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TEACHING AND LEARNING IN HIGH SCHOOL BIOLOGY LABORATORY CLASSES IN ISRAEL

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Sharp criticism has been levelled at previous research studies dealing mainly with regard to the limited scope of these studies and their research methods, which were not suited to the special features of laboratory teaching (Blosser, 1981; Hofstein & Lunetta, 1982). In light of this criticism and the awareness of the complexity of laboratory teaching we chose a number of strategies, so that each of them would be able to verify the results obtained by the others.

As the framework for our research we used the model suggested by Hegarty (1979). The advantages of this model lie in the detailed categories, the operational definition of variables and in the suitability to the teaching-learning process in the laboratory. We were concerned only with those parts of the model dealing with the laboratory, and excluded the theoretical lessons. Since the biology curriculum in Israel is inquiry oriented, scientific inquiry was chosen as a main focus of the study.

Purpose of Study

The aim of this study is to describe the teaching and learning practices in biology laboratory classes in Israeli high schools. According to our model, we defined four objectives which were derived from the main aim:

a) Analyzing the planned activities as presented in the laboratory manuals. (The intended curriculum)

b) Examining the importance and degree of achievement of different instructions objectives in the laboratory as perceived by teachers and students in high school. (The perceived curriculum)

c) Describing and analyzing the activities actually taking place in the laboratory. (The implemented curriculum)

d) Assessing the outcomes of the learning as exhibited by the students' achievement on laboratory tests. (The achieved curriculum)

METHODS

1 The planned activities in the textbooks commonly used in schools were content analyzed to establish their level of inquiry (based on Herron, 1971) and the inquiry activities (based on Tamir & Lunetta, 1978). Additional features of the laboratory manuals such as layout, distribution of questions in the text, clarity, drawings, and diagrams, were also studied. Altogether 12 biology textbooks were analyzed.

2 Perceptions related to instructional objectives in the laboratory were examined by questionnaires, in which teachers (N=62) and students (N=221) were asked to rate each of 31 objectives, a) with regard to its importance and, b) with regard to the extent to which it was achieved in their classes. In order to increase the teacher sample, an additional questionnaire which included eight main objectives was mailed to another group of teachers (N=93). Altogether we had responses from 155 teachers. The teachers were also asked to indicate what reasons would account, in their opinion, for any gap between the rating of the level of importance and the degree of actual achievement.

3 Description of the activities actually taking place was done by observations in 75 laboratory lessons (160 hours) in six different schools (religious: girls only, rural, developing town, three city), in Grades 9 to 12. Observations were conducted with the aid of a special observation instrument, developed as part of this research project, which focussed on the inquiry components of the lesson (see Appendix I). The structured observations were accompanied by interviews with students ('open observations') in which the difficulties they encountered during the lessons were assessed. The observers filled an additional form at the end of the lesson, in which they provided information concerning the frequency and location of laboratory lessons at various grade levels, the presence and role of the laboratory assistant, the use of teaching aids, the use of instruments and tools in laboratory work, as well as the number of students and their grouping in the lesson. In addition, teachers and students were interviewed about their attitude towards laboratory lessons. Frequency of homework assignments was checked, and the written homework was analyzed to establish their demands for inquiry skills and the students' mastery of these skills. The analysis of the homework questions was done by a method similar to that used in analyzing the inquiry activities in the textbooks (see 1. above). Analysis of student answers was done by a method similar to that used in the analysis of the matriculation examinations (see below).

4 Assessment of the outcomes was done by analyzing a sample of laboratory matriculation examinations in the years 1980-1983. There are great advantages in using existing matriculation tests:

a) the tests already exist;

b) information is collected from a large population;

c) the tests are a 'natural' part of the educational system, hence the teachers and the students do not perform 'specially' for the researcher.

In analyzing the questions, we identified the demands for inquiry skills, in a method similar to that used in analyzing inquiry activities in the textbooks. In analyzing the answers we checked the difficulties students encountered in those skills, with the aid of the tool used for evaluating matriculation examinations in this country, which includes a list of inquiry skills, for each of which the various expected levels of answers are listed (Tamir, Nussinovitz, & Friedler, 1982). For a number of skills (defining a problem, formulating a hypothesis, planning an experiment, reporting data) we conducted a more detailed analysis of a limited number of examinations, as we wanted to study in depth the difficulties students have with these skills. There are three unique features to our method:

a) Combining a number of sources of information about the teaching-learning situation in the laboratory.

b) Developing an observation strategy based on a combination of structured and open observations.

c) Analyzing matriculation tests. We believe this method has potential generalizability for other studies.

