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ABSTRACT

Abstracts and abstractors' critiques of 10 published research reports related to misconceptions, attitudes, gender and miscellaneous issues are presented in this issue. Studies include: (1) the development, revision, refinement, and partial validation of an instrument to assess preservice elementary teachers' process orientation toward science; (2) a comparison of the effectiveness of three different methods for pooling student scores to provide daily data points for a time series analysis; (3) a study done to determine underlying factors associated with students' interests in science and to see if these factors differed by gender and race; (4) an attempt to identify concepts and propositions necessary for grade 10 students to comprehend the mechanisms of inheritance and to see which of these concepts and propositions were most frequently misunderstood; (5) a study hypothesizing that inadequacies in textbooks contribute to student misunderstandings and analyzing the genetics content in three widely used high school biology textbooks; (6) an examination of the conceptions of the human circulatory system held by students from grade 5 through college; (7) a study which examined the effect of preservice elementary teachers' cognitive responses on their attitudes toward energy conservation; (8) the validation of the Student Opinion Survey in Chemistry (SOSC), an existing student attitude scale, and a comparison of cross-national data collected using this instrument; (9) an examination of science and mathematics enrollment during high school and college concerning achievement, participation, and sex differences among students; and (10) an examination of the predictive validity of various tests for success of women in a National Science Foundation Career Facilitation Project. Two responses to the critiques in this issue are included. (CW)

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NOTES FROM THE EDITOR:

Issue 3 of ISE begins with three miscellaneous studies. That reported by Scharmann et al. describes the development, revision and refinement, and partial validation of an instrument to assess preservice elementary teachers' process orientation toward science. Monk's study is a comparison of the effectiveness of three different methods for pooling student scores to provide daily data points for a time series analysis. Thomas's study was done to determine underlying factors associated with students' interest in science and to see if these factors differed by gender and race.

The next section contains three studies related to misconceptions research. Hackling and Treagust attempted to identify concepts and propositions necessary for grade 10 students to comprehend the mechanisms of inheritance and to see which of these concepts and propositions were most frequently misunderstood. Cho et al., hypothesizing that inadequacies in textbooks contribute to student misunderstandings, analyzed the genetics content in three widely-used high school biology textbooks. Arnaudin and Mintzes examined conceptions of the human circulatory system held by students from grade 5 through college.

In the third section, two studies focused on attitudes are critiqued. Koballa examined the effect of preservice elementary teachers' cognitive responses on their attitudes toward energy conservation. Schibeci reported the validation of the Student Opinion Survey in Chemistry (SOSC), an existing student attitude scale, and compared cross-national data collected using this instrument.

The fourth section contains two studies highlighting the effects of gender. DeBoer examined science and mathematics enrollment during high school and college and looked at achievement, participation, and sex differences among students. Wittig et al. examined the predictive validity of various tests for success of women in a National Science Foundation Career Facilitation Project.

Issue 3 ends with two responses to articles critiqued in this issue, from Scharmann and from Hackling and Treagust.

Patricia E. Blosser
Editor

Stanley L. Helgeson
Associate Editor

MISCELLANEOUS STUDIES

Scharmann, L., H. Harty, and J. Holland. "Development and Partial Validation of an Instrument to Examine Preservice Elementary Teachers' Process Orientation to Science." Science Education, 70: 375-387, 1986.

Descriptors--Elementary Education; *Elementary School Science; *Elementary School Teachers; *Measure Individuals; *Preservice Teacher Education; *Process Education; Questionnaires; Research Methodology; Science Education; *Science Teachers; Teacher Attitudes

Expanded abstract and analysis prepared especially for I.S.E. by Pinchas Tamir, Hebrew University, Jerusalem.

Purpose

The purpose of the investigation was to describe the development, revision, refinement, and partial validation of an instrument to assess preservice elementary teachers' "process orientation toward science." This construct is defined as the ability to recognize/identify the basic and/or integrated science process skills consistent with their application within and contribution to an emergent understanding of the nature of science.

Rationale

An understanding of the nature of science has been considered a primary outcome of undergraduate study in science. The inability of undergraduate coursework to foster such an understanding has been especially observed with respect to preservice elementary teachers. However, some researchers claim that the problem may reside in the inadequacy of the instruments used to assess the preservice teachers' understanding of the nature of science. Some of the instruments used (i.e., Kimball's Nature of Science Scale) are too sophisticated for this audience and others (i.e., Wisconsin Inventory of Science Processes) are not sophisticated enough. Therefore there was a need felt to develop a new instrument which will meet the special needs of preservice elementary teachers.

Research Design and Procedure

Two inter-related processes are described: 1) the derivation and development of the instrument, and 2) its validation.

An initial pool of 60 Likert-type (1 = strongly disagree, 5 = strongly agree) items was developed by the authors using ideas taken from three existing instruments. The new instrument, entitled Process Orientation Toward Science Scale (POTSS), underwent rigorous validation, revision and refinement. The major steps undertaken and their findings are summarized as follows:

1. Content validity was determined by a panel of judges. Their evaluation resulted in a 40 item inventory consistent with the validation criteria. The Scott's coefficient of interrater reliability was 0.79.
2. The 40 item version of POTSS was field tested by administering the instrument to 27 perservice elementary teachers and analyzing the data. Internal consistency (alpha) was found to be 0.86. Fifteen items were eliminated since these items had item to total correlation of less than 0.30.
3. The 25 item version was content analyzed by the panel of judges who found that:
   a) 19 items were judged as directly stating a science process skill, while for 6 items the skill was judged as easily inferred;
   b) 12 items were judged as measuring basic process skills, and 12 as measuring integrated process skills;
   c) 1 item was judged as measuring attitude towards teaching by inquiry.
4. This 25 item version was field tested on 27 preservice elementary teachers and found to have alpha coefficient of 0.83 and adequate item to total correlations.
5. Predictive validity was established by correlating the POTSS scores with the performance of the preservice teachers (final course grades) in a science process skills course. The correlation was 0.57.

6. POTSS was administered to three samples: 1) undergraduate biology majors; 2) preservice elementary teachers; and 3) preservice secondary science teachers.

   Since the biology majors had taken a course in the history and philosophy of science it was hypothesized that POTSS scores (both total and individual items) would follow from high to low in the following order: biology majors, preservice secondary, preservice elementary. The comparison of average ranks of the three groups showed a highly (statistically) significant difference in the predicted order. The same conclusion applied to 22 individual item comparisons. The remaining three items required further consideration.

7. A varimax factor analysis of the pooled results of the three samples mentioned in item 5 above (N = 106) yielded two factors, one corresponding to basic skills and the other corresponding to integrated skills. Seven items possessed insufficient factor loading values, and hence, required further consideration with regard to their inclusion and use.

Interpretation

The authors concluded that the POTSS discriminates in the expected direction among groups; however, the test statistics are not conclusive. Hence, they recommend that the instrument be administered to larger samples in a variety of situations in order to determine its generalizable worth. Two important implications of the study are:

1. it cannot be assumed that by teaching preservice elementary teachers the processes of science they will necessarily understand the underlying philosophical constructs/tenets;
2. preparation of teachers to teach process oriented programs should incorporate an orientation to the underlying philosophical tenets inherent to these programs.

In spite of the statistical limitations, POTSS appears ready for additional use as a diagnostic measure of preservice elementary teachers' process orientation toward science.

ABSTRACTOR'S ANALYSIS

The article deals with a very important issue, namely, teachers' understanding of the underlying philosophical constructs/tenets which form the basis for teaching science as inquiry by inquiry (Tamir, 1983). The need for an instrument to measure this kind of understanding is obvious and this is why similar instruments, some mentioned in the article, have been developed. The authors believe that none of the existing instruments are suitable for use with preservice elementary teachers and hence they set out to design POTSS. They also suggest that they deal with a new construct which they call "process orientation toward science," which they define as "the ability to recognize/identify basic and/or integrated science process skills consistent with their application within a contribution to an emergent understanding of the nature of science."

The first question to be raised is whether the ability to recognize/identify, can be regarded as orientation. Examination of the items of POTSS (which are included in the article) indicates that the title Understanding the Nature of Scientific Processes (UNSP) would fit better. Secondly, the definition is unclear: what does it mean to be "consistent with the application and contribution to an emergent understanding of the nature of science"? Whose emergent understanding is referred to? Again, examination of the instrument itself indicates that what is actually measured is understanding of the concepts which underlie processes such as observing, inferring, using replications, classifying, identifying cause and effect etc.

This leads to another question: since POTSS is intended for use as a diagnostic tool, would it not be helpful to obtain a description of the specific skills measured by each item? The authors describe in great detail the validation process, which is acceptable. However, users are at least as interested in the kind of information that may be obtained, beyond a total score. For example, items 2, 6, 12, 19 deal with the nature of observation; similarly, items 1, 8, 11, 17, 21 deal with classification. Thus, it may be useful to form subtests according to the particular process skills, thereby obtaining profiles in addition to total scores.

Although the authors feel that POTSS is especially adequate for preservice elementary teachers, other existing instruments such as TOUS (Cooley and Klopfer) may be no less suitable. This can be tested empirically by comparing results obtained with the two instruments.

The difference between "basic" and "integrated" process skills poses another problem. For example, why will item 23 (modern scientific measurements are presently so accurate they contain no source of error) be considered "integrated" and item 19 (scientists should reject data and observations from an experiment if their observations cannot be replicated in the next experiment conducted) will be considered "basic?"

The authors suggest that the results of the factor analysis support the distinction between "basic" and "integrated." However, we really do not have the detailed results of the factor analysis. We do not know, for example, if the authors asked _a priori_ for two factors, or whether only two factors have emerged just on the basis of the actual correlations. Also, using only 106 respondents to factor analyze 25 items is usually not recommended. If POTSS can be administered to at least 250 individuals and the results submitted to factor analysis, we shall be in a better position to search for the meaning of any clusters that will be formed.

Regardless of the particular instruments which may be used, the importance of assessing understanding of process skills and their underlying constructs/tenets is certainly high. If accompanied with pertinent experiences, such as the use of adequate instructional materials like the module _Basic Principles of Scientific Research_ (Friedler and Tamir, 1987), this assessment may help in training teachers to teach process oriented science courses more effectively.

Finally, the real validity test of an instrument such as POTSS is the extent to which it is capable of predicting the actual nature and quality of teaching science by inquiry and promoting the development of process skills in pupils. To test this we need studies which will follow graduating preservice teachers who have responded to POTSS in their classrooms and observe their actual instructional activities.

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Monk, John S. "An Examination of Methods Used to Generate Daily Group Scores from Single-Item-per-Subject Data Collected in Intensive Time Series Designs." Journal of Research in Science Teaching, 21 (3): 315-324, 1984.

Descriptors--*Data Analysis; Junior High Schools; *Research Design; *Research Methodology; *Research Problems; *Secondary School Science; Science Education

Expanded abstract and analysis prepared especially for I.S.E. by Frances Lawrenz, University of Minnesota, Minneapolis.

Purpose

The purpose of this study was to compare the effectiveness of three different methods of pooling student scores to provide daily data points for a time series analysis.

Rationale

This investigation was tied to a set of studies conducted using time series analysis to investigate progress toward cognitive and affective goals. Although the time series approach offers an innovative method for investigating progress, it presents some new problems as well. One problem is how to obtain daily measures of content and/or attitudes without disrupting the entire learning process. The suggested solution is to have each student in a class complete one test item, randomly selected from all of the available items, each day. The single item approach keeps the amount of class time spent on testing to a minimum. In order to represent daily, class scores, however, these single item scores must be aggregated in some way. Since few data were available on the effect of different approaches to pooling students' scores, this study was designed to compare the results obtained by using three different methods of pooling.

