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ABSTRACT

Reported is an assessment of a competency-based physics course designed to develop concepts through an activity-centered approach incorporating the processes of science. It was assumed that such a strategy would enhance a future teacher's understanding of science concepts and processes in addition to developing more positive attitudes toward science. The course is described as different from other available courses in three aspects. First, a philosophy of teaching elementary science was considered during development. Second, course content was selected according to the particular needs of elementary teachers. Preference was given to topics which were considered to honestly reflect the content of the discipline and still possess application value for teachers. Third, instruction incorporated competency-based strategies. Terminal objectives were explicitly stated at the beginning of each topic; a self-paced modular format allowed for individual differences in achieving and demonstrating competence. Course content, student evaluation, course evaluation, as well as changes in the understanding of science concepts and processes are presented. (Author/EB)

# ASSESSING THE EFFECTIVENESS OF A COMPETENCY-BASED PHYSICS PROGRAM FOR ELEMENTARY TEACHERS

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Competency-based teacher education (CBTE) is being developed at the University of Georgia. Approximately 200 students are presently enrolled in CBTE programs. Instruction in educational psychology, science methods, and other professional areas for these preservice teachers often reflects the six characteristics of competency-based instruction identified by Houston and Howsam (1972:5-6):

1. specification of learner objectives in behavioral terms;
2. specification of the means for determining whether performance meets the indicated criterion level;
3. provisions for one or more modes of instruction pertinent to the objectives;
4. public sharing of the objectives, criteria, means of assessment, and alternative activities;
5. assessment of the learning experience in terms of the competency criteria; and
6. placement on the learner of the accountability for meeting the criteria.

Instruction in academic courses does not generally reflect the competency-based influence, perhaps because specific terminal objectives have not been explicitly stated. Science courses for preservice elementary teachers are an exception (Capie and Markle, 1974).

Physics for Elementary Teachers is one of a series of science courses for preservice elementary teachers at the University of Georgia which attempts to use a competency-based model for developing the knowledge, skills, and attitudes prerequisite to successful elementary science teaching. The physics course is different from others available in three aspects.

First, a philosophy of teaching elementary science was considered during development. Elementary science should play an important role in helping the child learn the nature of scientific inquiry and the key operations, or processes, of science. A program based on inquiry and process will encourage real learning, not the memorization of facts. Elementary science programs should encourage the child to think critically and to develop scientific attitudes and skills. Science courses for preservice elementary teachers must be directed to the same goals if elementary science instruction is to reflect this philosophy.

Second, course content was selected according to the particular needs of elementary teachers. Many elementary science programs were examined before a sample of physics content was selected. Preference was given to topics which honestly reflect the content of the discipline and still possess application value for teachers.

The third and perhaps most significant difference between Physics for Elementary Teachers and conventional physics courses is that instruction incorporated competency-based strategies. Terminal objectives were explicitly stated at the beginning of each topic; a self-paced, modular format allowed for individual differences in achieving and demonstrating competence.

The content and sequence of the course are shown in Figure 1. Each block represents one modular unit of study. Students progressed through the modules at their own speed during open laboratory hours. Each module was structured to guide the student in making and organizing observations and arriving at experimentally testable inferrences based on their observations.

## Course Content

Students were introduced to the measuring process and metric system in the first module and extensively utilized measuring skills during later modules. Making accurate measurements and correctly reporting the precision of measurements were emphasized. Organizing information by means of graphs was stressed. Student discussions concerning the best measuring technique, the need for extra measurements, and the correctness of graphic representations were common and often became quite complex.

The concepts of motion, velocity, acceleration, and force were encountered in concrete situations before definitions and/or equations were presented. Observing the motion of toy hot-wheel cars provided an intuitive feel for the ideas. Forming concrete concepts was preferred to mechanically solving abstract problems. Some pencil-paper problems were solved at the end of appropriate modules.

Slides and film loops provided observations not conveniently seen in the laboratory. Use of this technology was necessary for the Force-Motion and Momentum modules.

Activities from the Conceptually Oriented Program in Elementary Science were adapted for use in the Energy module. Observations of interactions between rolling metal balls and stationary blocks of wood provided basis for symbolic representations. The conservation of energy principle was developed by the Energy module and expanded during the activities in the Heat and Electricity modules.

Developing "scientific models" to explain observations and to aid in making predictions was emphasized during the final four modules. Activities related to heat and electricity were adapted from the Conceptually Oriented Program in Elementary Science, Elementary Science Study, and the Science Curriculum Improvement Study. The relevance of the activities was easily demonstrated by reference to these programs and related portions of conventional elementary science textbooks.

In all activities students were made aware of their use of scientific processes such as observing, inferring, measuring, communicating, predicting, controlling variables, and formulating and testing hypotheses. Laboratory experiences were designed so that principles emerged from first-hand interactions. Whenever possible, rules and principles were experimentally applied and tested in new situations.