MAJOR FINDINGS AND MAIN CONCLUSIONS

1 Teachers rate the importance of learning scientific inquiry skills the highest among the clusters of learning objectives in the laboratory. Students rate it fourth (out of six). This difference hints at difficulties that teachers have in communicating the importance of scientific inquiry to their students.

2 A statistically significant difference exists for most objectives between the assigned level of importance and the rating of their achievement, the former being higher. Teachers explain this gap mainly in terms of administrative constraints, such as: budget cuts, insufficient instructional time, unsatisfactory work conditions (e.g., crowding in the labs), as well as by the need to adapt subject matter and teaching methods, in the eleventh and twelfth grades, to the requirements of the matriculation examinations.

3 Half of the laboratory exercises in the laboratory manuals commonly used in high schools are at level 1 of the inquiry scale (problem and methods provided to the student) and a third are at level 0 (problem, methods and even expected results are provided). The rest of the laboratory exercises (one-fifth) are at level 2 (only the problem is provided).

4 Forty per cent of laboratory lessons during the observation period took place in twelfth grade, 28 per cent in ninth grade, and very few (11%) in tenth grade. Most laboratory lessons (84%) occupied double periods (100 minutes). All took place in specially equipped laboratory rooms. In two-thirds of the observed lessons the number of students ranged between 11 and 20. The students worked in pairs in 50 per cent of the lessons observed, in groups of three to six in a quarter of the lessons and individually in a quarter of the lessons. In 97 per cent of the lessons a laboratory assistant was available to prepare the necessary equipment and materials. The tool most widely used was the microscope. Students were assigned homework in 86 per cent of the lessons. Evaluation of the students' performance in the laboratory, i.e. by a special laboratory test, was practically non-existent.

5 The potential of group work, as far as student enrichment, developing concepts and self-criticism are concerned, was not actualized. The verbal interaction among students in the groups was mainly on a low cognitive level featuring techniques and procedures such as: 'Put a drop of water', 'Bring the test tube', 'What do we have to do now?'. Teachers did not interfere with setting up work groups.

6 The laboratory matriculation examination was found to play a decisive role in setting up laboratory lessons and in shaping their nature.

7 The same texts were used in most laboratory lessons in all schools, especially in the ninth and twelfth grades.

8 Only a small part of the discussions in the lessons was devoted to inquiry processes. This part was larger in the twelfth grade than in the ninth grade. This finding can be explained by the fact that in the ninth grade most laboratory exercises are on inquiry level 0, while in the twelfth grade they are on inquiry level 2.

9 The rise in inquiry levels in laboratory lessons (especially those which followed the series 'Inquiry Oriented Laboratory Problems') was accompanied by an increase in the time needed for arrangements as well as that required for conducting the experiment, but very little additional time was devoted to discussion. These findings raise serious doubts about the meaningfulness of learning in these inquiry oriented laboratory lessons.

10 The following difficulties were discovered through the interviews (the 'open observations'): a distorted understanding of fundamental concepts (such as: cell, enzyme); inability to link theoretical knowledge to observed phenomena; inability to distinguish the relevant from the irrelevant in the experiment; misleading associations and deficiencies in knowledge, especially of chemistry related to biological processes. The value of problems in chemistry, especially in eleventh and twelfth grades, was also stressed by teachers in the interviews.

11 Students' achievement in the matriculation examinations was on the average very high. However, it was lowest in the following skills: defining a problem, formulating a hypothesis and planning an experiment. In addition we found difficulties in defining the variables and in the ability to plan systematically a complete experiment including controls, conditions, replications, etc.

12 All teachers and students who were interviewed considered the laboratory lessons to be an essential part of learning biology.

Many studies would end at this stage. However, we feel that it is important to translate research findings into action. Hence we designed an instructional module to deal with some of the difficulties which were identified.

In light of the findings which pointed at too little consideration of scientific inquiry in the textbooks as well as in the classes, and at deficient mastery of inquiry skills as evidenced by the students' answers to the matriculation examinations, a module entitled 'Basic Concepts in Scientific Research' was designed. In this module the text is accompanied by 'dry' as well as 'wet' laboratory tasks, constructed hierarchically according to skills. The goal of the module is to clarify the concepts: problem, hypothesis and experimental design, while incorporating information and explanations about the historical and philosophical origins of these concepts, and about the way they are used and applied in scientific research. Furthermore, the module stresses the everchanging nature of scientific knowledge and the rule of the scientist in formulating scientific theories and in creating scientific knowledge.

