DOCUMENT RESUME

ED 354 145 SE 052 941

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TITLE A Preliminary Assessment of Science Process Skills Achievement of Preservice Elementary Teachers.
PUB DATE 92
NOTE 11p.; Paper presented at the Annual Meeting of the National Association for Research in Science Teaching (Boston, MA, March 1992).
PUB TYPE Reports - Research/Technical (143) -- Tests/Evaluation Instruments (160) -- Speeches/Conference Papers (150)

EDRS PRICE MF01/PC01 Plus Postage.
DESCRIPTORS *Education Majors; Elementary Education; Higher Education; Preservice Teacher Education; Process Education; *Science Education; Science Teachers; Scientific Attitudes; *Skills; *Student Attitudes
IDENTIFIERS Hands on Science Activities; Preservice Teachers; *Science Process Skills; Second International Science Study

ABSTRACT

This paper suggests that if teachers expect students to learn the processes of science, then at least three conditions must be present: the teacher must have a command of the process skills; the students must be taught and given opportunities to practice the skills; and student progress in acquiring the skills must be evaluated. This research study gathered data for a preliminary analysis of the first of these conditions, the command of process skills by preservice elementary teachers. Process skills achievement was measured using performance items from the Second International Science Study (SISS). The other two conditions are indirectly addressed through an attitude survey. Fifty undergraduate elementary education majors enrolled in teacher education programs in Florida and Louisiana were given items from the practical laboratory skills test developed for SISS. An attitude survey was developed to assess preservice teacher's attitudes toward science, science teaching, science process skills, and assessment of science content processes. The items for this instrument are presented in the appendix. The preservice teachers scored higher on the fifth grade and ninth grade science process skills test than a U.S. sample of students. Elementary education students who had taken a science methods course had significantly more positive attitudes toward science and science teaching than did elementary education majors who had not yet taken a science methods class. (PR)

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# A Preliminary Assessment of Science Process Skills Achievement of Preservice Elementary Teachers

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Boston, March 1992

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## A Preliminary Assessment of Science Process Skills Achievement of Preservice Elementary Teachers

Current curricular reform in science education calls for a decrease in the amount of memorized vocabulary, facts, and procedures and an increase in the teaching of ideas, concepts, and thinking skills (AAAS, 1989). The importance of involving students in the skills used in doing science (as opposed to merely reading about science) has long been recognized (Gagne, 1965; NSTA, 1971). Various models have been presented for introducing and teaching science process skills to students (Padilla, Okey, & Garrard, 1984; Radford, 1988).

Skills that are important enough to teach are important enough to evaluate, and vice-versa: Assessment frequently drives curriculum. Numerous instruments have been developed for assessing process skills achievement (Dillashaw & Okey, 1980; Okey, Wise, & Burns, 1985; Padilla, Cronin, & Twiest, 1985; Padilla & Cronin, 1986). Most of these instruments have been in the paper-and-pencil multiple-choice format. Recently, much interest has been expressed in the need for more authentic assessment of students (Raizen, 1989; Lawrenz, 1991). Rather than simply measuring students' abilities to recall and repeat facts, authentic assessment seeks to measure students' facilities with the processes and concepts central to the discipline being studied. In authentic assessment, students are asked to perform tasks similar to those performed by people in the field being studied. For example, students in a drama class are asked to produce a play, or students in a history class are asked to research and write a local history. One aspect of authentic assessment applicable to science students is the assessment of higher order thinking skills and manipulative skills embodied in the ability to use science process skills to solve problems in science.

One criticism of standardized tests has been that teachers teach for the tests, which usually neither reflect the local curriculum nor measure the kinds of understanding and critical thinking that should be the outcome of a science course. If the test drives the curriculum, then one way to improve the curriculum is to improve the test. The implementation of performance assessment of important skills may encourage teachers to adjust their curriculum to give students more opportunities for developing those skills.