Research Design and Procedure

The data used for this study were part of a larger program which was investigating the effect of instruction on learning outcomes using a time series approach. In this larger study, data were gathered during three phases; baseline, intervention, and follow-up. This study uses only the data gathered during the intervention phase. The subjects were 100 eighth grade and 135 ninth grade students taught by two different teachers. The students were divided into three groups on the basis of their scores on the Test of Logical Thinking. The daily items were randomly selected from a pool of 75 items on plate tectonics.

The individual test item data for each day of the intervention period were pooled using each of the three methods under investigation, and the results obtained from each method were compared. One method of pooling was to produce a mean score (MS) by averaging the single subject scores. The second method of pooling the single-item-per-subject measures was to calculate a difficulty score (DS). In this method the average difficulty of the items responded to on a given day was used as a weight for the MS for that day. The difficulties were derived post hoc from an item analysis of the entire instrument administered at the end of the study. The third method of pooling produced a Rasch score (RS). In this method the daily group score was adjusted for both item difficulty and variations in subject ability using the Rasch formula.

Least squares regressions were conducted by teacher and by logical thinking group by teacher, using the scores obtained from each pooling method. The pooled scores obtained from each method were standardized to provide comparable scores. The assumption was made that the pooled scores had similar overall means and therefore comparisons were made of regression slopes, regression residuals and overall variance explained. Additionally, to determine more carefully the effect of the day-to-day pooling method, the daily residual sign and slope were examined for differences and pairwise multiple regressions were performed to examine the amount of unique variance that could be attributed to each method. Further, to assure the validity of the regressions, the data were examined to assess the degree of auto-correlation.

Findings

The graph of the daily scores obtained from each of the pooling methods and the regression results showed little difference among the methods. Additionally, the tests for auto-correlation were negative and none of the pairwise comparisons of regression parameters showed significant differences. The day-to-day sign and trend comparisons also revealed that no pooling method consistently produced results different from those obtained by any other pooling method. Finally, the pairwise multiple regressions showed that only 4 of the 48 $R2$ changes obtained for each pooling method when added to each other method were significant, and that these few differences exhibited no consistent pattern.

Interpretations

For these data it appears that any one of the three pooling methods would be acceptable, since the method of pooling had no significant effect on the analysis results. These data, however, were somewhat unique in that they did not exhibit any daily difficulty trends and in that each group of students had taken the same set of daily items. Other researchers have found that when there are daily trends in item difficulty, analyses completed on data pooled using the MS method produce different results than analyses completed on the data pooled using the DS method. Further, if students from both groups did not receive the same set of items on each day, the Rasch procedure would be the only method that could provide valid pooled scores. For these reasons, and for the theoretical support it adds, the Rasch pooling method was suggested as the method of choice.

ABSTRACTOR'S ANALYSIS

This is a very cohesive report of a well designed measurement study. The author poses a practical measurement question: "How should daily scores be pooled?" and uses science education to answer it. Appropriate and rigorous statistical techniques are used in the analyses, and the author is careful to not over-extrapolate from his findings. Further, he is particularly adept at providing intuitive descriptions of some of the less common analyses to help the reader understand what purpose each statistical test serves. The comprehensive statistical testing produces an almost overwhelming amount of tabular data -- six tables and one figure in nine pages -- but it is presented clearly and is all relevant to the study goals.

The paper is a little unusual in that it is strictly a measurement study. It really contains no science education content. It does, however, serve a very real need for the science education research community. The time series approach to science education is reasonably new (Mayer and Lewis, 1979) and very few researchers have tried to incorporate it into their research designs. The technique needs to have more exposure in the literature and the various details of how to practically implement this type of design need to be worked out. This paper does just that.

A serious problem in the daily item approach utilized for time series data collection is how to pool the data, and the author presents and tests three alternative solutions. In the spirit of a measurement study, however, the author may have been better off generating contrived data sets to represent the biases that might occur and then showing the effect of the pooling method. This would have eliminated the problem of finding no difference between methods and then having to say things like; if the daily items exhibit difficulty trends, the pooling methods do produce different results. It appears to me that the author was trying to support the use of the Rasch method of pooling scores (something I agree with), but his data set did not provide the opportunity to fully demonstrate the flexibility and superiority of this method.

Another valuable addition in the measurement vein would have been a more in-depth discussion of the Rasch pooling. The author did do a brief presentation of the Rasch formula which was consistent with his succinct style, but since Rasch modeling is also a fairly uncommon approach in science education research, more explanation would have been helpful. Of particular value would have been an actual example of how such pooling would be done, incorporating advice on how to interpret the logarithmic values. Also, a sentence or two about the heuristic case supporting the use of the Rasch method would have been beneficial.

The time series approach offers a rich new technique for science education research, and this study helps to make the approach more accessible. This and other science education studies using the time series approach may be combined to confirm the validity of this technique. Mayer and Lewis (1979) conducted one of the first science education studies using this technique and in doing so they pointed out some of its advantages and its feasibility for research. Mayer and Kozlow (1980) compared the use of daily one-item tests with daily three-item tests and in doing so further demonstrated that this data collecting procedure could be used for measuring concept understanding. Mayer and Rojas (1982) reported that the frequency of testing (daily) had no effect upon the measurement of achievement and thereby curtailed criticism of the technique on that account. Willson (1982) provided an excellent discussion of the time series technique and provided an example of formal analysis using Mayer and Kozlow's data. Most recently, Farnsworth and Mayer (1984) demonstrated the effectiveness of the time series approach in differentiating among students of different reasoning levels.

Although, as shown by these studies, the time series approach appears to have great potential, there are still some limitations. There are some difficulties in quantifying comparisons, e.g., comparing correlations and examining graphs, in obtaining sufficient numbers of data points to meet theoretical concerns and in accessing appropriate software. Further, none of the studies have as yet actually used the technique to answer science education research questions. The studies, like the one reviewed here, have focused on measurement and validation issues. More directed science education investigations are needed to adequately demonstrate the feasibility of this approach and to encourage its use by science education researchers.

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Thomas, G. E. "Cultivating the Interest of Women and Minorities in High School Mathematics and Science." Science Education, 70 (1): 31-43, 1986.

Descriptors--Blacks; Females; Higher Education; High Schools; *Mathematics Education; *Performance Factors; *Racial Differences; *Science Education; *Sex Differences; *Student Interests

Expanded abstract and analysis prepared especially for I.S.E. by Marsha Lakes Matyas, Office of Opportunities in Science, American Association for the Advancement of Science.

Purpose

The purpose of the study was to determine "...what underlying factors are associated with students' interest in mathematics and science" and whether these factors "differ for men and women or for blacks and whites" (p. 32). Specifically, it was hypothesized that the following variables would be positively and significantly related to students' interests in mathematics and science: academic achievement, encouragement from significant others to pursue mathematics and science, early interest in math/science-related hobbies, and high educational aspirations and occupational goals.

Rationale

The data used for this study were derived from a larger study of students' college major choices and career orientations. The current study was based upon the wealth of research investigating sex and race differences in science and mathematics interest, achievement and participation. Specifically, the author details current knowledge of the relationships between interest in science and mathematics among females and minorities and the following factors: academic performance in mathematics and science, exposure to adult mathematics/science role models, encouragement to pursue college math/science majors, teacher praise for academic success, childhood interests in science hobbies and careers, educational aspirations, occupational expectations, and participation in high school science/math clubs.

Research Design and Procedure

This non-experimental study utilized a mailed survey with two follow-ups. The survey was mailed to junior and senior undergraduate students majoring in a wide variety of science and non-science majors at one of eight South-Atlantic colleges and universities. Selection procedures for the initial sample were not detailed further. Overall response rate was 43% (N = 2, 046). A large proportion of respondents were black (44%); distributions of respondents according to sex and college major field were not given.

In addition to those variables listed earlier, participants also provided information on parental income and education, high school math and science grades, and race/sex of high school math/science teachers. None of these latter variables were significantly related to the dependent variables and, therefore, were not included in further data analyses.

All independent and dependent variables were assessed by single items; most utilized either a dichotomous ("yes/no") or 5-point Likert-type scale. High school grades and SAT scores were self-reported and occupational expectations were coded by Duncan SEI scores. Neither reliability nor validity data were provided for any of the variables.

Findings

Item means, standard deviations, and inter-item correlations were not detailed in the study due to space constraints. Rather, the author chose to utilize multiple regression analyses as "an exploratory and comparative technique as opposed to a causal and predictive method for examining variable relationships" (p. 35). Separate regression analyses were conducted for the total sample, males, females, blacks, and whites for each of the two dependent variables.

Science interest. Regression analyses for each group indicated that early interests in science hobbies, early aspirations to be a scientist, and encouragement in science were related to science interest at the high school level. Few differences were found between males and females and between black and white students. For the total sample, neither race nor sex were significant factors in high school science interest. Percent variance in science interest explained by the equations ranged from 45% to 50%.

Mathematics interest. The equations for mathematics interest explained considerably less variance in expressed interest (16% to 22%) than did those for science interest; according to the author, this was primarily due to the failure to include measures of childhood mathematics hobbies and career aspirations in the survey. In each of the five equations, mathematics interest in high school was positively related to mathematics encouragement, high school grades, and participation in high school mathematics club. For the total sample, higher SAT scores were also related to greater mathematics interest and race was a significant variable as well.

In sum, the findings confirmed the hypothesized relationships between mathematics and science interests in high school and academic achievement, encouragement, and math/science hobbies, but did not confirm a significant relationship between mathematics/science interests and either high occupational goals or educational aspirations.

Interpretations

The author indicates that, although the study is exploratory, it has "important policy implications":

- Since interests appear to develop at an early age, encouragement at home and at school must begin during preschool and elementary school;
- Programs to increase mathematics participation, interest and skills may be more effective if instituted at the junior high school level, rather that at the high school level;

- Informal participation in mathematics through math clubs and other programs should be encouraged, especially for minority students; and
- Further data should be collected on a national scale at both the junior and senior high school levels in order to increase the generalizability of the current findings.

ABSTRACTOR'S ANALYSIS

Thomas's study seeks to expand our understanding of the factors contributing to science and mathematics interest at the high school level. The study includes many of the factors known to be related to science and mathematics interests among women and minorities and their inclusion in the study is well-justified by the author in the review of previous research. Ultimately, the study reconfirms some of the findings in previous literature with a different sample of subjects. However, the strength of these findings and their generalizability to other populations are somewhat limited by the methodology employed. Specifically, the following questions must be raised:

1. <u>How did the sample selection affect the results?</u> Since the sample was selected for a study of college major choice, data for the current study reflect junior and senior college students' retrospective look at their high school attitudes and perceptions. This strongly limits the validity of accepting the results as indicative of the actual perceptions of junior and senior high school students and of using the results to justify strategies for students at the junior/senior high school levels.

   Second, although the initial sample of students who received surveys included both science and non-science majors, the composition of the final respondents (in terms of primarily science or math-related majors who have been interested in science/math since elementary school (for example), then the validity of generalizing to junior/senior high school students who have little interest in science and math is, again, questionable.

2. How did the instrument influence the study results? Since the respondents were asked to complete and return the survey voluntarily, the survey length was, of necessity, brief. However, then single items (with no estimates of reliability or validity) are used to assess attitudes and perceptions, extreme caution should be used when interpreting results, generalizing findings, and suggesting actions based on those findings.

   The measurements of the dependent variables point out how a single item assessment potentially can confound results. The dependent variables for the study were "interest in high school science" and "interest in high school math," yet the two items used to assess these interests asked students to indicate "...the extent to which they like high school mathematics and science" (p. 35). The assumption is that "interest is equivalent to liking," yet these perceptions may be influenced differently by in-school factors (such as the quality and style of individual teachers, the quality of available facilities and equipment, and the curriculum) and out-of-school factors (such as clubs, extracurricular activities and jobs, family activities, and hobbies). In sum, the exclusive use of single item assessments in the survey instrument may limit the validity of the findings.

3. How were results interpreted? Understandably, space constraints prevented the inclusion of item means, standard deviations, and inter-item correlations. However, an indication of the extent of inter-item correlation would have been useful since beta-weights were interpreted as though the independent variables were not significantly intercorrelated. If inter-item correlations were large, direct comparison of beta-weights may not have been warranted.