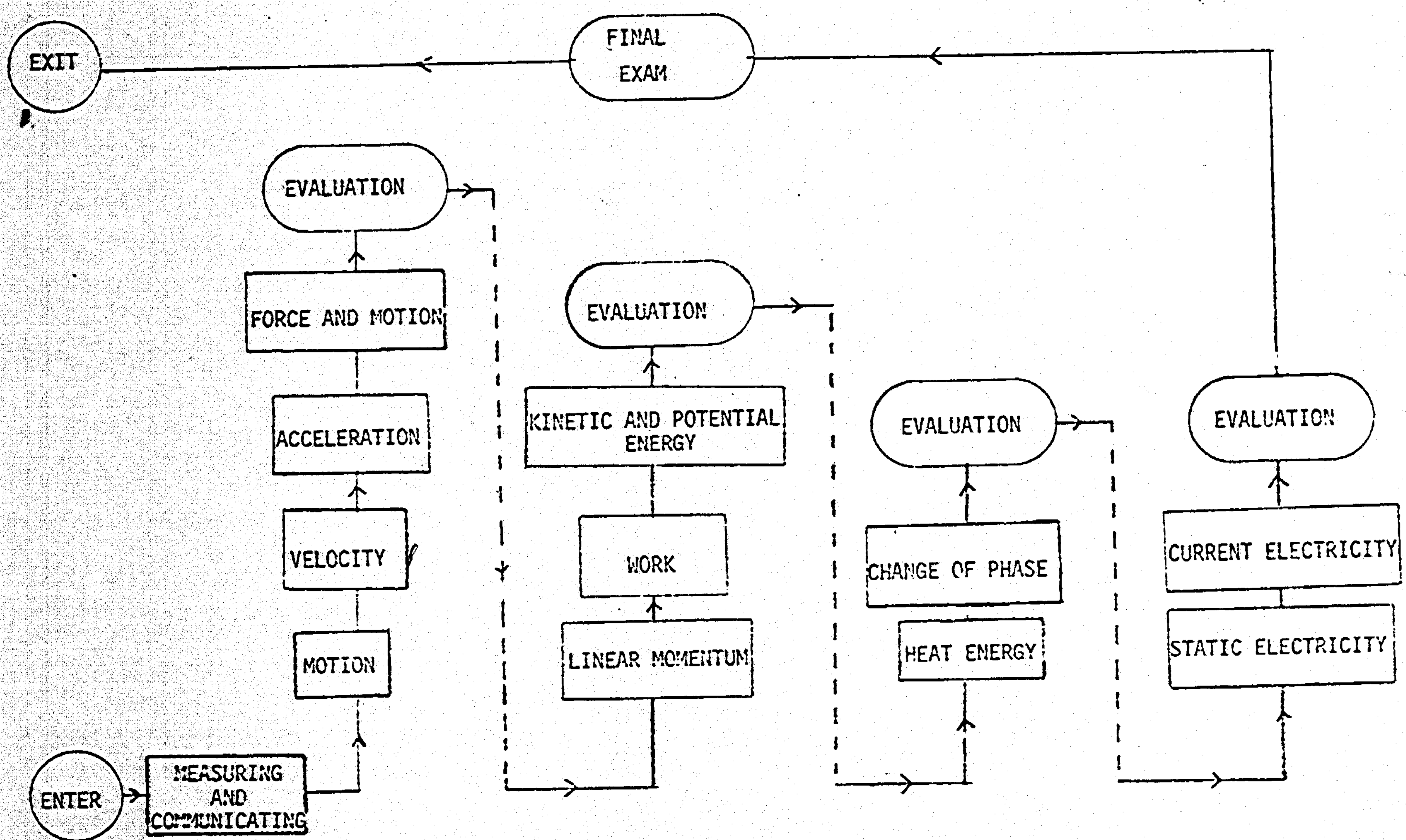


FIGURE 1. Course content and sequence for Physics 105, Physics For Elementary Teachers.

When designing the course it was assumed the relevance of physics could be illustrated by showing that mathematical abstractions associated with the subject are derived from concrete interactions. Mathematical models representing the interactions studied in the laboratory were developed in discussion sessions. Two hours each week were devoted to discussion sessions which emphasized the process of interpreting information rather than deriving known principles of physics. The assumption was made that skillful guidance from "one who knows" would lead to acceptable concepts.

Occasionally during laboratory sessions, small group seminars were held to discuss information not easily presented in written modules. Some laboratory time was also used to help individuals having difficulty with specific parts of the course. The individual instruction allowed some students to respond more effectively than they might have in more conventional physics courses.

