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An Interactive Multimedia Tutorial Teaching Unit and its Effects on Student Perception and Understanding of Chemical Concepts

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Introduction

With microcomputers, a new, powerful and challenging education tool has been brought into the classroom; this tool enables the development and implementation of new teaching and learning strategies which support the development of many important science skills, e.g. inquiry skill, communication skill (Maor & Fraser 1996; Dori & Barnea 1997). Therefore, much research in science education is directed towards study of the impacts of the new learning and teaching environment on students' perception of scientific concepts, as well as on their performance. Among the major studies are those by Leonard (1992), Greenbowe (1994), Whitnell *et al.* (1994), Hyde *et al.* (1995), Smith & Stovall (1996), Tissue (1996), Doerr (1997), Dori & Barnea (1997), Escalada & Zollman (1997), Andaloro *et al.* (1997). Most of the studies report about higher achievements and better attitudes towards science and computers when computer-based approaches are introduced in the classroom, e.g. Dori & Barnea (1997). Escalada & Zollman (1997) demonstrated in their study the effects on student learning and attitudes of using interactive digital video in the physics classroom, showing that interactive video materials are appropriate for the activity-based environment used in the course on concepts of physics. Furthermore, this type of video material has the potential to enable physics teachers effectively to explore and conduct activities which incorporate existing resources and the latest user-friendly technologies to introduce active learning processes into their classroom. An integrated approach to the concept of force is presented and evaluated in a study by Doerr (1997). The integration is based on coupling computer simulations with first-hand experiments and a computer-based analysis tool. Doerr argues that the model building has great potential for facilitating conceptual change by enabling students to make explicit and test their own hypotheses. Leonard (1992) reports that among the justifications given for the use of microcomputer-based technology in science education the following must be considered important: (a) more economic use

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of laboratory facilities and materials; (b) more efficient use of instruction time; (c) individualisation of student work; (d) drill and practice; (e) rapid evaluation of student response and feedback; (f) interactivity of simulations and games; (g) ability of the screen to provide more concrete representations of abstract concepts; and (h) the ability to interact with phenomena not usually accessible in a normal classroom. Many chemical concepts and processes are difficult to communicate effectively because the concepts require individuals to visualise three-dimensional (3-D) arrangements of molecules and the movements of molecules, ions, or electrons Greenbowe, 1994; Hyde *et al.*, 1995).

Herron & Greenbowe (1986) stressed the importance of instructors in helping students to make connections between three levels of representation: macroscopic, microscopic and symbolic. The application of the symbolic representation of chemical concepts is the most abstract, and therefore can be understood and coped with only by the best students. Laboratory experiments and demonstrations enable students to directly observe chemical phenomena at the macroscopic level. The missing component, however, is a way of conveying the microscopic level of representation of a chemical process. According to Greenbowe (1994), this level could be bridged by appropriate computer animation or simulation of these processes. The advantages of using multimedia for lectures appear to be obvious according to Whitnell *et al.* (1994), who especially mentioned the following: increased student interest in and, potentially, better retention of the subject material, the ability to illustrate concepts in a number of ways not available elsewhere; and the availability of the multimedia presentations to the students outside of the classroom. Whitnell and his co-workers also found that the most successful parts of the multimedia lectures were those that were least like traditional lectures. The study by Treadway Jr. (1996) leads to the conclusion that the use of interactive videodisc laboratory lessons enhances the experience and the performance of general chemistry students. Students found the videodisc laboratory lessons enjoyable, and the use of these discs seems to increase student morale concerning topics perceived to be difficult.

The Purpose of the Study

The purpose of our study was to investigate the effects of using an interactive tutorial multimedia unit which integrates macroscopic, microscopic and symbolic presentation of selected concepts of the interactions of light with matter on students' perception of these concepts and the effects of the multimedia interactive tutorial unit on the understanding of selected chemical concepts.

