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ABSTRACT

The project's purpose was to revise the introductory biology material in a freshman course for biology majors so that it is based on Piagetian learning theory and incorporates the three phases of the learning cycle teaching strategy: (1) exploration; (2) concept formation; and (3) concept application. The approach presented concepts structured so they were chronologically congruent with the natural and historical discovery of scientific concepts. Within subject areas conceptual development was initiated using concrete or experiential encounters. Teachers developed presentations that modeled concept formation, presented a series of related problems, and developed solutions cooperatively with students. Formative evaluation of the program involved analysis of scores on periodic exams and pre- and post-tests. Summative statistical evaluations compared the numbers of "successful" and "unsuccessful" students from previous classes with those participating in the project. Reorganization of the introductory curriculum reduced the rate of "unsuccessful" students substantially and improved student attitudes. Contains 43 references. (MSE)

RESTRUCTURING INTRODUCTORY BIOLOGY ACCORDING TO THE LEARNING CYCLE INSTRUCTIONAL STRATEGY

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AASCU/ERIC Model Programs Inventory Project

The AASCU/ERIC Model Programs Inventory is a two-year project seeking to establish and test a model system for collecting and disseminating information on model programs at AASCU-member institutions--375 of the public four-year colleges and universities in the United States.

The four objectives of the project are:

- To increase the information on model programs available to all institutions through the ERIC system
- To encourage the use of the ERIC system by AASCU institutions
- To improve AASCU's ability to know about, and share information on, activities at member institutions, and
- To test a model for collaboration with ERIC that other national organizations might adopt.

The AASCU/ERIC Model Programs Inventory Project is funded with a grant from the Fund for the Improvement of Postsecondary Education to the American Association of State Colleges and Universities, in collaboration with the ERIC Clearinghouse on Higher Education at The George Washington University.

ABSTRACT

Students entering the University of Missouri-St. Louis vary greatly in their academic backgrounds. Such urban universities face a critical challenge in providing programs of academic excellence which attempt to meet the needs of students at opposite ends of the college preparatory spectrum. This two year curriculum development program addressed this problem for the instructors of Introductory Biology (Biology 10) and for approximately 100 freshman students who elect to major in biology annually and must, therefore, successfully complete the Introductory Biology course.

In the past ten years prior to this project, grade distributions in Biology 10 had been consistently bimodal, with as many as 45% of the students in the "unsuccessful" group. Moreover, 75% of the ethnic minorities failed to complete the course satisfactorily and not one of the 20 such students enrolled in the two semesters prior to this project obtained a "successful" grade (A, B, or C).

The purpose of the "Restructuring Introductory Biology" project was to revise the introductory biology course material so that it is based on Piagetian learning theory and incorporate the three phases of the learning cycle teaching strategy: (1) Exploration; (2) Concept Formation; and (3) Concept Application. The goal was to develop student skills in synthesizing concrete knowledge into formal concepts and, subsequently, foster the utilization of these concepts in solving related problems.

The approach structured the concepts presented so that they were chronologically congruent with the natural and historical discovery of scientific concepts and within subject areas started the conceptual development utilizing concrete or experiential encounters. The lectures incorporated 3 dimensional and 2 dimensional class inclusive examples. The teachers developed presentations that modeled concept formation and a series of related problems were presented with teacher/class cooperative solutions developed to provide the application phase. One hour discussion sessions allowed assessment and broadening of the understanding of concepts derived in lectures. Utilizing the three phases of the learning cycle, laboratory experiences were designed to lead students in the production of data that was to be used in concept development and application in lecture and discussion.

During the project, formative evaluations involved analyses of scores on periodic examinations and pre- and post-tests. Summative statistical evaluations compared the number of "successful" and "unsuccessful" students from previous (conventional) classes with those participating in this project.

By the implementation of the learning cycle strategy the unsuccessful rate in the introductory course was substantially reduced and the affective domain was enhanced.