If teachers expect students to learn the processes of science, then at least three conditions must be present: the teacher must have a command of the process skills, the students must be taught and given opportunities to practice the skills, and student progress in acquiring the skills must be evaluated. This research study seeks to gather data for a preliminary analysis of the first of these conditions, the command of process skills by preservice elementary teachers. Process skills achievement was measured using performance items from the Second International Science Study (SISS). The second two conditions are indirectly addressed through an attitude survey. Teachers who express positive attitudes towards the value of teaching and assessing process skills are more likely to teach and assess process skills.

### Procedure

The sample consisted of students enrolled in the elementary teacher education programs at a private college in Florida and at a public university in Louisiana. Items from the practical laboratory skills test developed for the Second International Science Study were administered to 20 undergraduate elementary education students in Florida

and to 30 undergraduate elementary education students in Louisiana within the first few weeks of the required course in science teaching methods. As part of their academic program these students were required to have taken at least two courses in science, such as biology or earth science. Because of the preliminary nature of this study, the type of data collected in each location were not identical. The Florida study collected pre and post data on preservice teachers' science content knowledge and their ability to use process skills to solve problems during a laboratory practical examination. The Louisiana study collected data on the laboratory process skills and on the attitudes of preservice teachers towards teaching and assessing process skills. The results of the analysis of the content knowledge data and posttest performance data for the Florida study are reported elsewhere (DeTure & Escudero, 1992); the results of the analysis of the preliminary practical performance tests for preservice teachers in Florida and Louisiana and the attitude survey of preservice teachers in Louisiana will be reported in this paper.

The procedure followed during the performance tests of process skills was as specified in the SISS manual (Kanis, Doran, & Jacobson, 1990). Six performance tasks were set up for students to perform. Items included such tasks as describing similarities and differences between two plastic dinosaurs, assembling an electrical circuit and testing for electrical conductors, and determining the density of a fishing weight using a spring scale and graduated cylinder. The Florida education students performed both sets of the tasks designed for fifth grade students (three tasks in Set 5A or three tasks in Set 5B) and for ninth grade students (three tasks, either Set 9A or 9B). The Louisiana education students performed one set of the fifth grade tasks (Set 5A) and one set of the ninth grade tasks (Set 9B). Results of the performance tasks from the two groups of preservice teachers may be compared with each other and with the SISS data for approximately 1,200 fifth grade students and 1,100 ninth grade students who performed one set of the performance tasks during the U.S. administration of the SISS.

The attitude survey was developed by the Louisiana researcher to assess preservice teachers' attitudes towards science, science teaching, science process skills, and assessment of science content and processes. The instrument included 22 Likert-type items to which the respondents indicated their level of agreement on a 5-point scale from strongly disagree to strongly agree. The sample included 50 elementary education majors, one fourth of whom had not yet had a science teaching methods course.

Data were analyzed using SAS statistical software. Significant differences (alpha = .05) were determined by separate one-way ANOVAs (SAS General Linear Models procedure).

## Results

### Process Skills Achievement

The performance test of science process skills was scored according to the protocol specified in the SISS manual (Kanis, Doran, & Jacobson, 1990). Elementary preservice teachers in both Florida and Louisiana did significantly better than the sample of U.S. elementary students on the fifth grade test and the ninth grade test, scoring higher than the students on each task. The preservice teachers in both areas scored similarly on the tests. The average percentage of correct responses for the fifth grade test was 83% for the Florida preservice teachers and 77% for the Louisiana preservice teachers. The average

percentage of correct responses on the ninth grade test was 65% for the Florida preservice teachers and 67% for the Louisiana preservice teachers. A breakdown of the results by test item for the fifth grade test is presented in Table 1 and for the ninth grade test in Table 2. Comparisons may be made between the results of the preservice teachers and the U.S. students on each test item. The only item for which the preservice teachers did not score significantly higher than the students was item 2 in Task 9B2. Ninth grade students were 95% correct in describing the changes in colored dots during a paper chromatography task. Preservice teachers in the Florida and the Louisiana samples scored 73% and 93% correct, respectively.