The study was conducted in two parts. In the first part, the groups of issues identified as follows were addressed.

- Any potential differences between:
  - (i) the students' average study grade in the last trimester, and
  - (ii) their grade in chemistry in the last trimester; and
  - (iii) the role of gender.
- Their general attitude towards chemistry as a school subject.
- Students' perception of the concepts presented in the teaching unit.
- The attractiveness of different parts of the teaching unit.
- Students' perception of the new teaching–learning environment.

In the second part of the study, measurement was made of the effect of visualisation elements in the interactive multimedia teaching unit on student understanding of selected concepts.

Interactive CD-ROM Tutorial Unit 'Light and Chemical Change'

The interactive multimedia tutorial unit 'Light and Chemical Change' was developed in 1997 at the University of Ljubljana, Faculty of Natural Sciences and Engineering, Department of Chemical Education and Informatics. The teaching unit was designed with an interdisciplinary approach, integrating chemical, biological and physical concepts which are related to the phenomenon of photosynthesis, and describing interactions of light with matter on the macro- and microscopic levels. The selected concepts, as well as the level of their presentation, is appropriate for pupils in the age group 16–18 years. The topics were designed as four interrelated segments:

- oxygen, the life-supporting gas;
- light phase of photosynthesis;
- interaction of light with matter;
- a simple photochemical reaction—bromination of hydrocarbons.

The Sample

In the first part of the study, the sample consisted of 27 third-grade high school students in the city of Ljubljana, Slovenia, who volunteered for this study (Tables Ia and Ib).

TABLE Ia. Structure of the sample according to grades in chemistry and general grades

Grade in chemistry	Number f	Frequency f(%)
Excellent	0	00.00
Very good	4	14.81
Good	10	37.04
Poor	13	48.15
Very poor	0	00.00
Total	27	100.00
General grade		
Excellent	3	11.11
Very good	11	40.74
Good	9	33.33
Poor	4	14.82
Very poor	0	0.00
Total	27	100.00

f = frequency (absolute value)

TABLE Ib. Structure of sample according to gender

Gender	Number f	Frequency f(%)
Male	8	29.63
Female	19	70.37
Total	27	100

f(%) = frequency (relative value)

TABLE IIa. Structure of the experimental and control groups according to their achievements at the pre-test

Scores at the pre-test	Experimental group f	Experimental group f(%)	Control group f	Control group f(%)
7–8	2	7.70	3	12.51
9–10	4	15.38	5	20.83
11–12	9	34.62	8	33.33
13–14	10	38.45	8	33.33
15–16	1	3.85	0	0
Total	26	100	24	100

TABLE IIb. Structure of the experimental and control groups according to their grades in chemistry

Grade in chemistry	Experimental group f	Experimental group f(%)	Control group f	Control group f(%)
Excellent	2	7.70	0	0.00
Very good	4	15.38	4	16.67
Good	6	23.08	9	37.50
Poor	11	42.30	10	41.67
Very poor	3	11.54	1	4.16
Total	26	100	24	100

TABLE IIc. Structure of the experimental and control groups according to gender

Gender	Experimental group f	Experimental group f(%)	Control f	Control f(%)
Female	11	42.31	16	66.67
Male	15	57.69	8	33.33
Total	26	100	24	100

In the second part of the study, 50 third-grade high school students participated. They were divided into an experimental group (26 students) and a control group (24 students) based on scores achieved at the pre-test. The structure of both groups according to their achievements at the pre-test, grades in chemistry in the last trimester, and gender is evident from Tables IIa, IIb and IIc respectively.

Methodology

In the first part of the study, the 27 high school students worked in pairs (one worked alone) with the multimedia teaching unit for three 45 minute sessions. The interviewer supervised their work and took notes on their interactions. Afterwards, the students answered a questionnaire; the time available for this was 20 minutes. Following this questionnaire, each pair of students took part in an interview lasting about 15 minutes.

