simple direct current (DC) circuits, involved high-level learning (reasoning skills and conceptual understanding). Achievement was measured by administering brief paper and pencil tests and individual interviews. Data were also collected for subjects (N=58 seventh and eighth grade students) on age, sex, grade point average, and family income. The study also investigated students' grasp of concepts being taught by having them apply their knowledge to appropriate non-computer tasks, and certain global aspects of the group session to provide generalizations of typical social and psychological behavior in the computer-based learning environment. Among the findings reported are those indicating an advantage of small group usage (two to three students per group) over individual usage of highly interactive computer-based instructional materials and that students working in such groups seemed more likely to interpret program questions as the authors of the materials had intended. (JN)

# RESULTS FROM AN INVESTIGATION OF GROUPS WORKING AT THE COMPUTER*



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## ABSTRACT

Computer based learning materials, enhanced by graphics, can provide ample opportunities for interactive learning. Materials which stimulate dialog can be particularly effective when more than one student works at the computer. This paper reports results of an investigation of interactivity among young adolescent students working at the computer. Groups ranged from individuals working alone to four students working together. Interactivity was enhanced when students worked in twos or threes.

## INTRODUCTION

As microcomputers gradually become available in schools and other learning environments, many questions arise as to how they can best be used. Since (at least in the near term) computers are expensive tools of instruction, and limited in number, it is important to consider the advantages and disadvantages of having students use computers in small groups.

The purpose of the current study has been to examine learning by individuals and groups in a computer envirorment. Individual interactivity as a function of group size was investigated by focussing on the various modes of interaction available to students using a computer. Achievement was measured by administering brief paper and pencil tests and individual interviews. In addition, a description of social interaction among students using computers was developed by making global assessments of the learning sessions,

Which context is better for learning: group or individual? Clearly, individuals working alone at the computer have exclusive access to the program, but normally do not articulate their ideas verbally. Students working as members of groups, on the other hand, may have less access to the keyboard, but have many opportunities for verbal and social interaction with other members of the group. How do these opportunities for interaction affect learning?

A number of research efforts have focussed on the effects of instructional group size on learning in non-computer environments.

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The results vary. Students working in groups have shown greater gains than individuals working alone in some cases but not in others. Klausmeier, Wiersma and Harris (1) examined the efficiency with which concepts were learned by students who participated in instructional groups of various sizes. They concluded that students working in pairs and quads grasped concepts faster than individuals. (Triads were not examined.) However, on transfer tests, subjects who had learned as individuals generally exhibited greater concept retention than those who had learned in a group.

In another study, Sharan, Ackerman and Hertz-Lazarowitz (2), found no differences between those students who worked individually and those who worked in small groups in the learning of low level information. In the learning of higher level concepts, however, they found that groups did better. Reviews of literature by Sharan (3), Johnson and Johnson (4), Slavin (5) and Webb (6) also point out that the small group enhances learning in some cases, but not in others.

The current study used instructional materials which emphasize high-level learning: reasoning skills and conceptual understanding. The materials utilize simulations of science experiments which students perform on the screen. A Socratic dialog format encourages active participation by the learner.

RESEARCH METHODS

The science materials were produced at the Educational Technology Center under two previous development projects. They were designed specifically to develop formal reasoning skills and scientific literacy, and have been described elsewhere (7,8,9,10). Subjects were middle ability students drawn from seventh and eighth grade classes in the Irvine Unified School District. Individually or in groups of 2, 3 or 4, they participated in unsupervised activities at the computer. Sessions lasted about 40 minutes each.

Each session was videotaped; an interface device connecting the videotape recorder to the computer enabled researchers to review the course of the computer program during their observations of student behavior. Three components of the group activity were recorded on videotape: (1) video of the students working together, (2) audio of their conversation, and (3) all key pushes of the computer keyboard.

The videotape data collection system consisted of a microcomputer that ran the interactive learning materials, a video cassette recorder with two separate audio channels (one channel for voice, the other for keystrokes), an interface device for connecting the computer to the recorder, and associated utility software for handling input and output during recording and playback sessions.

