DOCUMENT RESUME

ED 362 389 SE 053 659

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TITLE	Effect of HyperCard and Traditional Performance Assessment Methods on Expert-Novice Chemistry Problem Solving.
PUB DATE	Apr 93
NOTE	10p.; Paper presented at the Annual Meeting of the National Association for Research in Science Teaching (Atlanta, GA, April 15-19, 1993).
PUB TYPE	Reports - Research/Technical (143) -- Speeches/Conference Papers (150)
EDRS PRICE	MF01/PC01 Plus Postage.
DESCRIPTORS	*Chemistry; Classroom Research; *Computer Uses in Education; Educational Technology; High Schools; High School Students; *Problem Solving; *Science Instruction; *Secondary School Science; *Student Evaluation
IDENTIFIERS	Expert Novice Problem Solving; *HyperCard

ABSTRACT

This study examined the relative effect of a HyperCard based approach to solving stoichiometric equations using Hyperequation, and traditional pen-paper methods on the performance of expert and novice high school chemistry students. Hyperequation is programmed to register student responses, provide immediate feedback, and keep a record of all the responses made including the overall time needed for problem solving for each student. The sample consisted of 30 honors and 30 regular chemistry students comprising the expert and novice groups respectively. The students were from a public high school in Columbus, Ohio. Half of each group received the traditional pen-paper test and half the HyperCard tests. The findings indicate that students from both the expert and novice groups scored significantly higher on the HyperCard method than on the pen-paper method. (PR)

Effect of HyperCard and Traditional Performance Assessment Methods on Expert-Novice Chemistry Problem Solving

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Paper presented at the 66th annual meeting of the National Association for Research in Science Teaching, Atlanta, GA, April 15-19, 1993.

Introduction

This study examined the relative effect of a HyperCard based approach to solving stoichiometric equations, the Hyperequation (Kumar, 1993), and traditional Pen-Paper methods on the performance of Expert and Novice high school chemistry students. The Hyperequation software was developed in the HyperCard on a Macintosh microcomputer platform. Hyperequation is programmed to register student responses, and it provides immediate feed-back and keeps a record of all the responses made including the overall time taken for problem solving by each student. In addition, the classroom teacher could retrieve overall as well as individual records of student performance in Hyperequation.

The reasons for choosing the task of balancing chemical equations in this study are three-fold. First, the enigma of balancing chemical equations has intrigued students for generations (Loercher, 1986), and remains an integral part of chemistry courses (Niaz & Lawson, 1985). Because chemical equations are descriptions of chemical processes, they have qualitative and quantitative significance (Brown & LeMay, 1981; Hines, 1990). Second, the task of balancing chemical equations requires varied levels of hypothetico-deductive reasoning ability (Karplus, Lawson, Wollman, Appel, Bernoff, Howe, Rusch, & Sullivan, 1977 cited in Niaz & Lawson, 1985, pp. 41-42), and thus provides an ideal test-bed for studying Expert-Novice problem-solving.

For example, Niaz and Lawson (1985) have identified a set of five chemical equations in the order of increasing difficulty levels, as follows.

Equation 1: $H_2SO_4 + 2NaOH = Na_2SO_4 + H_2O$

Equation 2: $HCl + Na_2CO_3 = NaCl + H_2O + CO_2$

Equation 3: $Fe(OH)_3 + H_2SO_4 = Fe_2(SO_4)_3 + H_2O$

Equation 4: $H_3PO_4 + CaSO_3 = Ca_3(PO_4)_2 + SO_2 + H_2O$

Equation 5: $2H_2XO_3 + H_3ZO_3 = HX + H_3ZO_4 + H_2O$

According to independent research by Niaz and Lawson (1985) and Pachaury (1991) these equations increase in difficulty from Equation 1 to Equation 5, requiring a progressively greater number of steps to solve them. The difficulties associated with solving these equations have been associated with the developmental level of students. Third, from a programming point of view, a computer software containing these chemical equations and the tasks involved are easily programmed and affordable using HyperCard.