INTRODUCTION

This report describes a project which developed collegiate curriculum materials for an academically diverse introductory biology student population based on the learning cycle instructional strategy. The need for the new curriculum materials, their description, their focus, scope, goal, the target population, and staffing are presented. The major findings of the project are given.

There is a large volume of literature on Piagetian theories of cognitive development. An explanation of these is given in Wadsworth (1984).

Piaget grouped development of the learning process into four stages. The first and second stages are developed by children early in life and are not of concern here. The third stage, concrete logical operations, involves patterns of reasoning applied by the individual to directly observable objects, their properties, or their simple relationships. The fourth stage, formal operation, includes more complex thoughts and reasoning skills who do not require the presence of concrete object or their properties. Piaget theorized that a learner moves from concrete to formal reasoning after a period of manipulating concrete objects and after the subsequent establishment of a formal operational concept. The length of manipulating time required varies with the individual.

Karplus (Atkins and Karplus, 1962) suggested that three phases are needed when applying Piagetian developmental theory to the advancement of student reasoning skills. (1) Exploration, (2) Concept Introduction, and (3) Concept Application. During the exploration phase, students work with concrete materials--observing, questioning, and identifying problems that cannot be explained by their current understanding. The second phase, concept introduction, is initiated when a concept or reasoning pattern is presented to the student or invented by the student and then is used by the student to increase understanding of the exploratory experience. The student's ability to apply the concept is extended during the concept application phase, which provides time and experiences for stabilization of the idea or reasoning process. Karplus called these three instructional phases the learning cycle strategy. Detailed explanations of the learning cycle concept are provided by Renner and Lawson (1973) and Lawson and Renner (1975). Workshop materials on the learning cycle strategy can be found in Karplus _et al_. (1977).

There are reports of learning cycle strategies applied to curriculum materials at elementary levels and in chemistry and physics at the collegiate level. Lawson (1978) provides elementary teacher training materials. Renner (1973) reports of collegiate use in physics. Herron (1975) reports a project in the discipline of chemistry at postsecondary level.

BACKGROUND

The purpose of this project was to reduce the number of unsuccessful students that enrolled in the Introductory Biology 10 and, therefore, increase the number of students that have an opportunity to major in biology or prepare for careers in the life sciences or allied health fields. In the ten years preceding the project, grade distributions in Biology 10 were consistently biomodal, with as many as 45% of the students in the "unsuccessful" group. Moreover, over a five year period, 75% of the ethnic minorities fail to complete the course satisfactorily and not one of the 20 such students enrolled in the two semesters prior to this project obtained a "successful" grade (A, B, or C). This problem occurs with greater or lesser severity in most institutions of higher learning that are attempting to maintain quality academic standards.

The major underlying cause of this problem was perceived to be the level of thinking skills possessed by the incoming freshman. The level of thought, concrete, transitional or formal, was highly correlated to the degree of success for each student. Entrance ACT scores of the students are at that national average for public institutions. In addition, approximately 50% of the students enrolling in the Introductory Biology course are at the concrete level of thought, about the same level as national studies indicate for other schools. Problems of dropout and failure in introductory courses are common in science disciplines in higher education.

A history of unsuccessful attempts to alter subject matter content, administrative procedures, textural materials, etc. caused increased concern and anxiety within the members of the Department of Biology. Considerable changes in attitude and perspective among faculty members had to take place before a project that focused on pedagogy, and specifically learning theory, could be undertaken to help remedy the situation.

DESCRIPTION

The major feature of the project was to prepare curriculum materials that would give students at either the concrete or formal levels of thought equal opportunity to master basic concepts in the biological sciences. These materials were based on the learning cycle instructional strategy as derived from Piagetian learning theory. Twelve major laboratory experiences were written and tested; each included exploration, concept formation and concept application components, the three phases of learning cycle strategy. In addition, lecture outlines that were designed to formalize the concepts were prepared. Since the completion of the original project, curriculum materials have been developed for the discussion period.