Finally, the author suggests a variety of intervention strategies. These are all well-grounded in previous research and are supported by the current findings. As the author suggests, it will be necessary to reconfirm the current study findings with a younger sample of students.

MISCONCEPTIONS

Hackling, Mark W. and David Treagust. "Research Data Necessary for Meaningful Review of Grade Ten High School Genetics Curricula." Journal of Research in Science Teaching, 21 (2): 197-209, 1984.

Descriptors--Cognitive Development; *Concept Formation; *Concept Teaching; *Genetics; Science Curriculum; Science Education Research; Science Instruction; Secondary School Science

Expanded abstract and analysis prepared especially for I.S.E. by Angelo Collins, Stanford University.

Purpose

The research reported in this article has two stated purposes. The first is to identify which concepts and propositions are necessary for students to comprehend the mechanisms of inheritance at the level of sophistication of meaning expected of grade 10 high school students in Western Australia. The second is to identify which of the inheritance concepts and propositions are most frequently not understood or misunderstood and therefore limit students' understanding of the mechanisms of inheritance.

Rationale

In the literature review, the study is placed in the framework of research on students' misconceptions in science both before and after instruction. References are made to research in students' misconceptions in science, to research in teaching and learning genetics, and to a study that identifies student misconceptions in genetics prior to instruction.

Research Design and Procedure

As would be expected from the purposes of the research, the study has two phases. In the first phase, the identification of concepts and propositions necessary to comprehend inheritance, three lecturers in science education identified such concepts and prepared concept maps. These concept maps and the Teacher's Guide for the Lower Secondary Science Genetics topic from the Education Department of Western Australia were analyzed to identify a sequence of 18 propositions which would lead to an understanding of inheritance. For example, the first proposition is that the mechanism of inheritance passes characteristics of parents to offspring during reproduction. The 18 propositions were cross-validated by tertiary lecturers in genetics and secondary biology teachers.

The second phase of the study, the identification of the concepts and propositions most frequently not understood or misunderstood by students, had three steps - the design of an interview for students derived from the propositions and concepts identified in the first phase of the research, the administration of the interview, and the analysis of the data from the interviews. A semi-structured interview protocol, the Inheritance Concepts and Propositions Interview, was designed to explore and assess students' understanding of the 18 propositions and of five concepts - inheritance, locus, meiosis, fertilization, and mitosis. The interview instrument was refined through three iterations of pilot testing. In the final form, the interview questioned students about subideas of the concepts and propositions. Content validity of the interview instrument was ensured by reliance on the previously validated 18 propositions; construct validity was obtained by the evaluation of the instrument by three science educators. The interview instrument consisted of a set of figures shown to students and a series of statements and probing questions on cards that were read by the interviewer. Many of the probes required students to apply their understanding to explain a novel situation. When students were asked to make a judgement of any kind, they also were asked to explain the reasons for their judgement.

Forty-eight students in grade 10 (15 years old) from six different schools and from 13 different science classes in the Perth metropolitan region were selected by a modified random sampling technique to be interviewed. The interviews of the individual students were conducted several days after these students had completed six weeks of instruction on genetics. The instruction followed the Teacher's Guide used in the process of identifying the propositions necessary for understanding genetics. The instruction focused on the mechanisms of inheritance. Each interview was tape recorded.

In the analysis of the data, each of the subideas probed by the interview was identified and listed. The tapes were replayed and each of the students' responses was coded. There were four possible categories for coding students' responses: comprehension and/or application, recall, lack of knowledge, and misunderstanding. The reliability of the coding procedure was determined by both interrater and intrarater reliability. The judgement of the primary investigator coded some data on separate occasions, 96% of the student's responses were scored identically.

Findings

A table presents the results of the data analysis. The table consists of six columns: 1) the concept or proposition number; 2) the statement of the concept or proposition presented as a series of subideas; 3) the percent of students able to comprehend the subidea of the concept or proposition; 4) the percent of students able to recall the subidea of the concept or proposition; 5) the percent of students who were inconsistent, contradictory, or unable to recall or comprehend the subidea of the concept or proposition; and 6) the percent of students whose respor es in the interview indicated they misunderstood the subidea of th concept or proposition.

Two statements summarize the data. First, less than 25% of the students in the study fully comprehended eight of the propositions considered essential for understanding genetics. "Fully comprehend" means that a student did not comprehend at least one of the subideas of the concept or proposition. Second, nine misconceptions were identified as being held by 25% or more of the students in the sample; three of these misconceptions were held by more than 50% of the students.

Interpretations

The discussion of the results of the study is presented in four sections: 1) the idea of inheritance; 2) the influence of genes and environmental factors on the development of individuals and their features; 3) alternate forms of genes and the role played by chance in inheritance; and 4) the pairing of genes and chromosomes, and the separation of gene and chromosome pairs during meiosis.

In some instances the discussion includes possible explanations for the data. For example, one explanation for the high percentage of students able to comprehend four of the propositions is that these propositions could have been learned from the experiences the students had with their own families. Propositions that high percentages of students were not able to comprehend were more likely to be related to abstract phenomena. Students having direct experience with a phenomenon was also offered as the explanation for why a higher percentage of students was able to comprehend propositions about environmental causes of features than about genetic causes. In another instance, the fact that few students were able to comprehend the number of genes involved in the control of the development of a feature was explained by general conversation with the teachers of the students in the study that indicated that the concept and propositions associated with polygenic inheritance had not been taught. Two possible explanations were offered for the fact that sixty-five percent of the students were unable to comprehend that different types of cells had the same genes - that students did not understand the role of mitosis in growth and nor did they understand the nature of gene regulation.

Considerable discussion is given to the difficulties students had in comprehending the nature of chance in reproduction and inheritance. Tentative explanations for these result were not offered. However, two statements were made about the teaching of phenotypic ratios: that the teaching of phenotypic ratios appears to be detrimental to students' understanding of the role of chance in inheritance; and that the idea of phenotypic ratios is of historical interest but has limited applicability to human genetics.

In the discussion, some of the data were used to corroborate other studies. For example, while the majority of the students understand that chromosomes and genes occur in pairs, most students do not understand that gametes carry one chromosome and one gene from each pair. This finding agrees with studies of student understanding in genetics conducted in Nigeria and in the United States.

Two other points from the data emphasized in the discussion were that the idea that the sperm carries the genes for half the features found in an offspring, while the egg carries the other half is a common misunderstanding, and that students find it very difficult to explain the meaning of the terms dominant, recessive, and blending inheritance.

Lastly, several important implications from the study for teachers and curriculum developers are presented. First, the 18 propositions provide a framework for planning instruction and evaluating curricula. Second, that the common misconception that gametes carry pairs of genes and pairs of chromosomes might be less prevalent if a concrete genes-on-chromosome model was used for teaching genetics. Third, that phenotypic ratios be de-emphasized in the teaching of genetics as they have little relevance for human genetics. Fourth, that mitosis be taught in the context of growth and development. Fifth, that students' ability to comprehend the mechanisms of genetics is limited by the abstract nature of the concepts and the extent to which teachers can illustrate the nonperceptible attributes of these concepts. As a result of the low level of comprehension of students in Western Australia, and similar difficulties in other English-speaking countries, the issue of the suitability of teaching the mechanisms of inheritance to grade ten students is raised but not discussed.

ABSTRACTOR'S ANALYSIS

Several articles about studies in teaching, learning and problem-solving in genetics were published between 1980 and 1984. In addition to this article and the references to the research of Stewart (1980) and Stewart and Dale (1981) made in this article, there were other articles on students' difficulties in understanding genetics. For example, Johnstone & Mahmoud (1980) identify student problems with probability, the meaning of the term dominance, and the relation between chromosome behavior in meiosis and gene behavior in inheritance. Kinnear (1983) describes the student misunderstanding of probability in genetics as being deterministic probability. Other studies include those by Longden (1982), Peard (1983), Radford and Bird-Stewart (1982), Stewart (1982), and Tolman (1982). In light of this research, the results of this study are not especially new.

What makes this article most difficult to review now is the research findings about understanding and teaching genetics that have been published since 1984. A small number of researchers have continued to explore problems associated with student understanding in genetics and solutions to these problems. Included in this group are Collins (1987), Hildebrand (1985) Jungck & Cailey (1985) Kinnear (1986, 1987), Smith (1984), Simmons (1987), and Stewart (1988; Stewart & Dale, 1987; Thomson and Stewart, 1985), as well as Hackling himself (1988).

One result of the on-going research in teaching genetics is the concern about precision in language. In the current article, the terms characteristic, trait and feature apparently are used interchangeably. The term variation is not used at all in the article. Yet the relationship of trait to variation is analogous to the relationship between gene and allele. In another example of precise use of language, there are no such things as dominant genes. There are dominant alleles, or alleles that produce dominant variations. Language has also become more precise through many studies of students' alternate conceptions in natural science.

Although in the introduction the study is placed in a framework of alternate conceptions, the language used in the article assumes a Piagetian framework. For example, a reference is made to concrete operational thinking. Because the study is placed in the alternate conceptions framework, it would be of value to see a comparison of the misconceptions of students after instruction identified in this study and the misconceptions of students prior to instruction referred to in the study by Kargbo, Hobbs, and Erickson (1980). One wonders which, if any, misconceptions are the result of instruction.

One question about the validity of the study is the identification of the sequence of eighteen propositions a student needs to comprehend to understand the mechanisms of inheritance. Despite the knowledge and experience of three science educators, the authors of the Western Australia Teacher's Guide, some tertiary lecturers in genetics, and some secondary biology teachers, the knowledge structure of the mechanics of inheritance is too complex to be reduced to a sequence of 18 propositions. Reducing the content knowledge of the mechanisms of inheritance may have seemed reasonable five years ago, but is no longer valid. There are several reasons this list may be questioned. Even the authors have difficulty with this linear sequence. First, they have asked the science educators to draw a concept map, which is a non-linear representation of knowledge. Later, they have to break the propositions into subideas to analyze the student responses. This may be indicative that a list of propositions is not an adequate representation of the knowledge needed to understand the mechanisms of inheritance. Another reason to question the validity of the list is the obvious absence of concepts, both alone and situated in propositions, usually associated with understanding the mechanisms of inheritance. Such concepts include homozygosity and heterozygosity, and segregation and assortment. Lastly, with the acknowledgement that much of their knowledge may be tacit and that they may speak jargon, it would seem necessary to ask geneticists to contribute to a listing or mapping of their area of expertise.

Although some may question the validity of the research because of the smaller number of students in the sample, the number is adequate for the research design. The design is appropriate to answer the research questions.

There are two aspects of the written report that are unclear. One is the nature of the genetics being taught. In one place it is stated that the topic focuses on mechanisms of inheritance and applications of genetics to medicine and agriculture. Later, it is suggested that chance is not important because it is difficult to understand when referring to human genetics. It would be very helpful to be able to see a list of the subtopics included in genetics in the Teacher's Guide.

Second, it would be helpful to the reader to be able to trace a question in the Inheritance Concepts and Propositions Interview, through some samples of students responses, to the assigning of a code and the identification of a misconception. For example, I would be interested to read the phrasing of the question and the student responses that provided the link between the proposition that chance determines what genes/features the baby will have and the misconception held by 25% of the students that all children produced by a pair of hybrid parents will have the dominant trait. It is noteworthy that, although the student misconceptions were derived from the interview, there is such unanimity of misconceptions. The origin of these common misconceptions is worth studying.

The report concludes by raising the issue of the suitability of teaching the mechanics of inheritance to grade 10 students. In this article, it is shown that grade 10 students have not been successful in comprehending eight of 18 propositions essential for understanding the mechanisms of inheritance. It is further stated, in the discussion and implications section of the written report, that this situation exists because students are unable to comprehend the propositions. It is further stated that students cannot comprehend genetics because they are limited to concrete operational thinking. In other words, the problem is the students'. However, it may also be that the students brought misconceptions to the course of study which were not addressed and therefore persist. Or the students may not have been taught the content in a manner that was clear and explicit and allowed them to build meaningful knowledge.

