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Concept Mapping as a Strategy for Teaching and Developing the Caribbean Examinations Council (CXC) Mathematics Curriculum in a Secondary School.

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INTRODUCTION

This study was designed to assess the usefulness of concept mapping as a technique for the teaching and learning of mathematics and the development of the CXC mathematics curriculum at the secondary school level.

It had as its focus the use of concept mapping as a technique that would facilitate students' transition from rote learning towards more meaningful learning. The central argument was that learning mathematics required certain modifications of conventional teach- ing practices, since the teacher's role was that of a facilitator of learning who helped provide a learning environment within which students could construct their own mathematics.

In particular, the study sought to examine the teaching and learning situation in a classroom of a secondary school in Barbados where students' understanding of certain mathematical concepts was explored using concept mapping strategies. Concept mapping was proposed as a metacognitive strategy. It was invented by J.D. Novak in l972 as a tool for assisting students learn-how-to-learn, both in the classroom as well as in other spheres of human activity. The study was planned and conducted as a contribution to the teaching and development of the CXC mathematics curriculum in secondary schools. A subsequent replication study took place exactly two (2) years later.

THE PROBLEM

There is a crisis in mathematics education in the Caribbean (and world-wide) today. This has been with us for some time, but the situation seems to be deteriorating from year to year.

The CXC annual reports for the period 1981 to 1992 have shown that 524,950 students were tested by CXC, commencing with 32,030 in 1981 and increasing annually until it reached 53,138 in 1992. However, only 139,139 (26.5%) succeeded in obtaining the minimum standards indicative of comprehensive knowledge of the CXC syllabus or working knowledge of most aspects of the syllabus (Grades 1 and 2).

This crisis in performance can be delineated as the gap between two dimensions of mathematical understanding, conceptual knowledge and procedural knowledge. Eisenhart et al (1993) described conceptual knowledge as the conceptual understanding of the underlying structure of mathematics, that is, as the relationships and interconnections of ideas that explained and gave meaning to mathematical procedures. On the other hand, procedural

knowledge dealt with the mastery of computational skills and the knowledge of procedures for identifying mathematical components, algorithms and definitions.

The problem can be phrased as follows:

WHAT IS THE NATURE OF THE RELATIONSHIP BETWEEN STUDENTS' CONCEPTUAL GRASP OF MATHEMATICAL TOPICS AND THEIR PERFORMANCE IN THESE TOPICS?

Novak (1977), Gowin (1981) and Novak and Gowin (1984) probed for a solution of the research problem by developing Ausubel's assimilation theory of meaningful learning (1963, 1968, 1978) and by invent- ing two metacognitive strategies, concept mapping and vee diagramming as aids to meaningful learning.

Ausubel viewed performance as proportional to the quantity and quality of relevant knowledge that students possessed when they commenced an area of study; he parted company with the prevailing behaviourist outlook by emphasising concepts as components of cognitive organization and by proposing a hierarchical ordering of concepts in cognitive structure from the most inclusive to the less inclusive to the most specific. Novak developed this notion and invented concept mapping as a graphical representation of the learner's prior knowledge: the size (or quantity) of a student's knowledge was measured by the number of Propositions and Examples, while the degree of understanding (or quality) was measured by the Hierarchical Levels and Crosslinks that comprised the typical concept map. He put forward concept mapping as one way of bridging the gap between conceptual and procedural knowledge. Gowin (1981) went one step further and invented Vee diagramming as a pictorial representation of the interplay between the dimensions of conceptual and procedural knowledge in the construction of new knowledge. He also viewed the concept map as a representation of the conceptual aspect and as a procedural element.

Novak (1992) proposed a Learning Matrix, depicting as its vertical component a continuum from rote to meaningful learning, that is, from little association of new knowledge with existing cognitive structure, to high levels of integration with a well-integrated, relevant conceptual framework. The horizontal component comprised a reception-discovery continuum for instruction. Concept mapping and vee diagramming were located as both meaningful learning and reception instructional modes. The thrust of this study was the use of these two (2) strategies so as to answer the research qeustion, the relationship between conceptual and procedural knowledge.