### Attitude Towards Teaching and Assessing Science Process Skills

Elementary education students who had taken a science methods class had significantly more positive attitudes towards science and science teaching than did elementary education students who had not yet had a science methods class. The overall difference on the total instrument was largely due to significant differences on 5 of the 22 items. (Survey items with mean responses for each group of preservice teachers are included in Figure 1.) Two of these items (items 6 & 7) dealt with the preservice teacher's level of confidence in teaching science content and process skills. Preservice teachers who had experienced a science teaching methods course were more confident about teaching content (78% agree or strongly agree responses) and teaching process skills (72% agreement) than those students who had not yet had science methods (69% and 46% expressing confidence in teaching content and process skills, respectively).

A third item (item 10) dealt with the preservice teacher's commitment to teach process skills. Commitment to teach process skills increased from 69% for those students who had not had science teaching methods to 95% for those who experienced the course.

Another item (item 18) concerned the importance of identifying students' misconceptions. Although preservice teachers who had taken a science methods course expressed somewhat higher levels of agreement about the importance of identifying misconceptions, both groups of preservice teachers indicated high levels of agreement (92% for those who had not had science methods and 95% for those who had science methods).

The last item showing a significant difference in attitudes (item 15) related most clearly to the topic of this study, performance tests. The preservice teachers were asked whether the time required to give a performance test of science process skills was worth the information about student understanding that it provides. Only 31% of the students who had not had science methods agreed that the time spent was justified by the information gained. This percentage increased to 73% for those students who had had a science methods class.

Students who had taken a science methods class included some who had experienced a performance test of process skills and some who had not. Of the 50 elementary education students surveyed, 37 had taken a science methods class. Data from these 37 students were reanalyzed on the basis of whether or not they had experienced the SISS performance testing. Three items on the survey showed significant differences in the attitudes between students who had experienced the performance test and those who had not. The methods course students who had experienced the test were more

positive about the importance of measuring student's ability to perform science (item 12). More than three fourths (77%) of those who had experienced the test expressed agreement, while less than half (40%) of those who had not experienced the performance test agreed to the importance of measuring performance in science.

Most (91%) of the preservice teachers who had taken the SISS performance test agreed that the time required to give a performance test of science process skills is well spent because of the information about student understanding that is provided by the test results (item 15). Fewer than half (47%) of those who had not experienced the performance test agreed that the information gained would be worth the time spent for the assessment.

A final difference in attitudes of the two groups concerned the validity of the assessment of performance assessments compared to paper-and-pencil tests (item 21). The percentage of agreement to the statement that performance assessment gives a truer picture of a student's understanding of science concepts than does a paper-and-pencil test increased from 73% for preservice teachers who had not experienced the SISS performance items to 86% for those who had.

## Conclusions

The results of this study are preliminary. The size of the samples, especially when broken down for group analysis, is rather small (subgroups ranged from 13 to 37). However, the similarity of results in both sample areas suggest some generalizability.

Preservice elementary teachers display a greater ability than the students they will be teaching to use science process skills as measured by the SISS performance items. However, their achievement level has room for improvement, especially on items that require reasoning. In this area, the preservice teachers' scores reflected the performance of the U.S. students who took the SISS. The lowest scores for both groups of preservice teachers and for the U.S. students on both the fifth and ninth grade tests were for items that required the use of reasoning to solve problems.