An overall estimate of split-half reliability of these five equations, using correct (1) and incorrect (0) responses was reported in the literature as 0.83 (Niaz & Lawson, 1985). In the present study, an overall (HyperCard and Pen-Paper combined) split-half reliability of 0.80 was obtained by correlating the sum of the Performance Scores of odd equations with that of the even equations, followed by Spearman-Brown correction. (See definition of Performance Score under Scoring.) Individual split-half estimates of reliabilities of the HyperCard and Pen-Paper versions of these equations were found to be 0.74 and 0.83, respectively.

Null Hypotheses

1. There is no significant difference between the HyperCard and traditional Pen-Paper assessment methods for balancing chemical equations.
2. There is no significant difference between the performance of Expert and Novice students using the HyperCard and traditional Pen-Paper assessment methods for balancing chemical equations.

Methodology

The study proceeded through the following stages.

Development of Test Materials:

A Pen-Paper version of the five equations shown above was prepared. The same set of chemistry equations was developed for the Macintosh using HyperCard.

Sampling:

Thirty honors and thirty regular chemistry students were chosen from a public high school in Columbus, Ohio to form the respective Expert (E) and Novice (N) samples of this study. The Expert group differed from the Novice as follows. The Experts had experience with chemistry more in depth than Novices by the nature of the honors chemistry course. They represented the best in achievement and were more academically talented than the Novices. The Experts paralleled real-world chemists in such a way that they used chemistry and chemical equations in more practical problem solving situations. They had to figure out how to solve problems and prepare for laboratory experiments by themselves without any help from their chemistry teacher. According to the chemistry teacher, the Experts were exceptionally talented in actually using equations to solve practical chemistry problems. Both the Expert and Novice groups received instruction in stoichiometry as a part of their curricula about four months prior to the administration of the study. The Expert and Novice groups were further randomly divided into HyperCard (HC) and traditional Pen-Paper (PP) groups, respectively, each with 15 students.

Procedure:

The traditional Pen-Paper (PP) and HyperCard (HC) tests were administered to the respective Expert and Novice groups. The maximum response time was set to 15 minutes and the maximum attempts allowed was set at five per equation. The students took the HyperCard version of the test using Macintosh computers. Those who took the traditional version of the test were required to use an ink pen for registering their responses in order to keep track of their attempts.

Scoring:

The scoring was based upon five dependent variables: Performance Score; Number of Attempts; Rate of Attempts; Time on Task; and Correctness. The Performance score was determined using the following formula.

Performance Score = [6-Trial] x Correctness x Difficulty Level

(Trial = Number of attempts per equation; Correctness = 1 for right or 0 for wrong answer; Difficulty Level = 1 through 5 for Equations 1 through 5 respectively)

The Number of Attempts in the Pen-Paper tests was tabulated by counting the number of times a student placed coefficients in front of a formula before arriving at a correct or incorrect final response. Student attempts above five were not counted. The Rate of Attempts was determined by dividing the total Number of Attempts for each individual by their total Time on Task. The Time on Task was based on the time required by each student to complete the task (whether successfully or not), with a maximum limit of 15 minutes. The Correctness was scored by assigning a one (1) for a right and a zero (0) for a wrong answer.

Findings

- Students with high Performance Scores correctly balanced more chemical equations than did students with low Performance Scores.
- Students with high Performance Scores required fewer attempts to balance the chemical equations than did students with low Performance Scores.
- Students with high Performance Scores had a lower Rate of Attempts than did students with low Performance Scores.
- Performance Scores for both Expert and Novice students were significantly higher on the HyperCard method than on the Pen-Paper method.
- Performance Scores of Novices using the HyperCard method nearly equaled the Performance Scores of the Experts using the Pen-Paper method.
- Correctness Scores for both Expert and Novice students were significantly higher on the HyperCard method than on the Pen-Paper method.

• Significant interactions were found for Time on Task and for Correctness.

• Time on Task for the Experts decreased from Pen-Paper to HyperCard while Time on Task for the Novices increased from Pen-Paper to HyperCard.