However, as mentioned previously, the problem may be with the propositions. It may be that the complexity of the knowledge required to understand the mechanisms of inheritance was not considered in the design of curriculum and instruction. (See Collins, in press.) It is also possible that the problem may be a problem of instruction. It should not be unexpected that students who have been taught a complex subject in a linear fashion may not fully comprehend. Or, as was indicated earlier, certain concepts and propositions may not have been taught. Also, the lack of precise language used in the written report may be a reflection of a lack of precise language in the Teacher's Guide or in the language used in instruction. Cho, Kahle, & Nordland (1985) have indicated that one source of student misconceptions is the lack of precise language used in textbooks. It is important in research on student misconceptions to be sure that the source of the misconception is the student's lack of understanding and not the result of inaccurate or inadequate instruction of complex content.

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Cho, Hee-Hyung, Jane Butler Kahle, and Floyd H. Norland. "An Investigation of High School Biology Textbooks as Sources of Misconceptions and Difficulties in Genetics and Some Suggestions for Teaching Genetics." Science Education, 69 (5): 707-719, 1985.

Descriptors--Biology; *Concept Formation; *Genetics; Science Education; *Science Instruction; Secondary Education; *Secondary School Science; *Textbook Content; Textbook Research

Expanded abstract and analysis prepared especially for I.S.E. by David R. Stronck, California State University, Hayward.

Purpose

The purpose of this article is to make recommendations for the reduction of students' misunderstandings of genetics that are occasioned by inadequacies in the most commonly used high-school biology textbooks. Teachers are encouraged "to design more appropriate instructional materials."

The hypothesis presented is that genetics is considered to be difficult by secondary-science teachers and high-school students because the most commonly used high-school biology textbooks promote many misunderstandings. Several studies (e.g., Finley, Stewart, & Yarroch, 1982) are cited to provide evidence that genetics is considered difficult. Most of the article by Cho, Kahle and Nordland is an explanation that the textbooks inadequately present many concepts. This explanation suggests to the reader that the students will become confused and therefore will assume that genetics is difficult to understand.

Rationale

The authors use the term "misconception" to identify "any conceptual idea whose meaning deviates from the one commonly accepted by scientific consensus." Several studies have identified misconceptions in genetics and attempted to ascertain the sources of these difficulties. Fisher (1983) and Stewart (1982) reported that students may understand individual concepts but fail to relate between and among them.

Tolman (1982) observed that students frequently misunderstand the relationship between a pair of alleles and chromosomal movement in meiosis. He recommends that textbooks should include in the discussion of meiosis the terms commonly associated with genetics (such as dominant, recessive, homozygous, heterozygous, genotype, and phenotype). Similarly Logden (1982) observed that the students (1) fail to relate the timing of chromosomal division with that of DNA replication, and also (2) fail to relate homozygous or heterozygous alleles with dominant or recessive traits.

Students often have difficulties with solving mathematical problems of genetics. Kinnear (1983) described most of these problems as coming from the students' treatment of "genetic ratios as deterministic rather than probabilistic." (p.84). They fail to apply chance events to genetic problems and fail to recognize the probabilistic nature of meiosis.

The authors summarize the major learning problems in genetics (identified by previous research studies) under the following four categories: "A. Conceptual organization, particularly sequencing of topics; B. Conceptual relationships; C. Use of terms; and D. Mathematical elements."

Research Design and Procedure

The research design is to assess the most widely used high-school biology textbooks for the four categories of misconceptions identified above. The following three texts were considered because they were used by more than two-thirds of the students in high-school biology classes (Hurd, et al., 1980): (1) Biological Sciences: An Ecological Approach (BSCS, 1978); (2) Biological Sciences: An Inquiry into Life (BSCS, 1980); and (3) Modern Biology (Otto, Towle, & Bradley, 1981).

Findings

The authors conclude that the four major categories of student misconceptions were found in each textbook. The textbooks are the source of the misconceptions for students because the textbooks are the curriculum for most science courses (Hurd, Bybee, Kahle, & Yager, 1980).

A. Conceptual Organization.

All of these textbooks treated meiosis and genetics in separate chapters. There is no assistance to relate meiosis with genetics and the genetic material of chromosomes.

B. Conceptual Relationships.

None of the textbooks show when and how chromosomes doubled to form two chromatids from each of the homologous chromosomes. Nor did any of the textbooks relate homozygous to dominant (and heterozygous to recessive) in terms of alleles. The three concepts of (1) chromosomal division, (2) alleleic segregation, and (3) independent gene assortment are discussed in different parts of the texts without any attempt to interrelate them. None of the textbooks say that more than one gene may be responsible for a trait.

C. Use of Terms.

All of the textbooks use the terms allele and gene interchangeably. Only one of the textbooks provides the current understanding of the gene-polypeptide relationship adequately. All of the textbooks describe the term mutation with such adjectives as "rare," "harmful," and "recessive." Modern Biology describes all mutations as harmful to individual organisms.

D. Mathematical Elements.

All of the textbooks give the Punnett square as a mean of solving problems involving two or more traits. But none mentions the limitations of using the Punnett square or relates it to the random segregation of chromosomes and independent assortment of genes. All of these textbooks encourage a rote procedure with the Punnett square, leading to the likelihood of assuming perfect and fixed ratios. None refers to the events which form the basis of the predictions with an emphasis on probability.

Interpretations

The authors propose a variety of ways to improve the treatment of genetics in textbooks:

A. Conceptual Organization.

The assimilation theory proposed by Ausubel, Novak and Hanesian (1978) recommends proceeding from the generalized concept to more specific information and therefore from genetics to meiosis to chromosome theory. The instruction should stress linkage among the concepts.

B. Conceptual Relationships.

Students will be able to develop more advanced and sophisticated concepts only when they understand scientifically correct relationships among reductional division, allelic segregation, and gene assortment. Textbooks need to state clearly that chromatids result from DNA replication. The following terms should be defined in such a way as to emphasize relationships: alleles, gene, DNA, chromosome, trait, gamete, and zygote. For example, an allele is best defined as "one of the many possible forms of a gene." A gene is "a segment of DNA on a chromosome." A gamete has "only one homolog and, therefore, one allele of a gene."

C. Use of Terms.

The analyzed textbooks used interchangeably the terms allele and gene. The most commonly misused terms were allele, gene, and mutation. Teachers must correctly define these terms and correct the errors of the textbooks.

D. Mathematical Elements.

None of the textbooks discusses the limitations of using a Punnett square or the probability approach to solving genetics problems. Teachers need to present the probability approach in order to show correctly how gametes are involved in genetic crosses.

ABSTRACTOR'S ANALYSIS

In recent years there have been many excellent studies done in the area of misconceptions and difficulties in learning. Studies done in physics pioneered this area, e.g., "Problems in Understanding Physics (Kinematics) Among Beginning College Students - With Implications for High School Courses" (McDermott, 1982) and "Conceptual Development Research in the Natural Setting of a Secondary School Science Classroom" (Minstrell, 1982). These studies in physics clearly demonstrated how preconceptions can block learning.

The article by Cho, Kahle and Nordland mentions preconceptions but does not demonstrate that the difficulty in learning genetics is from the students' preconceptions. This article describes that the difficulty with genetics comes from errors and confusing oversimplifications in the textbooks. The greatest mistake found in the textbooks is the omission of relating terms among the areas of reductional division, allelic segregation, and gene assortment. The most widely used high-school biology textbooks may be described as an encyclopedic collection of unrelated and unclear definitions.

An excellent summary of errors in textbooks is found in A Conspiracy of Good Intentions: America's Textbook Fiasco by Harriet Tyson-Bernstein (1988). She observes: "Textbooks have gradually lost overall coherence. Even important topics are treated so skimpily that a beginner often fails to get the point. Under current selection procedures, those responsible for choosing the best among available books seem blind to the incoherence and unreadability of the book because they are merely ascertaining the presence of the equired materials, not its depth or clarity. It is therefore more profitable for publishers to include everything in the 'bid-specifications' of ten or fifteen major market areas, whether or not students can actually get any pleasure or meaning out of the text."

During the last year, a new monthly publication, Bookwatch, has been providing detailed reviews of textbooks. In general, the reviews have condemned textbooks as encyclopedic lists of unrelated and incorrectly defined terms. For example, Lawrence Swan (1988) found Heath Life Science 1987 "loaded with errors, misleading omissions, and confusing inconsistencies." Cho, Kahle, and Nordland have found the same problems in the treatment of genetics by three textbooks. They have contributed to the growing literature that condemns textbooks' incoherence and failure to develop concepts.

The National Science Foundation (NSF) well recognizes the disaster in textbooks and has attempted recently to change the situation through the "Troika" program. This program requires the development of new curriculum materials by the cooperative efforts of three groups: (1) a major national publisher, (2) scientists and science educators, and (3) schools providing field testing and review of each draft of the materials under development. In 1988, the NSF funded eight projects for the development of elementary-school curriculum materials.

Unfortunately the Ohaus Scale Corporation has withdrawn its support from the "Full Option Science System" although it orginally committed $2.4 million to this Troika project. Other publishers are now showing resistance to cooperating with Troika plan. The publishers are forcing the NSF to delay or abandon the goal of funding Troika programs for the middle schools in 1989 and for the high schools in 1990. Publishers seem satisfied with the incoherent textbooks that now dominate the curriculum of the American schools. Perhaps great changes will not occur until the schools demand the type of revisions suggested by the NSF. States that adopt textbooks and teachers throughout the nation should demand a higher quality of textbook for science courses.

Cho, Kahle, and Nordland provide the following solution to errors and incoherence in the biology textbooks: "Identification of [the] sources [of misconceptions for students] should allow teachers to design more appropriate instructional materials." Unfortunately this solution seems naive because it assumes that most classroom teachers have the knowledge, time, and skills to produce new instructional materials that will replace their biology textbooks. Project Synthesis (Hurd, Bybee, Kayle, & Yager, 1980) explained that textbooks define the curriculum in most science classrooms because few teachers have the knowledge, time and/or skills to produce their own materials. Some science teachers write their own laboratory activities to make the most efficient use of avaiable resources. Very few are able to write their own texts or even units of study. Many biology teachers do not know enough about genetics to recognize the errors in the textbooks. There is a significant number of biology teachers who omit teaching genetics because they find the entire subject confusing both to themselves and their students.

Certainly we need better textbooks in biology. One major problem blocking the improvement of textbooks is the refusal of scholars to become involved in writing them. Harriet Tyson-Berstein (1988) has described "The Academy's Contribution to the Impoverishment of America's Textbooks." She defines this impoverishment as "topic glut, term mongering, name dropping, the indecent exposure of facts, and deadly prose." She explains that "real" scholars do not write textbooks because it is not considered "intellectual work" and does nothing toward getting tenure or promotion. Writing a textbook may prove harmful to an academic career. Mike Keedy, executive director of the newly formed Textbook Authors Association, has called this syndrome "publish <u>and</u> perish." Our national crisis with textbooks demands that universities adopt new policies toward the tenure and promotion of textbook authors. Perhaps legislation will be needed to provide external pressures for change on the universities. Ideally officials in the universities will realize that writing coherent, clear textbooks for high-school science is a difficult intellectual work.

The textbook enterprise in the United States is very complicated. Ideally, reform should start with demands from the science teachers. Unfortunately few teachers will read the article by Cho, Kahle, and Nordland or similar articles in <u>Science Education</u>, especially because the style of the article is unattractive to most teachers. The conclusions and recommendations of the article seem few and scattered through much dense prose. University professors who will be writing new textbooks should carefully read such articles and use the recommendations for the development of improved curriculum.