Science teaching methods classes do seem to increase preservice teachers' confidence in their ability to teach process skills and to positively influence their intentions to teach process skills. But a science teaching methods class alone does not influence preservice teachers to value assessment of students' abilities to use process skills to solve performance tasks. When preservice teachers are given the experience of taking a performance test of process skills, they express a more positive attitude compared to preservice teachers who have had science teaching methods but have not experienced the performance test. Preservice teachers who have experienced performance tests feel more strongly that it is important to measure students' ability to perform science, that the information about student understanding provided by performance tests justifies the time requirements for the assessment, and that performance assessment of process skills gives a truer picture of students' understanding of science concepts than does a paper-and-pencil test. Instructors of science teaching methods who wish to influence the assessment of students in science classes, and ultimately, the science curriculum, should consider giving their preservice teachers experience in taking performance tests of science process skills.

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**Table 1. Results of SISS Grade 5 Process Skills Performance Testing of U.S. Students and Elementary Preservice Teachers**

| TASK | PROCESS SKILL | POSSIBLE POINTS | PERCENT CORRECT U.S. | FL | LA |
|---|---|---|---|---|---|
| 5A1 Color Change in Solution | | | | | |
| Part 1: Describe change | Performing | 2 | 57 | 92 | 95 |
| Part 2: Explain change | Reasoning | 2 | 11 | 74 | 63 |
| TOTAL TASK A1 | | 4 | 34 | 83 | 79 |
| 5A2 Observe Toy Animals | | | | | |
| Part 1: Describe similarities | Performing | 3 | 20 | 81 | 57 |
| Part 2: Describe differences | Performing | 3 | 49 | 86 | 92 |
| TOTAL TASK A2 | | 6 | 35 | 84 | 74 |
| 5A3 Electrical Circuits | | | | | |
| Part 1: Assembly of circuit | Performing | 2 | 76 | 95 | 93 |
| Part 2: Testing for conductivity | Investigating | 2 | 70 | 89 | 82 |
| Part 3: Reason for conductors | Reasoning | 2 | 9 | 66 | 55 |
| TOTAL TASK A3 | | 6 | 52 | 83 | 77 |
| TOTAL GRADE 5 TEST | | 16 | 41 | 83 | 77 |

*Note. n for U.S. students = 1,212; FL preservice teachers = 19; LA preservice teachers = 30.*

**Table 2. Results of Grade 9 SISS Process Skills Performance Testing of U.S. Students and Elementary Preservice Teachers**

| TASK | PROCESS SKILL | POSSIBLE POINTS | PERCENT CORRECT U.S. | FL | LA |
|---|---|---|---|---|---|
| 9B1 Determine density of object | | | | | |
| Part 1: Finding mass of object | Performing | 2 | 51 | 80 | 73 |
| Part 2: Measure volume of object | Performing | 2 | 29 | 80 | 57 |
| Part 3: Calculate density | Reasoning | 2 | 8 | 40 | 45 |
| TOTAL TASK B1 | | 6 | 29 | 67 | 58 |
| 9B2 Color Chromatography | | | | | |
| Part 1: Observe rates of movement | Performing | 1 | 74 | 90 | 90 |
| Part 2: Describe changes in dots | Performing | 2 | 95 | 73 | 93 |
| Part 3: Explain change in dot | Reasoning | 1 | 12 | 45 | 60 |
| TOTAL TASK B2 | | 4 | 69 | 70 | 84 |
| 9B3 Testing for Sugar and Starch | | | | | |
| Part 1: Determine plan for testing | Investigating | 1 | 41 | 80 | 77 |
| Part 2: Perform tests | Performing | 2 | 21 | 60 | 60 |
| Part 3: Identify sugar and reason | Reasoning | 2 | 42 | 54 | 67 |
| Part 4: Identify starch and reason | Reasoning | 2 | 40 | 60 | 60 |
| TOTAL TASK B3 | | 7 | 35 | 61 | 64 |
| TOTAL GRADE 9 TEST | | 17 | 41 | 65 | 67 |

*Note. n for U.S. students = 1,112, FL preservice teachers = 20; LA preservice teachers = 30.*