An observational instrument, akin to the systems of interactional analysis pioneered by Bales (11) and Flanders (12), was developed to categorize behaviors representing various kinds of interactivity. The videotaping system and observational instrument were tested and refined during a Pilot Study which has been described elsewhere (13,14,15). The coupling of computer and videotape recorder provides an authentic reconstruction of the original learning session which yields to systematic and reliable observation.

## REVIEW OF FINDINGS FROM THE PILOT STUDY

The purpose of the Pilot Study was to determine relevant variables and establish a means of analysis. Early observations of groups in this highly interactive environment had indicated considerable frequencies of cognitive and social behaviors which were indicative of important thinking and learning activity.

Several questions arose: Is access to the keyboard dominated by one member of the group to the exclusion of others? In the group setting, is behavior primarily beneficial to learning (e.g., restatement of questions or problems in ones own words, articulation of ones own thinking, formulation of hypotheses, predictions, evaluations and explanations, tutorial assistance to other members of the group, etc.), or detrimental to learning (e.g., distracting or irrelevant conversation, non-cooperation or withdrawal)? To what extent is the social interaction among members of groups supportive, and to what extent is it disruptive?

Thirty-five students in grades 6-8 took part in the Pilot Study (6). They worked at the computer individually, in pairs or in triads. A wide cross-section of students was represented, ranging from high to low ability. The composition of groups varied in terms of previous group history, ability, and sex. In addition, the computer based learning materials varied in several respects, including their emphases on textual and graphical input. Students worked in a room by themselves, unsupervised. Findings of the Pilot Study are summarized below.

1. Generally, engagement was high throughout the learning session (mean percentage of time on task: 95%).

2. Students working in pairs generally displayed greater interactivity than those working alone or in groups of three.

3. Cognitive behavior, indicated by verbalizations, accounted for a slightly larger fraction of interactivity among pairs than among triads.

4. Students working in pairs made fewer incorrect responses to program questions (about 30% fewer) than individuals or triads.

5. In groups consisting of members who had a prior group history, the tenor of the session was sometimes dictated by previously established social roles.

On the basis of these findings, we began a more controlled and more extensive investigation of this particular instructional setting.

## DESIGN OF THE FORMAL STUDY

In the Formal Study, the sample population was limited to middle ability students (and thus, homogeneous ability groups), to roughly equal numbers of groups who had worked together on academic tasks before and those who had not, and to a single sequence of computer based learning activities.

Fifty-eight 7th and 8th grade students participated in this part of the study. On the basis of their teacher's knowledge of their ability levels and prior group learning experiences, we selected a population of students which excluded individuals with exceptionally high or low academic abilities. In addition, we chose roughly equal numbers of groups with and without prior academic group experience. Thus, our population reflected the social groupings in a typical school. Our sample is summarized below:

| | Group Size 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| Numbers of Groups (with, without group experience) | 8 (5,3) | 8 (5,3) | 6 (4,2) | 4 (2,2) |
| Numbers of Students | 8 | 16 | 18 | 16 |

Data were collected for each subject on age, sex, grade point average, and family income. A one-way analysis of variance on individuals (16) indicated that none of these factors varied significantly from one group size to another.

Students worked in a quiet area separate from their classroom, in the presence of one researcher who unobtrusively monitored the videotaping but did not intervene during the session. The camera was in full view of the students. As we had discovered early in the Pilot Study, students quickly became involved in the computer program during these sessions, and seemed to ignore the fact that they were being taped.

A sequence of four activities from the computer dialog, "Batteries and Bulbs" was used for all sessions. Students manipulated pictures of batteries, bulbs and wires on the computer screen to perform simple experiments with simple DC circuits. The purpose of the materials is for students to discover the idea of current flow through a complete circuit. Titles of the first four activities are, "Light the Bulb," "Arrangements of Batteries and Bulbs," "Other Things in the Circuit," and "A Scientific Model."

Immediately before and immediately after the session, students took a brief quiz on their understanding of electrical circuits. In addition, the same paper and pencil quiz plus a brief interview involving a simple task of lighting a flashlight bulb with actual equipment was administered to all students three months after the computer sessions.

Three major goals were established: (1) to measure frequencies of interactivity and to look for variations as a function of group size. (2) to measure students' grasp of the concepts being taught by having students apply their knowledge to appropriate non-computer tasks. (3) to judge certain global aspects of the group session in order to provide generalizations of typical social and psycholcgical behavior in the computer based learning environment.