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Arnaudin, Mary W. and J. J. Mintzes. "Students' Alternative Conceptions of The Human Circulatory System: A Cross-Age Study." Science Education, 69 (5): 721-733, 1985.

Descriptors--Academic Achievement; *Biology; *Cardiovascular System; College Science; *Concept Formation; Elementary School Science; Elementary Secondary Education; Higher Education; Prior Learning; *Science Education; Science Instruction; Secondary School Science

Expanded abstract and analysis prepared especially for I.S.E. by John E. Penick, University of Iowa.

Purpose

This study examined conceptions of the human circulatory system as held by students at various grade levels from five through college.

Rationale

Based on the work of Selman and others (1982), this study looked at alternative explanations of cardiovascular concepts. Students are assumed to develop concepts about their environment, providing a rationale and consistent view. Many of these concepts, while being sensible, are not congruent with expert knowledge. But, since these alternative concepts are developed by the individual student, based on a personal interpretation, they are difficult to displace, even in the face of powerful evidence and teaching. Our ability to teach students accurate concepts provides one measure of success for our educational system.

Research Design and Procedure

Beginning with a naturalistic, constructive phase, the study progressed on to a validation phase. During the constructive phase, 25 fourth graders and 25 college freshman were trained in concept mapping. Then, given a list of eight cardiovascular concept labels such as heart and blood vessel, each of the 50 constructed a concept map of each label.

Using the maps as a basis for questions, students were then individually interviewed to determine their level of understanding on five cardiovascular concepts. These private interviews, lasting about 25 minutes each, provided additional data when students were asked to discuss various cardiovascular phenomena.

From these data, the researchers constructed student alternative concepts, those which were not scientifically acceptable. Alternative concepts were developed into a conceptual inventory providing 15 questions and response choices for a pencil and paper test instrument. Four of the items were open-ended. Following a choice, each student selected a word from a Likert-type scale to demonstrate confidence in the answer. A panel of experts reviewed all items for agreement with the various concepts and alternatives as well as for wording and meaning. Field testing with college biology students revealed an Alpha reliability for internal consistency to be 0.62.

During the second phase, 495 students, divided approximately equally among fifth grade, eighth grade, tenth grade, college freshman/non-biology majors, and college freshman/biology majors completed the 15 item inventory. All subjects were from one state university and nearby public schools in North Carolina. Analysis focused on response frequency by educational level.

Findings

In general, it was evident that more education does provide better congruence with accepted concepts. But, the frequency of alternative, incorrect responses was quite high at all levels. For instance, only 50% of college freshman/biology majors correctly reported the human heart to have four chambers and more than 10% report the heart to be a solid organ. Only 20% of those same biology majors were aware of the double circulation pattern; fully twice as many, when asked "what path does the blood take when it leaves the heart?", preferred "heart-lung-toe-heart." Students' confidence in their answers varied widely and had little relationship to the accuracy of the response.

Interpretations

Because relative frequencies of several incorrect concepts did not vary widely, the authors agree with prior research which indicates that concepts are difficult to change. Where there did appear some evidence of progressive learning, the authors felt the changes were "neither logical nor predictable."

In analyzing the concepts, the researchers note some, such as "function of the blood," probably require less restructuring of ideas than a concept such as "closed circulatory system." Part of this stems from the more readily accessible and concrete nature of some of the concepts. They further point out that teachers and texts may fail to emphasize the concepts which are least likely to change. Yet, they cite evidence that these concepts are amenable to change when confronted directly, especially as discrepant events.

Teachers who are aware of alternative concepts as held by students are in an excellent position to change them. But, they must establish a nonthreatening environment where ideas can be expressed. Rather than ignoring prior concepts, we must use, build on, and revise them.

ABSTRACTOR'S ANALYSIS

The authors' final statement, that "when students' prior knowledge is ignored, science is viewed as abstruse, difficult, incomprehensible, and irrational," reveals a major problem in education--our assumptions about the learners. Although no one believes in the Tabula Rasa hypothesis anymore, we often teach as though our students are, in fact, blank slates.

Arnaudin and Mintzes, in this paper, add a significant piece to the accumulating evidence of the extent of student misconception. By using a range of students from age 10 to 19 and a reasonably large sample size, we have a very nice picture of several progressions of concept development. This fits well with most prior studies which show that student concepts are rarely as we would like. While much of this is intuitively obvious to anyone who has seriously questioned students, it is important to document differences between student conceptions (even after instruction) and those we wish them to have.

In the arena of documentation, these researchers have done well by following the lead of Selman, Krupa, Stone and Jaquette (1982). In doing so, they help reveal both a technique, the structural-developmental model, and new and compelling evidence. This model, often used for instrument development, allows researchers to not only see concepts (via maps) but to follow up on ideas, pursuing them until finding weak points and ambiguity. While initial student concepts may seem sound, the slightest cognitive stress induced by a series of good questions will reveal voids, causing the concept, especially those developed verbally alone, to crumble (Almy, 1966).

The methodology of the study is one of its fine points and would be worthy of analysis for many endeavors. Certainly, in addition to being a way to do research, this same model would be quite beneficial to a teaching situation, both for students and teachers. As teachers, we can certainly do better when we eliminate our inappropriate assumptions about students. And, asking students to explain concepts while teachers continue to probe may well be the key to effective teaching. As students, the evidence is strong that we learn when confronted with unexpected events and ideas that must be accommodated and assimilated into our scheme of explanations.

Validity is always a problem in a study such as this. With a wrong answer in a multiple-choice format, one never knows for sure if the student is wrong, misguided, a poor reader, confused, or antagonistic. While interviews were conducted during the constructive phase of this research, none appear to have taken place in the validation phase. Without this, it is possible to have simple confusion. For instance, for concept number 1: structure of blood, the question is, "what does blood look like?" Many responded that blood is "a red liquid" while the desired response was "red cells in a straw-colored liquid." Few chose this latter response. And, looking at the original question, what should one answer? Seen with the naked eye, blood is a "red liquid", not "cells in a straw-colored liquid." Similar problems may also exist with other questions. Future research should, perhaps, include personal interviews with a sample of those who do not provide a correct response.

Further research on alternative conceptions would do well to spend more time on the constructive phase, attempting to seek explanation rather than documentation that ideas are wrong. While the numbers interviewed will be less, explanations will yield a richer variety and a better basis for analysis. Such explanations will also allow better development of pencil and paper instruments for use with large numbers of subjects.

Since this research focuses on concepts and all teachers are concerned with teaching concepts, this research holds much potential for laboratory-type studies comparing teaching strategies. What are effective strategies for teaching the path of blood flow? What misconceptions arise? How do students with alternative concepts respond to various teaching strategies and techniques? Do alternative concepts correct themselves or become buried under more confusion? How is any of this related to IQ, creativity, experience, expectations, or culture? Do exemplary teachers or programs, such as those identified by NSTA, do any better? Most important, what techniques, strategies, or activities best overcome these alternative conceptions?

This is a fertile area, one which has significant implication to teaching and teacher education. I look forward to more.

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ATTITUDES

Koballa, Thomas R. Jr. "The Effect of Cognitive Responses on the Attitudes of Preservice Elementary Teachers Toward Energy Conservation." Journal of Research in Science Teaching, 22 (6): 555-564, 1985.

Descriptors--*Attitude Change; *Communication Thought Transfer; Elementary School Teachers; *Energy Conservation; Energy Education; Higher Education; *Persuasive Discourse; *Preservice Teacher Education; Science Education; *Teacher Attitudes

Expanded abstract and analysis prepared especially for I.S.E. by Gerald H. Krockover, Purdue University.

Purpose

The purpose of Koballa's study was to "determine if subjects' cognitive responses to a persuasive communication are more highly correlated with attitude change than the recall of arguments presented in the communication using energy conservation as the content vehicle" (page 555).

Rationale

The rationale for this study was to investigate the relationship between persuasive communication and the persistence of attitude change. "The findings of several studies suggest that attitudes persist because the thoughts generated in response to the communication are remembered." (pp. 556-557) "It was hypothesized that the effectiveness of a persuasive communication is related to the evaluative content of the cognitive responses that is elicited and retained, rather than the communication arguments recalled." (page 557)

Research Design and Procedure

"Students (n-79) enrolled in several sections of an elementary science methods course participated as subjects in the investigation. A correlational method was employed in the investigation to explore relationships between changed attitudes, recall of the communication's arguments, and cognitive responses elicited and retained. No attempt was made to predict attitude change scores from subjects' recall of the communication's arguments or cognitive responses." (page 557) The investigation consisted of three experimental sessions utilizing preservice teacher attitudes towards energy conservation. The first experimental session consisted of administering the Likert-type attitude scale to all subjects. The second experimental session was conducted one week after the first. During the second experimental session, subjects listed their cognitive responses and the communication arguments that they could recall. At the conclusion of the second experimental session, the Likert-type attitude scale was re-administered. The third experimental session was conducted three weeks after the second. During this session, subjects listed the communication arguments and cognitive responses that they could recall. The Likert-type attitude scale was again administered.

Pretest and posttest attitudes were measured using the Attitude Towards Energy Conservation Scale. The two-sided communication used in this study presented both favorable and counter arguments concerning the importance of energy conservation and the need for elementary teachers to incorporate energy conservation topics into their teaching. The communication was presented in 10 minutes and 31 seconds using video tape. Subjects were provided with a series of seven boxes to list their thoughts or reactions as a method of recording their cognitive responses to the communication's main arguments. Subjects were provided with instructions concerning the recording of their cognitive responses after viewing the video taped communication. The written cognitive responses were scored. Juries were used to establish the reliability of the scoring scheme used by the investigator. Recall of the communication's main arguments and the subjects' cognitive responses was scored using a scoring scheme similar to one previously published. No control group was employed to verify the effectiveness of the persuasive communication.

Findings

Results indicated that the cognitive response score was significantly correlated ($p < 0.05$) with the Likert-type posttest immediately and three weeks following the communication. Recall of communication arguments was measured immediately after the communication in the second session and during the third session three weeks later. The findings suggest that cognitive responses and the recall of cognitive responses are significantly related to attitude change.

Communication recall, however, is not significantly related to attitude change. This study supports an increasing body of data indicating that attitude change is not dependent upon the learning of communication content.

Interpretations

This study, along with those of other studies, is consistent with the hypothesis that cognitive responses to persuasion moderate attitude change. Recall of communication content, on the other hand, does not appear to be directly related to attitude change.

ABSTRACTOR'S ANALYSIS

This study serves as an excellent model for the type of research that should be fostered in science education. It is well designed, has excellent supporting literature, is well thought out, and does not extend the results beyond the interpretations possible. In fact, the author is to be commended for indicating that "the data collected in the present correlational design are necessary, but not sufficient, to establish a definite relationship between cognitive response and attitude change in the milieu of science education." (page 561) Further experimental support is needed. In addition to the present type of correlational results, such support requires "(a) research in which systematically designed persuasive communications elicit different cognitive responses leading to differences in attitude change, and (b) research demonstrating that cognitive responses elicited by persuasive communications are responsible for a significant portion of the cognitive components of subjects' post communication attitudes. Both of these types of results have already been obtained by social psychologists, but only in a laboratory environment using contrived issues." (page 562) Furthermore the author states that, "The present investigation appears to be a positive step toward identifying the factors that play a significant role in changing the attitudes of teachers toward energy conservation and other constructs of interest to science educators." (page 562)

The author has also provided a superb set of references that have been utilized to support and refute the concerns a reviewer might have with respect to the topic being investigated. Furthermore, the selection of the content topic of energy conservation as the vehicle to use in assessing the effect of cognitive responses on the attitudes of preservice elementary teachers is a superb choice. The content is not discipline specific, possesses the potential for science, technology and societal issues, and is a subject that has been and will be debated for a considerable period of time. Thus, the author's choice topic and study are commendable.

