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Khawla Shakhshir Sabri & Abdul Hamid M. Emuas

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The Relationship between School Laboratory Experiments and Academic Achievement of Palestinian Students in Introductory University Science Courses

KHAWLA SHAKHSHIR SABRI
& ABDUL HAMID M. EMUAS
Birzeit University, Palestine

ABSTRACT This study examined the relationship between science laboratory experiments observed in secondary school and the academic achievement of Palestinian students in university Physics, Chemistry and Biology courses. The study revealed that there is a strong relationship between the total number of secondary science laboratory experiments in secondary school and the academic achievement of Palestinian students in science theory and laboratory courses. The size of this effect ranged between 26% and 50% for the various science courses. A regression analysis was conducted to determine the factors which most likely will predict the effect of observing an additional secondary school science laboratory experiment on the academic achievement of university students in introductory laboratory and theory courses.

Introduction

The teaching of science in laboratories has been a controversial issue. Laboratory work is both time consuming and expensive compared with other models of instruction. Hence, the efficiency of such a method of learning should justify the additional time and cost of using it, especially in primary and secondary education. In other words, the increase in the educational budget for using laboratories as a model of teaching should be more efficient in accomplishing the objectives of teaching sciences than other models of instruction. Teaching science through laboratories needs, therefore, to be constantly evaluated using one or more of the following methods.

First, there should be a comparison of the academic achievement of students who are taught through the laboratory method compared with the achievement of students taught through other models. Harty & Al-Felah (1983), for example, indicated that students exposed to laboratory-based education exhibited significantly greater chemistry achievement than students in comparable lecture-demonstration groups on both immediate and delayed post-tests. Babikian (1971) demonstrated that the expository and laboratory methods are significantly more effective than the discovery method for teaching science concepts to eight grade students. Zitoon & Al-Zaubi (1986) concluded that the laboratory method is more effective compared with the traditional method in developing the skill of scientific thinking for Jordanian science stream secondary students. Low achieving students using the laboratory method performed better than their counterparts who received the lecture method (Odubunmi & Balogun, 1991). In opposition to this, other studies have not found any significant differences in achievement between the laboratory and the demonstration methods (Thijs & Bosch, 1995).

Secondly, the extent to which laboratory instruction, experiments, and textbook are congruent with the expected objectives of teaching sciences should be investigated. Tamer & Lunetta (1981) reported that laboratory handbooks do not provide students with expected opportunities to investigate and use the scientific inquiry method of teaching. Lunetta et al (1981) reported that laboratory instruction may play an important part in the achievement of some science teaching goals, but not all the stated goals of science education, as many teachers have not incorporated laboratory goals into their instruction and evaluation systems. The discrepancies between teaching goals and laboratory handbooks instructions also was shown by Fuhrman et al (1982).

Thirdly, investigating the efficacy of science laboratories can be done also by examining particular aspects and conditions of laboratory instruction methods. Fraser et al (1995), for example, evaluated the efficiency and environment of laboratory activities, although textbooks and traditional curriculum can lead to inefficiency in teaching laboratory courses (Keulen et al, 1995). Despite freshmen students carrying out high quality laboratory work, they obtained less reliable results than experienced technicians (Hadady & Fablan, 1996).

Fourthly, the management of student groupings and tasks in laboratory experiments should be examined for their effect on students' performance. Niaz (1995) concluded that students who perform better on problems requiring conceptual understanding also perform significantly better on problems requiring manipulation of the data in chemical experiments. Lawrenz & Munch (1984) showed that grouping students in the laboratory on the basis of their formal reasoning ability affected the science content achievement of students, and the relationships between individuals in a particular group. On the other hand, Kyle et al (1979) concluded that there is significant difference in the behaviours of students (listening, observation, and writing notes) enrolled in introductory level and advanced laboratories in five sciences disciplines at the University of Iowa from the behaviours of their cohorts who did not enrol in laboratory classes. Kozma (1982) examined the impact of instructional design in a chemistry laboratory course on performance and attitudes of students and concluded that the students who used high structure laboratory manuals scored significantly higher on the quiz and felt more satisfied.