RESEARCH STUDY (1991) AND REPLICATION STUDY (1993)

The research question was operationalised as three (3) hypotheses as follows:

(i) Students who are taught specific mathematical topics by means of the concept map strategy will perform significantly better in these topics than students taught by conventional methods.
(ii) Scores obtained by students on their concept maps will correlate significantly with the scores obtained in the comprehension and reasoning components of certain CXC-type mathematics tests.
(iii) Students who are taught mathematical topics by means of the concept map strategy and who obtain high concept map scores, will tend to obtain high scores in the comprehension and reasoning components of certain CXC-type mathematics tests.

The research employed a quasi-experimental design with non-equivalent groups. The sample comprised four (4) intact groups of Form 5 students who were preparing for the CXC public examinations in June 1991 (Form 5 corresponded to grade 11). These groups were randomly assigned as follows: one group was designated as the experimental group that was taught by the Investigator, and the others as control groups, two (2) taught by an experienced mathematics teacher and one by the Investigator. Arrangements were made for the same syllabus, same topics and same examinations to be taken by all groups in the course of the experiment. Three topics were studied during an eight week period: Earth Geometry, Graphs, gradients and areas, and Linear Programming.

The research instruments that were constructed for collecting data or for facilitating the experiment were as follows:
(i) A multiple-choice test was prepared and administered by CXC prior to the experiment. It comprised sixty (60) multiple-choice items that were based on the CXC syllabus and excluded the topics that were studied during the experiment. These items measured specific objectives according to the profile dimensions of computation, comprehension and reasoning, and were weighted in the ratio 3:5:2. A KR-20 reliabilty coefficient of 0.68 was obtained. This test was used as the Pretest in the subsequent analysis.
(ii) Sociograms were constructed so as to form groups within both classes taught by the Investigator. This was in keeping with the constructivist perspective that children construct knowledge by interacting with others and presenting their solutions to the entire class for discussion and debate.
(iii) A teacher-constructed multiple-choice test was prepared. A Table of Specifications was set up by the Investigator, comprising sixty (60) objectives to be studied during the experiment and weighted in the ratio 3:5:2. Three (3) groups of twenty (20) objectives were chosen by random selection and randomly assigned to three (3) experienced mathematics teachers, including the Investigator. Test items were prepared and sent to two (2) independent mathematics educators who were asked to grade them according to the CXC profile dimensions. Finally, any discrepancies were reconciled by the Investigator and a CXC mathematics official, and a final list of items prepared. A KR-20 reliability coefficient of 0.84 was obtained. This test was used as the Posttest in the subsequent analysis.
(iv) A students' Questionnaire was prepared, and administered to the treatment group after each Topic studied. It aimed at providing specific

information about any attitudinal changes as well as formative evaluation data of the effectivenes of the concept map strategy.

(v) A student Interview schedule was prepared as an indepth sequel of the questionnaire responses. Interviews were conducted after each topic and at the end of the experiment.

(vi) Quizzes were administered at the completion of a topic to both groups taught by the Investigator, so as to determine the students' ability to solve problems and their understanding of the specific concepts taught. The mastery mode was used to evaluate the experimental group, while the traditional scoring was applied to the control group.

(vii) Three (3) concept maps were constructed by the Investigator based on the textbook material only. They were scored and used as criterion concept maps for grading the student-prepared concept maps.

(viii) The CXC mathematics examinations comprised an essay type and a multiple-choice type examination that were prepared and administered by CXC in June 1991. These were weighted in the ratio 2:1, with profile components the same as those of the CXC pretest and posttest. Reliability coefficients of 0.85 for the multiple-choice test, 0.91 for the essay-type test and 0.93 overall, were calculated.

Prior to the experiment, a Pilot study was carried out in another secondary school. It aimed at deter- mining whether the concept map technique could be taught over a period of four (4) lessons, and whether any changes should be introduced in the experiment.

The validation of the lesson plans administered by the Investigator to the two (2) groups taught, was effected using the following procedures. A panel of three (3) experienced mathematical educators was asked to critique the extent to which the concept map strategy was evident in the lesson plans. The actual teaching of the lessons was monitored by independent observers, who were asked to sit in on parallel classes taught by the Investigator and to determine whether any effects of the mapping behaviour might have entered into the teaching of the control group, and whether the concept map strategy was a significant feature of the teaching.