Several issues that researchers may wish to pursue in additional studies related to this field of research include: Are the responses derived from elementary science methods students typical of the responses one might expect from practicing elementary teachers? This study could easily be replicated utilizing a variety of sample populations that could serve to support the hypothesis presented by the researcher. Furthermore, the length of time that was involved in the three experimental sessions could also serve as an important point of investigation. Is a one week differential between the first and second experimental sessions sufficient when assessing attitude change? In the same manner, is a three week differential between the second and third experimental sessions sufficient to allow for the appropriate effects to occur? These are all questions that could be investigated by future researchers. In conducting further investigations, researchers should take note of the careful work that the author utilized in ensuring that his results were reliable and valid. This study does a superb job of increasing the knowledge base in science education regarding attitudinal research regarding cognitive responses.

Schibeci, R. A. "The Student Opinion Survey in Chemistry: Some Cross-National Data." Journal of Research in Science Teaching, 23 (1): 21-25, 1986.

Descriptors--*Attitude Measures; *Chemistry; High Schools; Science Education; *Secondary School Science; *Student Attitudes

Expanded abstract and analysis prepared especially for I.S.E. by Roger Hamm, California State University, San Bernardino.

Purpose

This study was conducted to validate the Student Opinion Survey in Chemistry (SOSC), one of many currently existing student science attitude scales. The study also compared cross-national data collected using the SOSC.

Rationale

Citing current calls for the renewal of science education and the Australian response of the development of the School Chemistry Project (SCP), this study was conducted to gather formative evaluation data. A slightly modified version of the SOSC was used as the data collection instrument. The SOSC was developed as part of the Interdisciplinary Approaches to Chemistry Project (Heikkinen, 1973). The modifications included replacement of one item and minor changes in the wording of items to be more appropriate for Australian secondary students.

The data collected were compared with data collected in studies by Sherwood and Herron (1976) and Heikkinen (1973).

The author assumed, in this cross-national comparison, that the populations were similar and that modifications made in the instrument did not significantly alter the instrument.

Research Design and Procedure

The sample used in this study consisted of 380 eleventh grade Australian students enrolled in high school chemistry as an elective subject. This sample was selected at random from each Australian state. This sample was selected to be similar to the comparison study (Heikkinen, 1973) in which 577 predominantly eleventh grade students enrolled in chemistry as an elective were used.

The School Chemistry Project was divided into four blocks and attitude data were collected at the end of each block, using the SOSC.

Sample mean and standard deviation were calculated for each set of data collected using the SOSC. Cronbach's alpha was determined to judge the internal consistency of the SOSC. Item-remainder correlation coefficients were computed. Factor analysis (principal components analysis with a varimax rotation) of student response data was conducted to provide data validating the SOSC.

Findings

The author reported an overall mean score on the SOSC of 69.5 with an overall standard deviation of 13.6. A high internal consistency on the SOSC was reported from the overall Cronbach's alpha of 0.93, with no value lower than 0.90. Item-remainder correlation coefficients ranged from 0.47 to 0.76, with the exception of a value of 0.33 for one item. Three items emerged from the factor analysis of the data. However, of these three items, Factor I accounted for approximately 81% of the variance.

Interpretations

From the analysis of the data the author reported that the mean and standard deviation on the SOSC of 69.5 and 13.6 respectively were quite similar to those reported by Heikkinen in his study: a mean of 69.6 and standard deviation of 15.6. The author concluded from these data that the SOSC appears to be an instrument which is potentially useful in cross-national research in chemistry education.

The author concluded from the Cronbach's alpha values that the SOSC had a high internal reliability. In addition, the author suggested that the data indicate that the SOSC can produce relatively reliable results in a test-retest sense. As a result, the author states that the SOSC is a worthy candidate for an instrument to assess student attitudes to chemistry.

Three factors emerged from the factor analysis. Of these factors, one factor accounted for approximately 81% (80.8%) of the variance. With this and the high value of the Cronbach's alpha, the author concluded that the instrument is a unidimensional instrument and justifies the simple summing of the responses on the individual items of the instrument as an index of the student's attitude toward chemistry.

ABSTRACTOR'S ANALYSIS

The author has raised a valid concern in this study. In the recent decade a headlong rush toward the improvement of science education has generated numerous programs for instruction in science and studies "proving" that each of these programs is significant in changing student attitudes toward the particular science. However, in many of these studies a particular course in science was developed and taught to a sample and the attitude measured using a scale specifically developed for the study. The result has been a plethora of science attitude instruments. This author raises a concern about the validity of these instruments and the usefulness of these instruments across studies. There is a need for studies similar to this to attempt to validate science attitude instruments and to identify a small group of instruments that can be useful to researchers across samples and science courses.

The author of this study has identified a useful technique for comparison of data collected across samples using one science attitude instrument. A methodology is also identified for examining the selected instrument in order to determine the validity of the instrument. Finally, the methodology selected was demonstrated on a grand scale (cross-national), but it can easily be utilized within a nation, state, or individual school system.

Although the author went to great effort to maintain similarity between samples used in the study, questions concerning validity can be raised in two specific areas. A major validity question arises in the similarity between the Australian School Chemistry Project and the Interdisciplinary Approach to Chemistry used in the comparison study. It is essential that the author indicate that the two courses being compared were indeed similar. Second, it would have been valuable to the author's case to more clearly demonstrate the exact changes that were made on the SOSC before it was used in his study.

The research design used in this study was appropriate for a study of this nature and intent. The addition of data collection prior to the implementation of the treatment would be valuable. Since the students enrolled in the chemistry course as an elective, it could be assumed that they already had a high attitude toward chemistry. The inclusion of pretreatment data would have been useful in determining the sensitivity of the SOSC to changes caused by the course. Pretreatment data would also have helped the author make some judgment about the worth of the course of study in respect to the students' chemistry attitudes. Finally, although this study made a qualitative comparison between data collected in two different studies, it would have been valuable for the author to identify the categories and criteria being utilized in the judgment process.

An adequate rationale was presented for conducting this study. As previously discussed, the study would benefit from the addition of more discussion and comparison of the two courses being compared. Additionally, the author should have expanded the section discussing the modifications of the instrument used in this study. Interestingly, the author elected to compare cross-national data using an attitude instrument. The current trend has tended to emphasize the need to increase student knowledge in science. The report on the research would benefit from a discussion to justify the selection of the SOSC and need to consider the effects of courses of instruction on student attitudes.

It is recommended that further research be conducted in an effort to identify a group of valid student attitude instruments for specific subject areas. Concurrent to identifying these instruments, an effort should be made to determine the technique, or techniques, of instruction that are most effective in bringing about positive changes in student attitudes toward science. A third line of research effort should address the need for considering the effect of science instruction techniques on student attitudes toward science with a focus on the effects of these various methods of instruction of the science intentions and science behaviors of the students.

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GENDER

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DeBoer, George E. "A Study of Gender Effects in the Science and Mathematics Course-taking Behavior of a Group of Students who Graduated From College in the Late 1970's." Journal of Research in Science Teaching, 21: 95-103, 1984.

Descriptors--*Academic Achievement; Elective Courses; *Enrollment; Females; Higher Education; High Schools; Mathematics Achievement; *Mathematics Education; *Science Education; Scores; *Sex Differences; Student Behavior; *Student Participation

Expanded abstract and analysis prepared especially for I.S.E. by Dale R. Baker, University of Utah.

Purpose

This study examined science and mathematics enrollment during hign school and college and focused on achievement, participation, and sex differences. The four hypotheses were: (1) Did men and women differ in the number of or performance in science and mathematics taken in college?, (2) Does a high level of participation and performance in high school mathematics and science insure a high level in college?, (3) Are the number of and grades received in high school science and mathematics related to participation and achievement in college?, (4) Are SAT math or verbal scores related to level of participation and performance in college sciene and mathematics?

Rationale

Statistics indicate that more women have entered technical fields during the last decade, but they still comprise only a fraction of the labor force. Consequently, researchers have tried to identify probable causes for these low numbers. Poor attitudes toward science, the priority of marriage and children, differential treatment in school science, and genetic differences in spatial and analytical ability have all been examined. None of these explanations have proven conclusive and the problem remains complex and unsolved.

Since participation and achievement in science are obvious prerequisites to technical careers, the author decided to examine sex differences in the effects of participation on performance and performance on participation.
Previous research led him to expect that (1) sex differences in participation would increase because more men than women would be preparing for technical careers, (2) a high level of participation in high school would not be strongly

related to college participation because of the boredom and difficulty of high school science and the esoteric and theoretical nature of college science, (3) successful performance might lead to continued participation or that a high level of participation might continue in college, and (4) given the importance of quantitative skills in science, students with high SAT math and low verbal scores would be more likely to enroll in science and mathematics courses.

Research Design and Procedure

A causal-comparative design was used to compare the high school and college transcripts of 269 men and 239 women at a selective liberal arts college. The subjects consisted of a 30% random sample who had graduated from the college during 1975, 1977, and 1979. The variables were science and mathematics courses taken in college and the grades received; number of years of high school mathematics and science and average grade in each area; number of students who completed high school biology, chemistry, and physics; and SAT math and verbal scores.

Analysis of covariance was performed to identify sex differences in participation and performance. Covariates were SAT math and verbal scores, performance, and participation levels. Multiple regression was performed by sex to determine the effect of predictor variables on outcome variables. The outcome variables were the decision to major in science, and the number of and grades earned in science and mathematics courses taken in college. The predictor variables were years of high school mathematics and science, average grades in high school and college courses, and SAT scores.

Findings

Students in this study exceeded the national average for science and mathematics courses taken in high school. Eighty-three percent of the women had taken chemistry; 41%, physics; 90%, three years of mathematics; and 56%, four years of mathematics. Eighty-eight percent of the men had taken chemistry; 71%, physics; 95%, three years of mathematics; and 73%, four years of mathematics.

This level of participation did not continue in college. Eighteen percent of the women and 13% of the men took no science. Women dropped from 3.13 years in high school to 2.21 years in college. Participation did not drop-off for men. The range also changed from three or four years of science in high school to zero to twenty courses in college.

In mathematics, the drop-off was greater. Men averaged 3.77 years in high school and 1.05 years in college. Women dropped from 3.51 years to .76 years. Participation dropped from 90% for women in high school to 51% in college and 95% for men in high school to 73% in college.

Men took more science and mathematics than did women in high school but did not perform as well. This pattern continued in college. Analysis of covariance revealed sex differences in performance levels in science and mathematics and in participation levels for science. A priori contrasts indicated that a preference for mathematics and science in high school continues in college.

Multiple regression indicated that grades in college science and mathematics were related to grades in high school science and mathematics as well as SAT math scores for men and women. SAT verbal scores also contributed to the prediction of college science grades. High school science grades contributed to the prediction of college mathematics grades for women. For men, the number of high school mathematics courses added to the prediction of college science grades.

The number of science courses in college was related to the number of science courses in high school for both men and women. SAT verbal and math scores added to the prediction of the number of college science courses for men, but not women. The number of mathematics courses taken in college by women was predicted by high school mathematics grades and SAT math scores. No variables were related to the number of mathematics courses taken by men.

Interpretations

Aptitude and performance do not explain the differences in the number of men and women who choose technical careers. Despite grades, women are not attracted to science and mathematics. Nevertheless, the decision to major in science is strongly linked to high school participation and grades in science for both men and women. The same pattern is true for women and mathematics, making early engagement in interesting, relevant courses important. Male participation in college mathematics is not linked to previous participation or grades. Men appear to be motivated to take mathematics because of career considerations regardless of past performance.

The decline in the number of science and mathematics courses between high school and college may be explained by two factors. First, astute students take mathematics and science in high school to increase college admissions opportunities. Consequently, participation drops once they have been admitted. Second, most college science and mathematics courses are not relevant or interesting to students. This seems to indicate that scientific literacy will not increase as a result of higher standards unless there is a change in college science courses.

Lastly, although there is a clear relationship between SAT math scores and taking mathematics and science in college the relationship of high SAT verbal scores to taking fewer mathematics and science courses is inconclusive.