The module was tried and evaluated in seven eleventh and twelfth grade classes in six different schools. Evaluation was carried out by observation, achievement tests and questionnaires administered to the teachers and the students. Positive results were found concerning the students' mastery of the skills of defining a problem, formulating a hypothesis and planning an experiment and their application to solving inquiry problems. In addition the module was evaluated by experts including high school teachers, professors of biology and professors of history and philosophy of science. The module was revised on the basis of the comments offered by these experts and is now available to schools generally.

RECOMMENDATIONS

Based on our findings, we offer (in addition to the 'module treatment') the following recommendations:

a) Relevant chemistry chapters must be incorporated as an integral part of biology studies, especially in higher grades (eleventh and twelfth).

b) The laboratory matriculation examination should be re-examined, with the purpose of modifying its topics and its form. This should be done in order to prevent routine learning of inquiry skills which might create a distorted image of scientific inquiry.

c) The laboratory activities in the textbooks should be re-examined, with the purpose of:

1 matching the topics of these activities to the level of students (especially in ninth grade);

2 increasing the inquiry level of laboratory activities (especially in ninth and tenth grades);

3 rewriting the theoretical material which is required for meaningful performance of the experiment and incorporating it in the text.

d) A substantial part of the preservice and inservice training of science teachers should be devoted to teaching in the laboratory.

Within this framework it is essential to:

1 explain to the teachers the aims and objectives of laboratory teaching and its importance, in each grade level;

2 clarify the concept of 'inquiry' while emphasizing the changing structure of knowledge and the role of creativity and intuition especially at the stages of defining the problem and planning the experiment. The module 'Basic Concepts in Scientific Research' can be very useful for this purpose;

3 provide opportunities to analyze laboratory exercises in textbooks so that the teachers learn to identify inquiry activities and inquiry levels, and consequently build lesson plans with an inquiry orientation and carry them out properly;

4 stress the complexity of the demands that laboratory lessons impose on teachers (preparing materials, trying the experiment beforehand, supervising the laboratory assistant, leading discussions, assigning a laboratory report and checking it), as well as on the students (they must be in command of relevant biological content, proficient in inquiry and manipulative skills and, in addition, able to apply them to the problem they try to solve). It must be stressed that the laboratory should be an integral part of the current curriculum. Each laboratory lesson should begin with an introductory discussion, aimed at clarifying the relevant biological content, the techniques and the inquiry skills involved in the experiment to be performed. Theory and practical work should be tied together. For this purpose post-laboratory discussions are essential as well.

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APPENDIX I

Some details about the method of the observation

The laboratory class was divided into three stages: pre-lab discussion, performance and post-lab discussion. The observations were carried out by two observers who observed simultaneously the pre- and post-lab discussions. During the performance stage one observer concentrated on the teacher and the other observer moved freely from one working group to another, staying with each group for 15 minutes. During the first 10 minutes the observer filled in the LOS observation sheet (time unit - 1/2 minute), shifting systematically each minute from one student to the next in the same working group. When all students in the group were observed, the first student was observed again. After 10 minutes the observer informally questioned the students in order to find out the students' difficulties in the specific lab.

The Laboratory Observation Schedule (LOS) contains the following categories:

PRE-LAB DISCUSSION*

1. Identify and formulate problems and hypotheses
2. Tie to previous lessons/ labs
3. Present theoretical background
4. Present facts and problems related to the design of the experiment
5. Talk about techniques
6. Predict results
7. Manipulate data

PERFORMANCE*

1. Talk about techniques
2. Present theoretical background
3. Present facts and problems related to experiment
4. Manipulate data
5. Talk about the results
6. Interpret results, draw conclusions

MISCELLANEOUS

1. Student talk-unrelated to the lesson
2. Students write in the notebooks
3. Students perform the experiment
4. Students read from the testbook
5. Student absent
6. Teacher illustrates
7. Teacher performs instead of the student
8. Teacher talk-administrative matters
9. Teacher talk-discipline
10. Teacher talk-unrelated to the lesson

POST-LAB DISCUSSION*

1. Manipulate data (reporting, making)
2. Talk about the results
3. Interpret results/draw conclusions
4. Talk about the experiment (variables, control, limitations)
5. Apply and make generalisations
6. Teacher gives instructions for the next experiment

* When not specifically stated the category may apply either to students or teachers.

The four main advantages of this observation method were: a) A simple way to gain a lot of information. b) Little disturbance to the ongoing lesson. c) Low cost. d) Immediate availability of the information for analysis.