Purposes of the Study

The aim of this study was to evaluate the efficiency of using science laboratory experiments in Palestinian (West Bank) secondary schools, particularly in their effects on the academic achievement of university students enrolled in introductory science courses having laboratory and theory components (Physics, Chemistry, and Biology). Specifically, the research attempted to answer the following questions:

- Does increasing the total number of laboratory experiments in secondary school improve the academic achievement in university science courses?
- Does increasing the number of laboratory experiments in one discipline in secondary school improve the academic achievement of university science courses for the same discipline?
- Does increasing the science laboratory experiments in the secondary school curriculum improve the prediction of university academic achievement in science courses?

Hypotheses

Using a null hypothesis approach, the following hypotheses were examined in this study:

- The total number of science laboratory experiments observed by the Palestinian students during their school study (grades 9–12) has *no significant effect* on their academic achievement in university introductory science laboratory courses in Biology, Chemistry, and Physics.
- The total number of science laboratory experiments observed by the Palestinian students during their school study (grade 9–12) has *no significant effect* on their academic achievement in university introductory science theory courses in Biology, Chemistry, and Physics.
- The one discipline laboratory experiments observed by the Palestinian students during their school study (grade 9–12) has *no significant effect* on their academic achievement in university respective theory courses.

Methodology

Target Population

School enrolment statistics for the West Bank in 1995–96 (Ministry of Education and PCBS, 1996) show that the total number of students was 662,627. The educational system includes 12 grades grouped into elementary, preparatory and secondary stages. Elementary and preparatory stages (grades 1–9) are compulsory for all students and are termed the ‘basic cycle’. The secondary stage includes grades 10–12. Students are divided in the secondary grades into literary or science streams. The new number of science students enrolled in the college of sciences in the Palestinian university were 1800 students in 1994–95. A total of 250 students were enrolled in Birzeit university (Council for Higher Education, Palestinian University Statistical Yearbook, 1994).

The secondary school science curriculum (Biology, Physics and Chemistry) is about one third of the total courses, while general science courses in the literary stream constitute 10% of the total curriculum (Shakhshir Sabri, 1996). The laboratory experiments conducted as a part of the curriculum and extra-curricular activities in the science stream secondary schools in the West Bank are the target of this study. The major science laboratory experiments are run in these secondary schools with a few simple experiments run occasionally in grades 7–9.

Sample

A total of 120 first year students at Birzeit University were selected in the academic year 1994–95. The sample comprised six sections of introductory science courses selected randomly from 13 sections.

Procedure

All students were asked to identify the number of experiments which they conducted or observed during their study in secondary school. Based on school curriculum, a list of science laboratory experiments in the West Bank secondary schools were identified, and experiments were classified into three groups: physics experiments, chemistry experiments and biology experiments (a list of the experiments is shown in the Appendix).

The number of experiments, however, conducted in Palestinian schools, varies according to laboratory equipment, materials available and teachers' experience. In general, students in secondary schools observed up to 20 science laboratory experiments in all science disciplines.

After collecting the school data, the respective university students' grades in the introductory sciences courses were collected. The courses are: chemistry 111 (laboratory) and 131 general chemistry (theory), physics 111 (laboratory) and 131 general physics (theory) and general biology 141 (one hour for laboratory and three hours for theory). The data of the study was tabulated, analysed and presented in different tables.

Statistical Analyses Performed

First, the correlation (Multiple *R*) between number of secondary school experiments and grades of science courses were computed. Second: *r* squares were computed to indicate the ratio of effect the number of laboratory experiments had on the science courses grades. Third: *F* values were determined to test significance levels of correlation coefficients among the stated assumptions of the study. Fourth: simple regression analysis was conducted between groups of data (number of secondary laboratory experiments and university science courses grades) to determine the predicting value of adding a new laboratory experiment.

Results

The relationship between the number of total experiments and part of experiments conducted in the secondary schools and the academic achievement of the same students in the introductory science courses are presented in three parts as follows:

Hypothesis One: effects of total number of science experiments

Table I presents the statistical tests of the correlation between the number of science laboratory experiments observed in secondary school and of university students' grades in the introductory science laboratory courses. It shows that the correlation between the two variables as indicated by multiple *r* values were r = 0.59 for Chemistry, r = 0.7 for Biology, and r = 0.62 for Physics.