ABSTRACTOR'S ANALYSIS

This paper was the first in a series by the author dealing with the relationship of participation on performance and performance on participation. As such, it laid the groundwork for subsequent research, raised new questions and led the author to use more sophisticated theoretical constructs and analysis techniques. It is important because it initiated and has become part of a systematic body of work.

It also represents a new attack on the complex problem of why so few women choose to enter technical fields. Although the author states that "....Participation and achievement in school science are obvious prerequisites for becoming career scientists..." until DeBoer began this line of research, the relationship of these two factors was not dealt with systematically in the science education literature.

However, using the number of high school science and mathematics courses taken and the grades received in those courses as a predictor of the number of science and mathematics courses to be taken in college may or may not prove fruitful in the long run. First, education is notorious for seesawing back and forth. We have gone from rigorous high school graduation requirements and college admission standards to lax graduation standards and open admissions, and back again. Consequently, the conditions under which a student in high school takes mathematics and science will affect the predictive value of these variables. If students voluntarily take mathematics and science courses in high school, then the likelihood that high school course taking behavior will be predictive of college course taking behavior is greater than if students are required to take a certain number of mathematics and science courses to graduate. Therefore, if future researchers use high school records as a source of data about prior participation, it will be very important to consider the educational climate of the time during which the subjects were in school, especially when interpreting the results. Failing to take such precautions could result in many contradictory studies. This situation would do more to confuse than clarify an already complex research question.

Other factors which may limit the predictive value of high school participation have to do with the highly selective nature of the private institution at which this study was conducted, and the fact that the author describes the institution as a liberal arts college. Students applying to large universities, less selective schools, or public institutions may have very different course-taking behaviors.

Although both the author and I are concerned about the generalizability of the findings, there are many good reasons for continuing this line of research. All caveats aside, the author has identified a very robust phenomenon that merits further examination in a variety of settings using samples which are drawn from different time periods. In addition, unlike many studies, the subjects' behavior in this investigation was followed over a span of eight years, contributing to the overall methodological strength of this research.

Another methodological strength of this work is that it is in the mainstream of investigations into why women do not choose technical fields. The findings add to what we know about sex differences in career choices and help explain the findings of others. In addition, the findings of DeBoer's research can also be explained by and related to the work of others.

Take, for example, the greater drop-off for women than men in college science and mathematics participation despite the women's higher achievement. Prior research has provided several explanations for this phenomenon. For many young women the motivation for good grades is more strongly related to wanting to please the teacher and/or pleasing parents than to subject matter interest or career goals. Women also attribute academic success to luck rather than effort and ability, while failures are the result of personal inadequacies. Consequently, for women, good high school performance does not necessarily have anything to do with their college performance. Indeed, their luck might change for the worse. In addition, doing well in science and liking science are not synonymous. Several studies which have focused on the junior high school found that girls who do well in science like the subject less than girls who are average to poor students.

Subsequent work by DeBoer indicates that the decision to take college science is based upon what a student believes his or her ability is. This belief or role specific self-concept is formed in high school. For women, this self-concept was unrelated to grades. Even though women received higher grades than men in high school, they rated their ability lower than men. He also found that the decision to continue taking college science beyond a first course is related to attributions of ability for both men and women. Feelings of competence were more important than measured aptitude, grades, or task difficulty.

The author has continued to pursue the question of the relationship of participation on performance and performance on participation using self-concept and a cognitive motivation model. However, the data collection techniques have been limited to the use of transcripts or short questionnaires of 4 to 8 questions which employ Likert scales. Further research directions and efforts suggest an expansion of the data collection techniques such as interviewing a sample of students after the initial analysis of high school or college transcripts and questionnaires.

For example, the author speculates that "...men feel that mathematics is important to their future careers and that this belief rather than aptitude or past achievement motivates them." He also states that "While the hard work and diligence of woman may result in the reward of a higher grade, this reward does not seem sufficient to attract women to science and mathematics courses to the same degree as men are attracted." Face to face interviews with men could confirm or disconfirm his speculation about motivation. Interviews with women might reveal why grades do not seem to be an adequate reward to attract them to science as well as what an adequate reward might be.

Indeed, Eccles suggests that we are approaching the problem of why women do not choose science from the wrong direction. Rather than asking why they do not choose science, we should be asking why they choose other options. Her model of occupational decision making suggests that women may not be avoiding science as much as they are choosing other activities that more closely reflect their interests and goals.

Additional questions might focus on the characteristics of high school science and mathematics instruction that caused many students to continue to take these subjects throughout high school. It seems contradictory to find that the more science and mathematics you take in high school, the greater the likelihood that you will take science and mathematics in college when the author and just about everyone else in education has commented on the boredom and irrelevance of high school science and mathematics classes.

Increasing the number of men and women who choose technical careers will only be successful when we understand the dynamic interactions of curriculum and instruction, interests and goals, role specific self-concept and other self beliefs, prior achievement and participation, and socialization. This paper has moved us another step in that direction.

Wittig, M., S. Sasse, and J. Giacomi. "Predictive Validity of Five Cognitive Skill Tests Among Women Receiving Engineering Training." Journal of Research in Science Teaching, 21 (5): 537-546, 1984.

Descriptors--Cognitive Processes; *Cognitive Tests; *Engineering Education; Engineers; *Females; Grade Point Average; Higher Education; *Mathematics Anxiety; *Predictive Validity; Science Education; Sex Differences; *Skill Development

Expanded abstract and analysis prepared especially for I.S.E. by Frances Lawrenz, University of Minnesota.

Purpose

This study examined the predictive validity of various tests for the success of women in a National Science Foundation (NSF) Career Facilitation Project and the independent contribution of these tests to the overall change experienced over the course of the project.

Rationale

The study was justified in the context of investigating reasons related to why so few women are in engineering and science careers. The Career Facilitation Projects were designed to update the skills of women with baccalaureate degrees in mathematics, science, and engineering who had not been employed in such fields for a number of years. Lantz investigated the projects and found a strong predictor for employment was the prospective employer's perception of the graduates' motivation level. Furthermore, she found that availability for work and financial need for work were important, but that the amount of previous related experience was not.

The authors develop the argument that existing aptitude screening or predictive tests are biased against persons not already in a particular profession. For example, the authors say, "Thus aptitude tests for such sex segregated careers as clerical worker and mechanical engineer are tests of skills shown by persons presently employed in those fields. These tests became filters for determining who is encouraged to train for these positions and thus may contribute to continued sex segregation." To counteract this bias, the authors propose that research strategies should not be so strongly tied to traditional definitions of success. In this study, then, the authors examine the predictive validity of a variety of assessment instruments.

Research Design and Procedure

The authors describe the design as one-group pretest-posttest. Since the authors were unable to secure an adequate control group, any changes in scores due to Career Facilitation Project effects are confounded with other effects. In other words, change can not be assumed to have been caused by the project alone.

In keeping with their theoretical justification, the authors selected a wide variety of testing instruments. Three were Differential Aptitude Tests (DAT) previously shown to be related to first-semester grades for a sample of 616 overwhelmingly male engineering freshmen: Abstract Reasoning, Mechanical Reasoning, and Spatial Relations. Three more spatial skill instruments that had been shown to reveal gender differences were also used: Card Rotations (rotate figures), Paper Form Board (rotate and perform serial operations on a figure), and Conservation of Horizontality (knowledge that the surface of a liquid remains horizontal regardless of the container). Participants also completed a questionnaire to assess indexes of brain lateralization and the Fennema-Sherman Mathematics Anxiety Scale. Data on age, academic preparation, undergraduate major, elapsed years since obtaining the degree, and employment were also gathered from records.

Testing took place throughout the year of the project, and results were known only to the evaluators. The participants were told that the data would be used to assess the project, not the participants. Five of the instruments were given before and after the project: Card Rotations, Paper Form Board, and DAT Spatial Relations were given in July and February, and DAT Abstract Reasoning and DAT Mechanical Reasoning were given in September and May. The brain lateralization instrument was given once in July, the Horizontality Task in February, and the Mathematics Anxiety Scale in May.

The sample consisted of 35 women who were the participants in the 1978-1979 NSF Women in Science Career Facilitation Project at California State University, Northridge. Of these 35, complete data were available for 24. These ranged in age from 23-55 ($\overline{x}$ = 33.3). All had baccalaureate degrees (14 in mathematics, 2 in biology, 2 in chemistry, and the remainder in other fields) and had not been employed in such fields for a number of years.

Findings

The data were analyzed in two ways. First a repeated measures MANOVA was performed on the five tests that were administered in a pre-post fashion. Using Wilk's criterion, the combined test scores changed significantly over time, $F(5, 19) = 9.62$, $p < 0.001$. The results reflected a large association between the pre and posttesting and the combined dependent variables $\eta^2 = 72$. Since the MANOVA showed significant results, each dependent variable was examined. The authors did this in two ways: by examining the effect each variable would have had if it had been the only one in the analysis and by examining the effect each variable would have had after the effect of all the other variables was taken out. Using the first procedure, three instruments showed significant change over time: Mechanical Reasoning, Paper Form Board, and Spatial Relations. When employing the second procedure, step down tests, only the Mechanical Reasoning Test showed a significant effect.

The second technique employed to examine the data was regression. The variable to be predicted was grade point average (GPA) category: high (3.51-4.0), medium (3.0-3.5), and low (2.3-2.99). Three separate regressions were performed, each with a different number of predictor variables. First, all variables were used, but the regression was not significant. Second, only the pretest scores on the five pre-post variables were used. This regression was statistically significant, $F(1, 17) = 3.46$, $p < .05$ with an R^2 of .36. The third regression contained only two predictor variables, DAT Spatial Relations and the Paper Form Board. This regression was also significant, $F(2, 20) = 9.61$, $p < .01$ with an R^2 of 0.44.

The final pieces of data were the results on the Mathematics Anxiety Scale. The results for these women were compared to the results from other studies. As would be expected, these women had greater mathematics confidence than women in other academic pursuits.

Interpretations

The authors suggest that participation in the project improved the spatial skills of the participants. This is consistent with findings in other studies of younger students. Further, the authors point out that the strength of spatial ability in predicting found for these women is different from studies on typical undergraduate engineering majors where mechanical reasoning and not spatial relations was found to be a predictor of GPA. They suggest that these differences might be due to a lack of the practical experience necessary to be familiar with the items on the Mechanical Reasoning Test. Finally, the authors suggest that these differences support their original contention that different populations may have different predictors of success.

ABSTRACTOR'S ANALYSIS

This study offers an excellent opportunity to examine a research effort conducted in a real world setting. The authors raise an important issue that has not yet been resolved and that needs to be dealt with if we are ever to improve the number of women employed in the sciences, engineering, and mathematics. The authors' argument against traditional prediction instruments is cogent and offers a new avenue for research to encourage diverse groups to pursue these careers. The article is also concise, well written, and uses fairly sophisticated statistical techniques in an appropriate and clearly explained manner.

The weaknesses and pitfalls of trying to design studies are also pointed out by the authors as they describe their attempts to obtain a control group. They encountered some of the difficulties involved in identifying an appropriate control group. For instance, is it fair, or conceivable, to allow only a random number of project applicants to participate in order to obtain a control group? How could a comparable group be defined? Would science teachers be appropriate? How can nonparticipants be encouraged to complete the large number of evaluation instruments? How can timing and testing situations be made comparable? Because of these difficulties, the authors were forced to give up on an experimental-control group design and settle on the less satisfactory one-group pretest-posttest design. With this design, the authors were unable to ascribe positive changes to participation in the Career Facilitation Project.