## RESULTS

### Interactivity

The observational instrument consists of 19 observable behaviors. Behavior codes fall into three categories of interaction: Keyboard, Cognitive and Social. The first category represents interaction between a student and the program via the computer screen and keyboard. The Cognitive category encompasses those verbal behaviors that were highly suggestive of thinking activity. We did not attempt to infer cognitive behavior beyond that which was directly observable in speech. The third category, Social, includes the verbal and non-verbal behavior which, though not specific to the intellectual content of the lesson, nevertheless appeared to facilitate the learning process.

Behavior Codes

| | Keyboard |
|---|---|
| k | types at keyboard |

| | Cognitive |
|---|---|
| T | tells, directs others |
| Q | queries, asks for suggestions |
| A | accepts, responds to suggestions |
| I | interprets in ones own words |
| X | explains, formulates reasons |
| M | formulates question or answer |
| P | formulates predition |
| E | evaluates using criteria |
| D | disagrees with program |

| | Social |
|---|---|
| n | neutral conversation, opinions |
| a | approval, agrees with another |
| d | disapproval, disagrees |
| s | shares keyboard with others |
| t | takes turns |
| h | gives help, assists another |
| v | polls others, solicits, votes |
| y | delegates task to another |
| e | encourages another |

The original list of behavior codes included a category for reading from the screen, and a few categories of Off-task behavior. Reading from the screen was so frequent and continuous, however, and Off-task behaviors were so infrequent that these categories were not deemed useful for the subsequent analysis of interactivity based on frequency counts.

For purposes of reducing the magnitude of the task of reviewing video tapes, observations were limited to Activities 2-4 of the Batteries and Bulbs dialog. During playback of the videotapes, raters focussed attention on one student at a time and recorded behavior codes in ten-second intervals.

Time to complete learning activities 2-4 ranged from 15 to 35 minutes, with an average of 25 minutes. Differences in average completion times for groups of different sizes were not significant. However, we did observe some variation in typing speed of students in our sample. Since typing speed can affect the frequency counts for keyboard activity, observations of interactive behaviors were normalized by dividing numbers of observations by the elapsed time of the session. Thus, we compare "Interactivity Rates" instead of behavior counts.

The following table displays the mean individual Interactivity Rates by group size for each category of interactivity. Percentages of the totals are shown in parentheses.

Individual Interactivity Rates:
Interactions per 100 seconds
(% of Total)

| | Group Size (conditions) | | | | F values (see note) | | |
|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | A | B | C |
| Keyboard | 3.36 (91) | 1.82 (34) | 1.36 (24) | 0.87 (23) | 13.94*** | 4.01** | 1.34 |
| Cognitive | 0.23 (6) | 1.61 (30) | 2.10 (38) | 1.45 (39) | 15.02*** | 4.15** | 1.71 |
| Social | 0.12 (3) | 1.90 (36) | 2.10 (38) | 1.43 (38) | 14.11*** | 3.06 | 3.26** |
| Total | 3.71 (100) | 5.33 (100) | 5.56 (100) | 3.75 (100) | 4.51** | 4.66** | 3.26** |
| sample size | 8 | 16 | 18 | 16 | | | |

* $p < 0.05$
** $p < 0.025$
*** $p < 0.01$

Note:
A: Anova on means, $F(3,54)$: conditions 1-4; total N = 58
B: Anova on means, $F(2,47)$: conditions 2-4; total N = 50
C: F test for equality of variances, $F(15,15)$: conditions 4 vs 2

Since members of groups of any size have opportunities for verbalization which individuals working alone do not have, we have separated the consideration of groups of size 2-4 from the overall consideration of sizes 1-4. The analysis of variance has been carried out first by considering all four sizes as conditions, then second, by considering pairs, triads and quads as a set of three conditions on which the interactivity rates depend.

A significant difference in total individual interactivity rates is evident whether or not the condition of working alone is included. The figures suggest not only that members of pairs and triads had higher rates of interactivity than individuals working alone, but that among groups of 2-4, they experienced greater rates of interactivity than members of quads.