Two (2) introductory lessons dealt with the rationale behind the use of concept maps, and the actual construction of concept maps, including the scoring criteria employed. Each topic was studied, with students constructing concept maps by working individually or in groups. Three (3) assignments were required from each student, to be submitted at the end of each topic, after the completion of the Quiz. The first concept map assignment was discussed with each student, so as to determine his/her strengths and weaknesses in concept map construction, as well as any difficulties experienced in the setting up of hierarchical levels. The second map was used to illustrate the choice of suitable link words and the identification of crosslinks. The third map was used as the touchstone of their understanding of the concept map strategy: students were urged to apply the scoring criteria carefully, and these scores were used in the choice of students for the Interviews at the end of the experiment. The student-prepared concept maps were scored by the Investigator and by another

mathematics teacher, and final scores were obtained by a reconciliation of both sets.

The hypotheses enunciated above were then analysed as follows. Hypothesis l was tested by an analysis of the pretest and posttest scores that employed a combination of a regression analysis and analysis of variance, namely analysis of covariance (ancova). Hypothesis 2 was tested by the setting up of a correlation matrix that compared the concept map scores and the profile components of the posttest and the CXC examinations in mathematics. Hypothesis 3 was tested by the setting up of a Table to compare concept map scores and the profile components of the posttest, quizzes and CXC examinations in mathematics, employing scoring criteria that identified high, medium and low scores. The questionnaires and interviews were also analysed to determine any attitudinal changes that might have resulted from the concept map strategy.

The replication study was undertaken two (2) years after the original study so as to improve the internal validity of the quasi-experimental study with non-equivalent groups, and to provide alternative scores for the subsequent statistical analyses. More emphasis was placed on students' construction of their concept maps, both individually and in groups. A few minor changes were made. The Investigator taught the experimental group, and two (2) control groups were taught by another teacher. There were no changes in the Instruments administered, with the exception of the Quizzes which were altered and scored according to the CXC profile components of computation, comprehen- sion and reasoning.

The following findings were obtained:

(i) The concept map strategy did not produce any significant difference in students'performance in certain mathematical topics when compared with conventional methods.

(ii) Scores obtained by students on their concept maps correlated significantly with the scores obtained in the comprehension and reasoning components of the CXC examinations in mathematics.

(iii) Students who obtained high concept map scores did not always obtain high scores in the comprehension and reasoning components of certain CXC-type examinations in mathematics.

(iv) Concept maps enabled students to acquire a more positive view of meaningful learning.

The overall conclusion was that concept mapping served as a useful instructional, curricular and formative evaluation tool.

CONCLUSIONS

One possible limitation of the study was the methodology used. Novak (1977) had observed that the most common type of doctoral study was the comparison of methods and that most studies concluded that there was no significant difference between the methods used. He suggested that some other approach might show more promise, and joined the increasing number of

thinkers who saw the need for a qualitative analysis that would attempt to evaluate the learner's thought processes and move away from a behaviourist to a con- structivist paradign.

The "facts" that were analysed, namely the scores from the CXC-type examinations, were generally restricted to the lower order levels of thinking (rote level, recall). At the same time, each item of the multiple-choice test measured one (1) behavioural objective. This, however, reduced learning to a set of independent behavioural objectives that were evaluated on a uni-dimensional multi-choice scale which presumed one correct answer from a choice of four alternatives. It would seem that the scores were flawed to some extent. Analyses of levels of meaning as understood by CXC did not measure the same things as analyses of hierarchical levels as understood by Ausubel/Novak. Hierarchy was understood in various ways, depending on whether behaviourist or ausubelian spectacles were being used. Gowin and Novak (l984) had observed that, while it was easy to write objective questions that test whether or not the objectives of rote recall of specific information were met, it was exceedingly difficult to design a test to determine whether new knowledge had been analysed, synthesised and evaluated by students. Concept mapping, on the other hand, required students to perform at all levels in one composite effort.

Three (3) recommendations were made, based on the findings of the study:

(i) Students should be encouraged to use concept maps at an early stage of their education. Vee diagramming could be introduced when it was felt to be most effective.

(ii) The concept mapping and vee diagramming techniques should be introduced into teacher training and into the educational system through workshops, seminars etc.

(iii) Further study of the CXC profile components and the validity of multiple-choice tests should be encouraged.

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