## Student Evaluation

Student evaluation was based on achievement of the course objectives. The objectives for each module were stated at the outset. Upon completion of a module students were tested on the objectives. At the end of each cluster of modules, students were given a one to two hour examination over the objectives in that cluster. Cluster tests required activity type responses, short answer responses, and problem solving. Success was defined as eighty percent correct. Students not achieving the criterion score had the option of retaking a similar test after extra instruction.

A midterm problem solving examination based on the information covered in discussion sessions and a final examination covering all aspects of the course were also administered. The total evaluation of the student, as announced at the beginning of the quarter, was determined as follows: successful completion of all modules and the corresponding module tests guaranteed a minimum grade of "C"; success on all cluster tests guaranteed a minimum grade of "B"; success on both the above and a final examination score of eighty-five percent or better guaranteed an "A".

## Course Evaluation

Physics for Elementary Teachers was offered and evaluated during the spring and fall quarters, 1973 and the winter quarter, 1974. Three areas were assessed in evaluating the physics course: achievement of course objectives, knowledge of science processes, and attitudes toward science and the course. The qualitative results were similar each quarter; the data reported below is a combination of the three individual sets of data.

## Changes in Understanding of Relevant Concepts

A forty-four item multiple choice test emphasizing comprehension and application of course relevant concepts and science processes was constructed. Content validity was established through examination of the instrument and course objectives by two members of the Physics Department and two members of the Department of Science Education. The test was administered at the beginning and end of each quarter. The average gain was approximately twelve points. The t-value for differences in individual scores was significant beyond the 0.001 level (Ferguson, 1966a). The results are shown in Table 1.

TABLE 1

Data related to the forty-four item course-relevant content test.* Combined results for three quarters.

| | Pretest | Posttest |
|---|---|---|
| N | 34 | 34 |
| $\overline{X}$ | 15.94 | 28.29 |
| s | 5.67 | 4.37 |
| t** | 30.82 | |

* The average KR-20 reliability for the test was 0.73

** Significant beyond the 0.001 level

## Changes in Understanding Science Processes

The Wisconsin Inventory of Science Processes (WISP) and the Welch Science Process Inventory (SPI) have been used to measure changes in understanding science processes. The validation procedures for the WISP test were described by Carey and Stauss (1968a) and for the SPI test by Welch and Pella (1970).

The mean score on the WISP increased by six points. The SPI test mean increased by five points. The t-value for matched cases was significant beyond the 0.05 level for both tests. The results are shown in Table 2.

TABLE 2

Data related to the WISP test administered during the spring quarter and combined data related to the SPI test administered during the fall and winter quarters.*

| | Wisconsin Inventory of Science Processes | | Welch Science Process Inventory | |
|---|---|---|---|---|
| | Pre | Post | Pre | Post |
| N | 9 | 9 | 24 | 24 |
| $\bar{X}$ | 59.22 | 66.00 | 106.40 | 111.51 |
| s | 9.77 | 8.29 | 8.89 | 5.85 |
| t** | 2.71 | | 4.43 | |

* The average KR-20 reliability for the WISP test was 0.82 and for the SPI test, 0.79.

** The t-value related to the WISP scores was significant beyond the 0.05 level. The t-value related to the SPI score was significant beyond the 0.001 level.

## Evaluating Attitude Changes

Attitudes toward science and physics were measured using a subject preference survey. Ten electives, six science and four nonscience, available to undergraduates were paired and listed in all possible combinations. At the beginning and end of each quarter, students were given the list and instructed to circle the preferred subject for each pair. The number of times a subject was circled became its score.

The subject preference survey has several advantages: it is easy to administer and requires only a short time to complete; it is easy to score; the internal consistency of individual responses can be quickly checked using Kendall's coefficient of consistence (Ferguson, 1966b); and a test - retest reliability can be estimated from the correlation between pre- and posttest rankings of subjects other than physics. The average internal consistency for the subject preference survey was 0.91. The test - retest rank order correlation coefficient for all subjects other than physics was 0.97.

Individual pretest and posttest selections of science over nonscience subjects and physics over other subjects were analyzed. Each quarter students indicated increased selections in both these areas. The t-values for matched scores of all students enrolled in the course was significant beyond the 0.01 level. The data are presented in Tables 3 and 4.