		Statistical tests	
1	Total science laboratory experiments observed in secondary school and university students' grades of the introductory *chemistry laboratory* course	Multiple *R*	0.58887
		R Square	0.34677
		Adjusted *R* Square	0.32811
		Standard Error	8.70023
		F	= 22.17
		Significant *F*	= 0.0000
2	Total science laboratory experiments observed in secondary school and university students' grades of the introductory *physics laboratory* course	Multiple *R*	0.62274
		R Square	0.38781
		Adjusted *R* Square	0.37032
		Standard Error	6.6222
		F	= 22.171
		Significant *F*	= 0.0000
3	Total science laboratory experiments observed in secondary school and university students' grades of the introductory *biology laboratory* course	Multiple *R*	0.69842
		R Square	0.48778
		Adjusted *R* Square	0.46808
		Standard Error	6.73137
		F	= 22.17
		Significant *F*	= 0.0000

Table I. Correlation between total science laboratory experiments observed in secondary school and university students' grades in the introductory science laboratory courses.

Considering *R* square values, it shows that the number of science laboratory experiments observed in secondary school accounts for 35% of the variance on student academic achievement in the introductory Chemistry Laboratory course. In Physics courses, it shows that the number of science laboratory experiments accounts for 39% of the variance on students' academic achievement in the university introductory Physics Laboratory course. The number of science laboratory experiments observed in secondary school accounts for 49% of the variance on students' academic achievement in the university introductory Biology Laboratory course. *F* values shown in Table I shows a significant effect of number of science laboratory experiments observed in secondary school on students' academic achievement in the university introductory Biology, Chemistry and Physics Laboratory course. This means that the first hypothesis has been rejected. In addition, the regression analysis stated that observing an additional experiment in secondary school would increase students' grades between 1.4% and 1.9% in university laboratory courses.

Hypothesis Two: the effects of the total number of secondary science experiments upon introductory science theory courses

Table II shows the statistical tests of the correlation between number of science laboratory experiments observed in secondary school and university students' grades in introductory science theory courses. Correlation values were $r = 0.50$ for Biology, $r = 0.64$ for Physics, $r = 0.56$ for Chemistry.

		Statistical tests	
1	Total science laboratory experiments observed in secondary school and university students' grades of the introductory *chemistry theory* course	Multiple *R*	0.56221
		R Square	0.31608
		Adjusted *R* Square	0.29654
		Standard Error	9.8617
		F	= 16.175
		Significant *F*	= 0.0003
2	Total science laboratory experiments observed in secondary school and university students' grades of the introductory *physics theory* course	Multiple *R*	0.63837
		R Square	0.40751
		Adjusted *R* Square	0.39058
		Standard Error	11.013
		F	= 24.07
		Significant *F*	= 0.0000
3	Total science laboratory experiments observed in secondary school and university students' grades of the introductory *biology theory* course	Multiple *R*	0.50821
		R Square	0.25828
		Adjusted *R* Square	0.22975
		Standard Error	8.341
		F	= 9.054
		Significant *F*	= 0.0058

Table II. Correlation between total science laboratory experiments observed in secondary school and university students' grades of introductory science theory courses.

The analysis of *R* square values shows that the number of science laboratory experiments observed in secondary school accounts for 32% of variance on university student academic achievement in Chemistry theory courses, 41% of the variance on university students' academic achievement in Physics theory course but accounted for only 26% of the variance on university students' academic achievement in Biology theory course.

To consider the stated null hypotheses for this part, the *F* values presented in Table II shows that there is a significant effect of number of science laboratory experiments observed in secondary school on university students academic achievement in Biology, Chemistry and Physics Theory courses. This too means that the second hypothesis has been rejected. In addition, the regression analysis stated that observing an additional experiment in secondary school would increase students' grades between 1.1% and 2.6% in university science theory courses.

Hypothesis III: effects of specific secondary science experiments upon achievement in respective theory courses

Table III shows the correlation for part of science laboratory experiments observed in secondary school and university students' grades in the respective science theory courses.