Another practical compromise exemplified by the study was the number of instruments and testing sessions. Although the authors argue for a wide variety of tests to help determine a groups' unique skills, only five tests were actually used pre and post, and these were not very diverse. Three were DAT tests that had already been shown to be predictive for the predominant group, men, and the remaining two were both related to spatial ability. A related shortcoming here was that these women were an unusual group with which to test for diversity since they had already demonstrated their commitment to mathematics, science, and engineering by obtaining undergraduate degrees in these areas. This uniqueness was further demonstrated by the low mathematics anxiety scores. Furthermore, the staggered pretesting sessions were two months apart, although the intervening time for the different sets of tests was the same.

Finally the attrition rate was fairly high, from 49 accepted applicants to 35 participants to 24 with complete data. This exemplifies another practical problem with research, especially over long time spans (year or more) and with large numbers of testing instruments. It would have been perhaps more in keeping with theoretical rationale of diverse variables for the prediction of success to have data on the original 49. GPA from a C+ to A is a fairly restrictive measure of success in such a uniform group. Information on the nonacademic predictors of success would be interesting.

The lack of a control group severely limited any inferences the authors could make about change due to participation in the project. The MANOVA and the conservative step down univariate F tests did indicate that the year could have affected Mechanical Reasoning. The authors' suggestion that this year had provided experiences in this area that the women did not have before certainly seems reasonable.

The regression analyses were the heart of the study since they showed the predictive nature of the selected instruments. The lack of a theoretical rationale for selecting the narrow dependent variable (GPA) and for making the selection of predictor variables for the second and third regressions made the results less interesting than they might have been. Furthermore, the number of subjects was somewhat too low to do the first two regressions. It was intriguing, though, to find that the Mechanical Reasoning found to be predictive for males was not as valuable for women. It is difficult to say whether or not this difference was because the women's scores on the pretest Mechanical Reasoning Test were too consistent within the group. If the authors really intended to provide status information for women on these instruments, more information on the actual scores and standard deviations should have been provided.

In summary, the authors have made reasonable use of the data they gathered originally for project evaluation to help shed light on an important issue.

RESPONES TO CRITIQUES

IN RESPONSE TO THE ANALYSIS OF

Scharmann, L., H. Harty, and J. Holland. "Development and Partial Validation of an Instrument to Examine Preservice Elementary Teachers' Process Orientation to Science" by Pinchas Tamir. Investigations in Science Education, 14 (3): 3-8, 1 88.

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I would like to thank Professor Tamir for his insightful analysis and constructive criticisms of the "Process Orientation to Science Scale" (POTSS), which appeared in Volume 70, Number 4 (Pages 375-387) of Science Education (1986). In representing my colleagues, Professors Harold Harty and James Holland, I welcome the opportunity to respond to several points raised by Professor Tamir. The critical questions delineated by Professor Tamir were:

1. Should the ability to recognize/identify processes of science be regarded as orientation?;

2. Whose emergent understanding is referred to in the definition, "consistent with the application and contribution to an emergent understanding of the nature of science?";

3. Since POTSS is intended for use as a diagnostic tool, would it not be helpful to obtain a description of the specific skills measured by each item?;

4. Is there a somewhat arbitrary item classification for some statements listed as "basic" versus "integrated" process skills (i.e., Tamir cites items 23 and 19 as they appear in the instrument, illustrated in the original journal article)?; and

5. Did the authors ask a priori for two factors, or did two factors emerge as a result of the statistical factor analysis?

The first question appears to be of a semantic nature. If we accept one explicit dictionary definition of "orientation" to be "... to acquaint with the existing situation," then the choice of the word "orientation" is certainly valid. If preservice elementary teachers are acquainted with the processes of science as a foundational context existing in science, then should we not be able to expect that correctly identifying and/or recognizing said processes constitutes an appropriate orientation to science as a process? This author believes so.

The second question also appears to be a semantic criticism. If the POTSS potentially functions as a diagnostic tool, and emergent is defined as "... arising as a natural or logical consequence," then acquainting preservice elementary teachers with science processes as an epistemologic foundation, should hopefully and ultimately foster an enhanced understanding of the process nature of science. Central to the thesis of the journal article was an attempt to measure a theoretically transitional orientation, which resulted in the formulation of the original survey instrument.

With respect to question three, two response levels are appropriate. On a more superficial level, the authors cited Livermore (1964) and the American Association for the Advancement of Science (1973) as acceptable descriptions of the "specific [science process] skills measured by each item." Thus, the item statements were written, reviewed, and revised in concert with process skill descriptions defined by reputable sources. However, on a more specific level, Professor Tamir discusses an extremely valuable consideration, in reference to the usefulness of forming item "subsets according to the particular process skills, thereby obtaining profiles in addition to total scores." The authors acknowledge the validity of this critical suggestion as one of considering the POTSS as a unidimensional "total score" versus multidimensional subset "profile." Such a "profile" would enable potential POTSS users to identify specific subset process skill development as well as provide a basis for the revision of course material to better address specific nonsignificant subset changes. The authors are encouraged by this suggestion, and will investigate the construction of such a profile in further validation/administrations of the POTSS.

Question four concerns the classification of item statements into "basic" and "integrated" categories; cited specifically by Tamir as considering item statement 23 (Modern scientific measurements are presently so accurate they contain no source of error) as "integrated" versus item statement 19 (Scientists should reject data and observations from an experiment if their observations cannot be replicated in the next experiment conducted) as "basic." It was the consensus of the content validators that item 19 dealt with the process of "observation" in the context of "precision" and the concrete interpretation of experimental data sets/tables; hence, "observation" as a basic process was being examined rather than "experimentation" as an integrated process skill. It was, in addition, the consensus of these same content validators that item statement 23 dealt with the process of "measurement" in the context of "accuracy" and an abstract analysis of the implications of the use of differently calibrated and/or sensitive instrumentation. This statement was classified as "integrated" in conjunction with item statement 16 (Scientists look upon the existence of measurement error as unavoidable), both of which are in concert with the necessarily uncertain nature of scientific measurement (Kimball, 1967).

Finally, question five concerns the factor analysis conducted by the authors. Since the factor analysis was performed, in part, to cross-validate the content validation, *a priori* assumptions were not appropriate. Professor Tamir is correct that, as the article stands, this must be inferred. It should indeed have been explicitly stated, especially since this procedure had such a critical contribution to the cross-validation. The fact that no *a priori* factor solutions were specified and that indeed, two factors resulted as described, lent credence to both the content validation procedures as well as conclusions drawn by the authors regarding the potential for the construct under investigation.

In closing, the authors are certainly cognizant of the need for further refinements of the POTSS, as indicated by the title of the article ("Development and Partial Validation ..."). What is essential, in harmony with Professor Tamir, is that researchers continue to examine both the understanding of the processes of science and their undergirding epistemologic foundations. This present investigation was an attempt to examine how preservice elementary teachers view such science processes in the context of these undergirding foundations. Again, Professor Tamir's insightful comments are highly appreciated. The authors are encouraged by Professor Tamir's recognition of the importance of this research issue, and will continue to explore the validity of the POTSS to examine changes that occur as a result of increasingly effective process oriented/inquiry-based science methods courses.

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IN RESPONSE TO THE ANALYSIS OF

Hackling, Mark W. and David F. Treagust. "Research Data Necessary for Meaningful Review of Grade Ten High School Genetic Curricula" by Angelo Collins. Investigations in Science Education, 14 (3): 23-32, 1988.

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Responding to Collins' review provides an opportunity to reflect on a piece of work that was originally reported in full as Hackling (1981) and subsequently published in brief as Hackling and Treagust (1984). This study must now be reviewed in an historical perspective as it was completed eight years ago, where eight years represents not only a significant part of the history of research into genetics learning but also a significant part of the history of the discipline of genetics itself. In examining a research study from an historical perspective there are three main questions that need to be addressed: What was the main contribution of the study at its time of publication? What impact have the research findings had on the teaching of genetics? What are the currently perceived limitations of the study in the light of subsequent research and publication?

This study represented an approach to research on misconceptions having a combination of three features; high quality of data made possible by an interview study, the scope of a whole science topic, and the basis of a clearly defined and validated set of propositions representing the declarative knowledge for that topic. A second study of similar design was subsequently reported for the topic of chemical equilibrium (Hackling & Garnett, 1985).

It is difficult to objectively evaluate the impact of any study of student misconceptions. However, as a result of this study the Teachers' Guide for the Western Australian genetics curriculum has been revised to take account of the study's recommendations.

The reviewer identified three limitations of the study that have become apparent through subsequent research and publication. These issues are the validity of the propositions representing the domain knowledge, precision of language in regards to genetics terminology, and the extent to which the misconceptions identified may have been due to the quality of curriculum materials being used and/or the quality of instruction.

The issue of validity of the propositions for the topic of 'mechanisms of inheritance' needs to be viewed in the context of the study. The intent was to define concepts and propositions at the level of sophistication of meaning expected of grade 10 students who were studying a prescribed curriculum about genetics in Western Australia. These propositions were not intended to be fully comprehensive and represented only a fraction of the domain knowledge that could be described by a professional geneticist. The reviewer questioned the validity of the propositions as the concepts of homozygosity, heterozygosity, segregation, and assortment could not be identified as part of the propositions. However, the meaning of the concepts homozygous, heterozygous, and segregation are implicit in propositions P10 and P16. The topic was taught to students from the full ability range in grade 10 and, as such, considered only simple monohybrid autosomal and X-linked modes of inheritance. For this reason the difficult concept of independent assortment was not included in instruction or in this study. The reviewer's claim that the concept of variation was not discussed in the article fails to acknowledge Hackling and Treagust's (1984) explanation that the idea of gametes carrying different alleles was probed in the context of explaining the variation between children in a family (p205).

The reviewer identified the need for precise use of genetics terminology in instructional materials and makes valid criticism of the use of some terms in the report of this study. Researchers have now been sensitized to this issue by the publication of Cho, Kahle and Nordland (1985).

The third issue raised by the reviewer relates to the origin of the misconceptions possessed by students following instruction. Possible causes of misconception could include alternative frameworks existing prior to instruction, poor quality instruction, inappropriate curriculum materials, and the developmental readiness of the learners (Lawson & Thompson, 1988).

It is likely that all of these factors have some influence on the origins of inheritance misconceptions. Developmental readiness is a prime suspect for students' failure to fully comprehend probability and the role of chance in inheritance. The curriculum materials used the term blending inheritance when referring to the phenomenon of incomplete dominance. As students are familiar with the kitchen blender as a mixing device it was not surprising that students believed that blending inheritance involved a mixing of genes. This is one example of misconceptions that could be traced to errors in the curriculum materials. It is likely that some of the misconceptions arose through incorrect instruction. Garnett and Hackling (1984), in a study of chemistry graduates who were completing a one year Diploma of Education programme, revealed that many of these teachers-to-be possessed the same misconceptions held by high school chemistry students. It is also likely that some misconceptions would have arisen through students misinterpreting instruction using pre-existing alternative frameworks that they brought to their genetics lessons.

The review claimed that Hackling and Treagust (1984) failed to compare t misconceptions of students after instruction with those revealed by Kargbo, Hobbs and Erickson (1980) prior to instruction when in fact the comparison was made:

> In their study of students' preconceptions about inheritance Kargbo, Hobbs, and Erickson (1980) reported that many students in their sample of 7-13 year-olds believed that environmentally induced characteristics, such as a missing finger, could be transmitted to offspring. In the present investigation, the inheritance of acquired characteristics was believed by only 13% of grade 10 students after instruction; 40% of students comprehended that such features are not inherited.
>
> (Hackling & Treagust, 1984, p205)

This response to the review acknowledges the valid criticism of the paper made by the reviewer, has discussed those issues that are a matter of perspective, and disagrees with some statements in the review that are factual errors. For example the claim that ..."it is suggested (by Hackling & Treagust) that chance is not important because it is difficult to understand when referring to human genetics" is incorrect since Hackling and Treagust (1984) clearly and explicitly stated that the role played by chance is essential to human genetics (p206).

When looking back over the past decade there has been considerable research into students' learning difficulties with genetics, as well as rapid advances in genetics itself. The combination of these two activities augers well for the future of genetics education.

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