TABLE 3

Selection of physics over other subjects on a subject preference survey.* Combined results of three quarters.

| | Pre | Post |
|---|---|---|
| N | 33 | 33 |
| $\bar{X}$ | 2.79 | 5.00 |
| s | 2.51 | 3.16 |
| t** | 3.28 | |

* The mean internal consistency of responses was 0.91. The test - retest rank order correlation coefficient for all subjects other than physics was 0.97

** Significant beyond the 0.01 level

TABLE 4

Selection of science subjects over nonscience subjects on a subject preference survey.* Combined results of three quarters.

| | Pre | Post |
|---|---|---|
| N | 33 | 33 |
| $\overline{X}$ | 5.09 | 7.55 |
| s | 4.22 | 4.40 |
| t** | 2.97 | |

* The mean internal consistency of responses was 0.91. The test - retest rank order correlation coefficient for all subjects other than physics was 0.97

** Significant beyond the 0.01 level

At the end of each quarter, an adjective checklist was given to the students to obtain a structured description of reactions to the course. For each word in the list, students could indicate that the word was an apt descriptor, that it was not, or they could leave the word unchecked. Among the instructions were the following statements: "Please check as many or as few of the words as you wish to describe your own experience. You may check either column or leave both blank." Student responses were generally favorable: beneficial, worthwhile, discovery-oriented, understandable, effective, and useful were commonly agreed upon as apt descriptors. A complete listing of the adjectives with a summary of student responses is included in Table 5.

TABLE 5

Summary of thirty-four student responses to the adjective checklist used to describe Physics for Elementary Teachers.*

| The course was | was not | | was | was not | |
|---|---|---|---|---|---|
| 33 | 0 | INFORMATIVE | 21 | 2 | MATURE |
| 32 | 0 | ORGANIZED | 21 | 4 | GROUP ORIENTED |
| 31 | 0 | PREPLANNED | 21 | 6 | FUN |
| 31 | 2 | BENEFICIAL | 18 | 0 | TRUSTING |
| 30 | 1 | HELPFUL | 17 | 12 | NERVE-WRACKING |
| 30 | 1 | RELEVANT | 17 | 13 | FRUSTRATING |
| 30 | 1 | USEFUL | 16 | 12 | HARD |
| 29 | 0 | UNDERSTANDABLE | 14 | 15 | DIFFICULT |
| 29 | 1 | DISCOVERY ORIENTED | 13 | 14 | COMPETITIVE |
| 29 | 1 | INFORMAL | 8 | 23 | BORING |
| 29 | 2 | FAIR | 7 | 17 | REPETITIOUS |
| 28 | 2 | EFFECTIVE | 7 | 21 | DREADED |
| 28 | 2 | WORTHWHILE | 6 | 16 | OVERLOADED |
| 27 | 0 | COOPERATIVE | 6 | 18 | RIGID |
| 26 | 0 | TRANSFERABLE | 3 | 21 | THREATENING |
| 26 | 0 | INDIVIDUALIZED | 3 | 23 | HARSH |
| 26 | 1 | REASONABLE | 3 | 24 | DISAGREEABLE |
| 26 | 3 | INTERESTING | 2 | 25 | IMPERSONAL |
| 25 | 0 | PARTICIPATORY | 2 | 28 | DISORGANIZED |
| 24 | 1 | PERSONAL | 2 | 27 | PURPOSELESS |
| 24 | 2 | INDEPENDENT | 2 | 27 | UNREASONABLE |
| 24 | 5 | ENJOYABLE | 1 | 16 | INCONSISTENT |
| 22 | 2 | STRUCTURED | 1 | 27 | MEANINGLESS |
| 22 | 5 | STIMULATING | 0 | 27 | IRRELEVANT |

* The adjectives in the summary table are arranged according to decreasing frequency of agreement. On the evaluation instrument, they were ordered alphabetically.

## Conclusions and Recommendations

The competency-based physics course at the University of Georgia was designed to develop concepts through an activity-centered approach incorporating the processes of science. It was assumed that such a strategy would enhance a future teacher's understanding of science concepts and processes in addition to developing more positive attitudes toward science. Based on the data several tentative claims about the physics course can be made:

1. Physics content may be effectively taught to preservice elementary teachers using a self-paced, activity-centered, modular approach.

2. Preservice elementary teachers can increase their understanding of the processes of science as measured by the WISP and SPI tests by using the processes during a physics course.

3. Future preference for science courses can be developed in preservice elementary teachers through an activity-centered course relevant to their needs.

4. Preservice elementary teachers have a positive reaction to a self-paced physics course designed to meet their particular needs.

Informal feedback and systematic analysis of student success on each objective are providing the basis for continuous program revision. At the present time plans are being formulated for additional modules. A desirable model seems to be having a core of common modules and a variety of content options for students. Of course, science teachers must have subject matter competence before teaching any science, but attitudes and skills must be considered as well. The emphasis on process and affective goals will be retained in the physics program and expanded in other science areas at the University of Georgia. It is almost impossible to create positive attitudes and skills among elementary teachers in a one quarter methods program if they have taken traditional intorductory courses. Such learning must occur in the context of meaningful science investigations. It would be regretable, indeed, if students who had the benefit of a special science course for teachers failed to improve their attitude toward science.

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