		Statistical tests	
1	Number of *chemistry* laboratory experiments observed in secondary school and university students' grades of the introductory *chemistry theory* course	Multiple *R*	0.09412
		R Square	0.00886
		Adjusted *R* Square	- 0.1946
		Standard Error	1.612
		F	= 0.31284
		Significant *F*	= 0.5795
2	Number of *physics* laboratory experiments observed in secondary school and university students' grades of the introductory *physics theory* course	Multiple *R*	0.10639
		R Square	0.01132
		Adjusted *R* Square	- 0.37032
		Standard Error	13.905
		F	= 0.40070
		Significant *F*	= 0.5308
3	Number of *biology* laboratory experiments observed in secondary school and university students' grades of the introductory *biology theory* course	Multiple *R*	0.05744
		R Square	0.00330
		Adjusted *R* Square	- 0.03503
		Standard Error	9.6699
		F	= 0.08608
		Significant *F*	= 0.771

Table III. Correlation between a part of science laboratory experiments observed in secondary school and university students' grades in the respecting science theory course.

The results show that some laboratory secondary experiments have no effect on the academic achievement of the respective science courses (*F* = n.s.). As some experiments did have an effect, the analysis means that the third hypothesis has been retained though with low predictor values.

Conclusion

This study aimed to evaluate the relationship between science laboratory experiments in the West Bank secondary schools and academic achievement in introductory university science courses. In addition, the study considered the extent to which increasing the total number of laboratory experiments in secondary school is likely to improve academic achievement in university science courses.

Based on the statistical analysis of the collected data the following conclusions may be drawn out. First, there is a good correlation between the total number of secondary science laboratory experiments observed in secondary school and the academic achievement of Palestinian students in university introductory science laboratory courses. Secondly, there is a good correlation between the total number of secondary science laboratory experiments observed in secondary school and the academic achievement of Palestinian students in university introductory science theory courses. Thirdly, the effect ratio of the total number of secondary science laboratory experiments observed on the academic achievement ranged between 26% and 50% for the various laboratory and theory science courses.

Moreover, the total number of secondary science laboratory experiments observed by the students whilst at school, however, do have higher effect ratio on the academic achievement of the laboratory science courses (41%) compared with the theory science courses (33%). In addition, there is a significant effect of number of science laboratory experiments observed in secondary school on students academic achievement in biology, chemistry and physics laboratory and theory courses.

Finally, the effect ratio of other variables on university students academic achievement in the introductory sciences courses have ranged from 74% to 50% according to the findings of this study. Consequently, further studies may be needed to investigate and identify such variables which may affect university students academic achievement in the introductory sciences courses.

Correspondence

Dr Khawla Shakhshir Sabri, Department of Education and Psychology, Birzeit University, 14 Birzeit, West Bank, Palestine (kshakhsh@arts.birzeit.edu).

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Appendix A
Physics Experiments

1. Measurement of acceleration due to gravity (g) using simple pendulum method.
2. Measurement of acceleration due to gravity (g) using free-falling method.
3. Measurement of index of restriction of a glass block.
4. Verification of Ohm's law.
5. Connecting resistors in parallel and in series.
6. Verification of Joel's law.
7. Planning the magnetic field for olenoide and long cabal.
8. The thermal effect of electrical current.
9. Faraday's law (electric painting).
10. Finding the focal length of a convex lens.

11. Identifying the properties of images formed by a convex lens.
12. Identifying the properties of images formed by spherical and planner mirrors.
13. Thermo coupling.
14. Photoelectric cell.
15. Identifying, and producing inductive current.
16. Magnetic effect of electrical current.
17. Factors affecting the inductive current.
18. Identifying the parts of electrical transformer.

Chemistry Experiments

1. Acid-base titration.
2. Detecting for glucose using Fehling solution.
3. Electrochemistry ‘electrical’ plating.
4. Discriminative experiments ‘between alcohol and ethers’.
5. Experiments involve the effect of concentration and temperature on chemical equilibrium.
6. Manufacturing of soap.
7. Electrolysis of water.
8. Production of ester by reacting alcohol with carboxylic acids.
9. Finding the D H of reaction ‘reacting acid with base’.
10. Conductance of electricity in electrolyte solutions.
11. Reaction between chromate and dichromate.
12. Alkali metal reaction with water.
13. Precipitation reactions and identifying the colour of the precipitates.

Biology Experiments

1. Detecting for fat, monosaccharides and proteins.
2. Demonstrating an experiment for osmotic pressure.
3. Detecting starch in a paper.
4. Making slides for different plants, and studying it under the microscope.
5. Dissecting a rabbit and studying its organs.
6. Measuring the amount of evaporation.
7. Proving that wood is responsible for water contacting/putting a plant in coloured water.
9. Proving the production of oxygen from the photosynthesis prices.