• The slope of the Method by Correctness plot for the Novices from Pen-Paper to HyperCard is greater than that for the Experts, indicating that the Novices benefitted more from the HyperCard than did the Experts.

Discussion

Significant differences were found between the HyperCard and traditional Pen-Paper assessment methods and the performance of Expert and Novice students using the HC and PP methods, and the null hypotheses were rejected. The HyperCard and Pen-Paper assessment methods influenced differently the performance of Expert and Novice students in balancing stoichiometric chemistry equations. The computer environment and the flexible structure of the HyperCard may be the reason for these differences. It could be argued that the hypermedia environment helps Novices perform better on the task than the Pen-Paper method, possibly due to the following reasons.

(1) The mouse-interface with the computer was less interfering than the Pen-interface with the Paper in solving the stoichiometric chemical equations. Perhaps, the mouse input device made the student-computer interface less obtrusive (Schneiderman, 1987) than the Pen input and the student-Paper interface.

(2) The HyperCard method of the test provided immediate feedback so that the student was motivated to stay on-task until a satisfactory solution was reached. Collins (1984) found that immediate feedback was the major contributing factor for enhanced achievement among biology students using computer generated biology tests.

(3) The computer itself provided an added external memory for the student while balancing the equations thereby reducing the cognitive demand on working memory.

According to Pascual-Leone and Goodman (1979) there is a relationship between the burden, size, and the amount of memory space required to think about a problem while engaged in problem solving. For example, Staver (1986) found that the performance of eighth graders on the Bending Rod problem went up as the number of independent variables was reduced, due to a reduced load on the working memory.

(4) Also, the use of HyperCard may tend to reduce the initial differences in student Expertise in solving stoichiometric equations in chemistry. In an experiment with computer-generated homework problems at the college level, Milkent and Roth (1989) found that the effectiveness of ACT scores as predictors of course achievement was significantly reduced. Whether standardized test scores as predictors of achievement bear any significance for expert and novice students balancing chemical equations using the HyperCard and Pen-Paper methods should be researched in its entirety. It is too ambitious at this point to generalize that hypermedia is capable of bridging the gap between the performance of Experts and Novices in balancing chemistry equations. Subsequent studies of this nature should analyze such issues in detail.

Summary and Conclusion

HyperCard appears to be a promising technology for alternative assessment in chemistry. The performance of both Expert and Novice chemistry students was different in the HyperCard equation as in the Pen-Paper method. Both the Expert and Novice performance in the HyperCard and Pen-Paper methods differed significantly. The Performance Score of the Novice group using HyperCard was higher than the Novice group using the Pen-Paper and came closer to that of the Expert Pen-Paper group. Even though it may not be possible to pinpoint what exactly prompted this latter effect, it is possible that the non-linear environment of the HyperCard and the computer platform involved may have played a significant role in helping the Novice problem solver improve his/her performance by providing for thinking in less restrictive ways.

The non-linear environment of the HyperCard provides opportunities for developing hypermedia assessment systems in the future, situated in broader instructional contexts. Such a flexible environment should also be conducive to the development of assessment methods that are capable of assessing various aspects of the processes of problem solving in addition to the products (solutions). In addition, the HyperCard equation is cost effective and requires no expertise in computer programming. This feature of HyperCard should encourage its use in the research and development of alternative assessment methods.

Acknowledgements

Thanks to Richard Shavelson at the University of California, Santa Barbara and Michael Waugh at the University of Illinois, Urbana-Champaign for the suggestions received during the development of this project. Also thanks to James Altschuld at The Ohio State University for the insights and feedback, to John Harwood at Vanderbilt University for the help in programming, and to Gary Sweitzer at the Upper Arlington High School for the help in gathering data for this study. This research was supported in part by the National Center for Science Teaching and Learning under OERI Grant No. R117Q00062, U. S. Department of Education. Any opinions, findings, conclusions, or recommendations expressed in this paper are those of the authors and do not necessarily reflect the views of the sponsoring agency.

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