The breakdown of various modes of interactivity is displayed in the first three rows. For example, in the row labelled Keyboard, we see that as the size of the group increased, the keyboard activity of each member decreased correspondingly. Rates of Cognitive and Social interactivity for individuals working alone were negligible; non-zero values were due to the fact that individuals occasionally talked to themselves.

Pairs and triads had higher levels of cognitive and social interactivity than either individuals or quads. Consideration of groups 2-4 alone led to the same conclusion: members of quads do not experience as high a level of interactivity in any category as either members of pairs or triads.

An F test for equality of variance was also performed for group sizes 2-4. As the size of the group increased, so did the dispersion in interactivity rates. The ratio of variances for quads to pairs was significant for total interactivity rates, suggesting that members of quads are more likely to vary in interactivity from high to low.

Another result of the analysis of Interactivity Rates was obtained by ranking members of each group according to their interactivity rates and comparing mean values. In groups of two, interactivity is divided roughly evenly between both members; in groups of three or four, the least interactive individual participates much less frequently than any of the other members. Thus in quads, we often observed one person "left out" of the group activity.

Percentage of Total Group Interactivity
Exhibited by Each Group Member: %

| Rank | Group Size 2 | 3 | 4 |
|---|---|---|---|
| Highest | 59 | 44 | 43 |
| 2nd highest | 41 | 31 | 33 |
| 3rd highest | | 26 | 18 |
| Lowest | | | 6 |

Achievement

Immediately before and after each computer session, students were tested individually using a paper and pencil task in which they were shown a picture of a battery and a light bulb and were asked to draw an arrangement of wires in which the bulb would light. After three months, students were again tested with the picture, and immediately afterward with an interview task.

In the interview, students were presented with an actual battery, bulb and wires, and were asked to light the bulb. They received a passing score only if they lighted the bulb successfully on their first attempt, without trial and error.

On both the paper and pencil version of the quiz, and in the interview with actual equipment, students were scored only as having passed or failed. A group of 96 control students also took the paper and pencil tests. Results are summarized in the following table.

Tasks to "Light the Bulb"

Number who passed, ( % )

| | N | Pre-Test | Post-Test | Delayed Post-Test | Interview Task |
|---|---|---|---|---|---|
| Experimental (used computer) | 58 | 7 (12) | 55 (95) | 56 (97) | 50 (86) |
| Control (no computer) | 96 | | | 23 (24) | |

Before using these instructional materials, very few of these students (12%) knew how to light a bulb. Immediately after the session with the computer, nearly all (95%) could light the bulb. On an interview task involving actual batteries, bulbs and wires, essentially all students who had used the computer materials (86%) could light the bulb immediately, without trial and error. Thus, for this particular task, transfer of learning to the actual physical case was straightforward.

Another paper and pencil test was administered immediately after the computer session and again three months later. This test involved eight items, each illustrating an arrangement of battery, bulb and wires, in which the student had to judge whether the given arrangement would light the bulb. Results are summarized below.

Mean Scores on 8-item Post-Test,
"Which arrangements will light the bulb?"

| Mean Score and Std. Dev | Group Size 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| Post-test | 5.8 | 6.4 | 5.9 | 5.7 |
| SD | 0.9 | 1.3 | 1.0 | 1.4 |
| Delayed Post | 6.2 | 6.2 | 6.2 | 6.1 |
| SD | 1.3 | 1.0 | 0.9 | 1.1 |
| Control | 4.5 | | | |
| SD | 1.4 | | | |

While students working in pairs had the highest mean score by a slight margin on the post-test that was administered immediately after the instructional session, differences were not significant. On the delayed post-test, administered three months later, differences were even less. Students who had used the computer materials did better than students who had not participated, as expected ($t = 6.45$, $df = 152$; significant at $p < 0.001$).

Global Aspects

In addition to the above measures which assessed individuals, another set of measures was developed to describe the group as a whole and the tenor of each session. Each of the following characteristics was judged with respect to the entire session:

1. Tenor of Session:

   a. Cooperative — Degree to which members help each other to formulate answers, encourage one another, and share the keyboard.

   b. Competitive — Degree to which members seek to compete with one another, gain advantage at the expense of others.

   c. Tutorial — Extent to which members assume roles of tutor and tutee, attempt to explain the material to one another.