The goal was to develop student skills, in synthesizing concrete knowledge into formal concepts and, subsequently, foster the utilization of these concepts in solving related problems. Population directly benefiting from the project were 80 academically disadvantaged undergraduate life science students per year and an additional 120 typical biology and allied health students.

The materials were developed based on our specific students' needs, faculty skills, equipment inventory and current physical facilities. Three faculty members, two outside consultants, three graduate students, one undergraduate student, and members of the preparation staff were involved in the development and testing of the materials. In addition, the equivalence of a quarter-time secretary was needed for clerical duties.

The project was originally scheduled to be completed within one year but an additional year was needed to rewrite and re-test outcomes. The project is still ongoing with some revision constantly occurring.

Total cost of the project was nearly $150,000 of which FIPSE sponsored $81,549. The project could be accomplished with less personnel cost if teaching loads could have been reallocated within the department.

During the project, lecture, discussion, and laboratory components of the course were closely integrated. The restructured course still has the not unusual components of lecture, laboratory, and discussion but is does differ in the sequence with which these three are utilized, in lecture style and in the role that the laboratory now commands.

The traditional sequence of lecture, in a relating role, preceding the other two components followed by confirmation of this material in the laboratory was reversed. Now laboratories are scheduled prior to lectures and cover materials not yet presented in lecture. Laboratory is the vehicle for the introduction of major concepts with the students developing concepts out of their own explorations. The lectures come after the laboratory experience, confirming and expanding the concepts already forming in the mind of the students. The discussion period deals with lecture presented topics and provides opportunities to apply concepts in new situations, solidifying the conceptual framework of the material.

The course framework was developed around six major themes or principles which are introduced at the beginning of the semester and are revisited at the various levels of biological organization. These principles are the structure-function relationship, unity with diversity, regulation-homeostasis, energy-metabolism, heredity-reproduction, and the integrating theme of evolution.

The learning cycle laboratories provide opportunities for students to explore aspects of digestive, circulatory, and nervous systems as well as animal development, the basic unit of life, pigments of photosynthesis, asexual cell division, and bacterial transformation. While pursuing these topics in these laboratories, students also experience some of the aspects of science as a way of knowing and interpreting the natural world. Other learning cycle laboratories emphasize the nature of science and provide experience in independent investigations.

These materials are being used currently with some ongoing rewriting. In addition, learning cycle materials have been and are being developed for use in the discussion period.

PROJECT RESULTS

The project developed a focus around which the 22 members of the Department of Biology rallied. The problems that plagued the introductory course had been ongoing and escalating prior to the project. Faculty concern had grown to anxiety and frustration after attempts to rectify the situation repeatedly failed. As the FIPSE materials were developed and tested the faculty immediately involved became excited and related their enthusiasm to other faculty members and staff. A strong cooperative effort began that started to be rewarded by highly positive feedback from students. This change in attitude concerning the introductory course for majors was one of the most significant results of the project.

Students were asked both verbally by the non-teaching project coordinator and in writing how they felt about the way the course was presented and about specific aspects of the curriculum materials. The overall tone of the comments was highly positive. In fact, from the samples taken, there were no direct negative comments. Quotes are included in this report to generate a feeling for student opinions. Representative comments are included only if they were mentioned by 5% or more of the students.

Grading and Evaluation

Grading is fair because you know all of the parts that contribute.
Tests are hard because they ask you to think about ideas in general.
Sometimes the labs were very difficult since we had to come up with the answers ourselves.

Laboratory Materials

I liked working with all of the materials and equipment.
Some labs were too long.
I thought figuring out the answers on my own was great but it sometimes took a long time.
The labs organized my thoughts.
I liked the lab experiences most. They were a lot of fun.
The labs were very "student friendly."
It is hard to believe that you are allowed to come up with your own answers.
The exercises were easy to follow but could get awfully involved.

Lectures

I still think I like lectures first.
They were well organized and always led to a point.
Most of the time they summarized the labs.
Some didn't follow the book.
It was easy to take notes and they made sense afterwards.
They followed along with the lab well.