**Figure 1. Results of Science Attitude Survey**

| | | Means[a] | | | |
|---|---|---|---|---|---|
| | Group[b]: | 1 | 2 | 3 | 4 |
| 1. | Science is a fun subject to study. | 3.5 | 4.0 | 3.8 | 4.2 |
| 2. | Science is a fun subject to teach. | 3.5 | 4.0 | 3.9 | 4.0 |
| 3.[c] | Science instruction is not as important as instruction in reading. | 3.5 | 3.5 | 3.5 | 3.5 |
| 4.[c] | It is more important for students to learn science content than to learn science process skills such as observing, forming hypotheses, and experimenting. | 3.8 | 4.1 | 3.7 | 4.3 |
| 5. | The same amount of time should be devoted to science instruction as is spent teaching reading or math. | 3.2 | 3.6 | 3.3 | 3.8 |
| 6. | I feel confident that I can teach science content. | 3.0 | 3.9* | 3.8 | 4.0 |
| 7. | I feel confident that I can teach science process skills. | 3.2 | 3.8* | 3.7 | 3.9 |
| 8.[c] | Students learn science better by reading the science text book and doing work sheets than by doing experiments. | 5.0 | 4.8 | 4.9 | 4.8 |
| 9. | When I teach science I will have my students do hands-on activities. | 4.5 | 4.8 | 4.7 | 4.8 |
| 10. | When I teach science I will teach process skills. | 3.9 | 4.5* | 4.4 | 4.5 |
| 11. | When I teach science I will have students do experiments in class. | 4.5 | 4.5 | 4.4 | 4.6 |
| 12. | It is important to measure students' ability to perform science. | 3.6 | 3.6 | 3.3 | 3.8* |
| 13.[c] | The best way to find out what students know about science is with a paper and pencil test. | 4.0 | 4.3 | 4.5 | 4.1 |
| 14. | Student understanding of science process skills is best measured by a lab practical performance test. | 3.3 | 3.8 | 3.6 | 3.9 |
| 15. | The time required to give a performance test of science process skills is worth the information about student understanding that it provides. | 3.3 | 3.9* | 3.5 | 4.2* |
| 16. | I feel confident that I can assess students' understanding of science content. | 3.4 | 3.8 | 3.7 | 4.0 |
| 17. | I feel confident that I can assess students' science process skills. | 3.5 | 3.9 | 3.7 | 4.0 |
| 18. | It is important to identify students' misconceptions about science concepts. | 3.9 | 4.3* | 4.2 | 4.4 |
| 19.[c] | Boys' ability in science is greater than girls' science ability. | 4.0 | 3.9 | 3.5 | 4.1 |

| | | Means[a] | | | |
|---|---|---|---|---|---|
| | Group[b]: | 1 | 2 | 3 | 4 |
| 20.[c] | Boys will do better than girls on a test that measures ability to use scientific equipment to solve problems. | 3.7 | 3.7 | 3.7 | 3.6 |
| 21. | Performance assessment of process skills gives a truer picture of a student's understanding of science concepts than does a paper and pencil test. | 3.9 | 4.1 | 3.7 | 4.3* |
| 22. | A practical performance test will identify student misconceptions better than a multiple choice test. | 3.8 | 4.1 | 3.9 | 4.3 |
| TOTAL SURVEY: | | 3.7 | 4.0 | 3.9 | 4.1 |

[a] Group means on 5-point scale with 5 indicating strongest agreement

[b] Groups of elementary education preservice teachers: Group 1 ($n$ = 13) Have not had science methods course; Group 2 ($n$ = 37) Had science methods; Group 3 ($n$ = 15) Have not taken SISS performance test; Group 4 ($n$ = 22) Have taken SISS performance test.

[c] Item worded so that disagreement indicates most positive attitude. Numerical values of responses (1 - 5) were reversed (5 - 1) so that means may be directly compared with means of other items.

* Mean is significantly greater (alpha = .05) than the mean of the group to the immediate left.