2. Success with Material:

   a. Error Frequency — Measure of the number of incorrect entries made in response to questions posed by the computer program.

| | |
|---|---|
| b. Response Quality | A subjective assessment by the researcher of the quality (thoughtfulness, consideration) of responses to dialog questions. |

3. Engagement:

| | |
|---|---|
| a. Attentiveness | Degree to which students are attentive to the instructional material. |
| b. Off-Task | Characterization of the session in terms of whether off-task behavior was displayed, and if so, how frequently. |

Immediately after viewing the videotape of the session, a researcher (R.D.) scored the session with respect to each of these characteristics on a three point ordinal scale. These scores represent a subjective assessment by an individual with several hundred hours of experience in videotape observations. Results were obtained as follows:

Median Scores Describing Session as a Whole

(Scale: 1 - low, rarely; 2 - medium, sometimes; 3 - high, usually)

| Factor | Group Size 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| Tenor of Session: | | | | |
| a. Cooperative | n.a. | 3 | 2 | 3 |
| b. Competitive | n.a. | 1 | 3 | 1 |
| c. Tutorial | n.a. | 3 | 1 | 2 |
| Success with Material: | | | | |
| a. Error Frequency | 2 | 1 | 2 | 2 |
| b. Response Quality | 2 | 3 | 2 | 2 |
| Engagement: | | | | |
| a. Attentiveness | 3 | 3 | 3 | 3 |
| b. Off-Task | 1 | 1 | 1 | 1 |

The following conclusions were drawn from global assessments:

1. Students working in pairs or quads were more likely to cooperate with each other than students working in triads.

2. Students working in triads were more likely to compete with one another than students working in pairs or quads.

3. Students working in pairs were more likely to give or receive tutorial assistance than students in triads or quads.

4. Students working in pairs made fewer incorrect entries and formulated higher quality responses to program questions than individuals, triads or quads.

5. Whether working individually or in groups, students were uniformly attentive during the instruction sessions and displayed little off-task behavior.

In addition, researchers observed that students working alone seemed to have a more difficult time answering program questions correctly on their first attempt at the keyboard than those in groups of any size. However, individuals were also more likely to review earlier parts of the instructional materials than those students who worked in groups. Among 8 individuals, six spontaneously returned to earlier material to review; among 8 pairs, one pair returned to review; none of the 6 triads nor 4 quads did so.

SUMMARY

This study has shown that small group usage of highly interactive computer based learning materials has certain advantages over individual usage. On the whole, verbalizations among pairs, triads and quads were relevant to the learning material and socially supportive. We found no evidence for any detrimental effects among students working in pairs or triads. Quads, however, seemed to be too large, in general, for all four members to maintain high levels of interactivity with either the program or with other members of the group. On post-session achievement measures of individual competance, no differences were found among individuals and members of groups.

Students working in groups seemed more likely to interpret program questions as the authors of the materials had intended. Often, discussion about multiple interpretations would converge to the correct interpretation. On the other hand, individuals working alone were more likely to misinterpret program questions and to pursue incorrect paths through the material than students working in groups. Individuals showed a greater willingness to go back and review material that gave them trouble, however, which may explain why we found no inferiority of individuals' performance on achievement measures.

A comparison of achievement between those students who had used the materials and a control group who had not indicated clearly that students had learned some elementary ideas of electric current flow by using the computer simulation. In addition, these students had no difficulty at all applying their knowledge to a task involving actual physical equipment.

CONCLUSION

Teachers and school administrators who are considering the use of computer based learning materials in the classroom need to examine the desirability of more than one student working at the computer. With the limited availability of computers in schools, teachers may wish to consider the advantages of having students work in groups.

While it is difficult to measure gains directly attributable to social interaction, a student working with one or two others at the computer typically verbalizes his or her own thoughts so frequently that an inference of cognitive gain is not unreasonable. Furthermore, performance is generally unimpaired.

Our conclusions suggest that the use of computer based learning materials should not be restricted to individuals alone. On the contrary, many benefits are to be gained by having pairs, and, under some circumstances, groups of three working together.

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