Discussion

They were sort of like tests that weren't graded.
It was a good opportunity to find out what you did or didn't know.
I'm not sure they were needed.
It gave everyone an opportunity to summarize what we learned.
Discussions gave us practice with the ideas we learned.

The Course

It was sure different from my high school class.
Everything you did had something to do with thinking.
It was tough but challenging.
The course would be easier if the lectures came first.
________ made it very easy to understand but she made us think for ourselves.
I feel good about the outcome.
It made me realize I could figure things out for myself.
One of the most fun aspects of the course was understanding how scientific information is obtained.
The class was great because I felt I learned a lot.

Although the statements are not always exact quotes, they are summary statements of feelings expressed by the students of the 1986 winter semester.

In the four semesters prior to the use of the FIPSE materials an average of 10% of the class received F's. The first semester yielded zero failures in a class that contained 9.5% minority students. This is a highly significant indicator of the success of the materials.

Reasoning level classification of students in classes prior and subsequent to use of new materials was based on pencil and paper proportional reasoning tasks as done by Fuller (1976). These were scored using a system condensed from Karplus and Peterson (1970). The results, 49% of the students at concrete level, 23% transitional and 27% formal, paralleled the findings of McKinnon and Renner (1971).

The results of comparing backgrounds between traditionally taught students and learning cycle taught students is given in Table I. The comparison of achievement of these two groups is given in Table II.

TABLE I

COMPARISON OF ACHIEVEMENT
BETWEEN
TRADITIONAL AND LEARNING CYCLE
TAUGHT STUDENTS

TEACHING STRATEGY		ACHIEVEMENT MEASURES			
		FORMAL OPERATIONAL % BURNEY	BSCS* (50)	NELSON (65)	SUBJ. PREF. (32)
TRADITIONAL 1983	$\bar{x}$	62%	29.9	48.1	27.4
	Range	11-29	13-42	15-61	12-32
LEARNING CYCLE 1986	$\bar{x}$	78%	34.9	49.6	29.8
	Range	12-28	14-45	15-61	16-32

* Means Significantly Different at > 0.05 Level

TABLE II

COMPARISON OF BACKGROUNDS
BETWEEN TRADITIONAL AND LEARNING CYCLE
TAUGHT STUDENTS

TEACHING STRATEGY		BACKGROUND MEASURES				
		MSSP* (100)	FORMAL OPERATIONAL % BURNEY	BSCS* (50)	NELSON (65)	SUBJ. PREF. (32)
TRADITIONAL 1983	$\bar{x}$	60.2	49%	26.4	40.8	24.3
	Range	3-99		13-38	7-58	4-36
LEARNING CYCLE 1986	$\bar{x}$	48.2	45%	24.2	38.8	23.8
	Range	0-99		8-35	7-54	0-30

* Means Significantly Different at > 0.05 Level

Comparison of student evaluation of laboratory experiences in the learning cycle vs. traditional format gave a significantly higher evaluation for the learning cycle laboratories. [Anova statistic-null hypothesis (Subject/Group x Trials) at $p < 0.05$.]

Statistical evaluations were conducted by an outside consultant.

CONCLUSIONS AND RECOMMENDATIONS

Because of the positive outcomes for both the students and faculty, the project was a success. It has involved a lot of work, re-education and training, extra hours in preparation and development, and considerable financial commitment. The rejuvenation of spirit and drive were worth the effort in themselves. The major insight that has been gained by the faculty is the realization that a systematic, philosophically based approach to problem solving in science education is as appropriate and effective as it is in science research. Random attempts at course modification are inappropriate and with respect to reaching students and assisting their learning processes.

Those who are interested in this project for their own use must make sure that they have identified the real problems that confront them. If this paradigm appears appropriate then it should be considered for their use but should not consider the specific materials generated the most appropriate for their students and faculty. Some parts may be directly adaptable, other may not. The key seems to be in the individual needs of the students and the expertise and materials that can be brought to bear on the specific situation.

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