In the second part of the study, students first took a pre-test with six open-ended questions. The duration of the pre-test was 45 minutes. Afterwards, students were assigned to one of two groups—experimental ($N_{ex} = 26$) and control ($N_{co} = 24$). The experimental group was presented with the multimedia tutorial teaching unit and supporting written materials, describing some basic elements of the teaching unit. Students in the experimental group spent five sessions, each of 45 minutes, working in pairs with the teaching units on multimedia personal computers (PCs), while the control group took part in a conventional teaching session on the same topics, given by the teacher. The conventional teaching was also arranged into five sessions, each of 45 minutes, but students were given materials which they could later study at home. After 1 week, both groups took a post-test, composed of eight open-ended questions, which contained the same concepts as in the pre-test, but set in different contexts.

Measuring Instruments

In the first part of the study, a structured interview and a questionnaire were used for measuring students' perception of the new learning environment. The questionnaire had two parts; the first focused on general student attitudes towards chemistry as a school subject, while the second related to the perception of the multimedia teaching material. During each interview, the student–interviewer conversation was recorded on audio-cassette and students wrote their responses on the questionnaire sheets. In order to identify the validity of both instruments, five questions from the structured interview also appeared in the questionnaire (they are marked in the appendix Table AI by an asterisk *). On average, the difference between the answer frequencies was 9%, meaning that the validity of both instruments was approximately 91%.

In the second part of the study, a knowledge pre-test and a post-test were used. The same set of concepts was tested with the pre- and the post-test; the difference was that in the post-test more stress was placed on the microscopic descriptions of interactions of light with matter. In both tests the following concepts were included:

- phenomena associated with light, e.g. spectrum of white light;
- parameters describing light as waves, e.g. wavelength, frequency, speed of light;
- interactions of light with matter: macroscopic level—perception of colours as a consequence of the absorption of light; microscopic level—absorption and emission of photon and changes in electronic states:
- examples of light-induced chemical changes, e.g. photosynthesis.

The pre-test and the post-test comprised six and eight open-ended questions respectively: the maximum score of any student on the pre-test and the post-test was 16 and 16.5 respectively. The reliability estimates of the pre-test and post-test were calculated to be 0.88 and 0.89 respectively, based on Rulon's split-half method equation (Sprinthall, 1997), which is higher than the lower limit of 0.80.

Measuring the Effects of the Tutorial Interactive Unit on Students' Perception

The following were defined as independent variables: (1) grade in chemistry in the last trimester; (2) average class grade in the last trimester; and (3) gender. The dependent variables were: (1) students' opinions about the number of chemistry hours per week; (2) difficulties of chemistry concepts; (3) activities which make students to like chemistry; (4) what makes chemistry dull and unattractive; (5) students' perceptions of the concepts in the teaching unit; (6) perception of the new learning environment; and (7) attractiveness of the different multimedia elements of the teaching unit. The hypotheses tested are presented in Table III.

TABLE III. Hypotheses tested

Hypothesis number	Hypothesis
I.	Students' perception of the difficulties of chemical concepts depends on the average study grade and the chemistry grade, but does not depend on gender.
II.	Students with a better average study grade and chemistry grade will have fewer problems understanding concepts presented in the multimedia teaching unit.
III.	The majority of students will be challenged to carry out experiments presented in the teaching unit also in a wet laboratory, regardless of their grade in chemistry, average study grade, and gender.
IV.	The attractiveness of different multimedia elements and students' perception of their interconnections depends on their average study grade, grade in chemistry and gender.
V.	Students with lower average study and chemistry grades will need teacher's guidance in working independently with the multimedia unit.

The comparative results and statistical evaluation (chi-square test) are presented in the appendix. (Table AI).

Part 2 of the Study—measuring the effect of a multimedia tutorial teaching unit on student understanding of selected chemical concepts

In the second part of the study the following hypotheses were tested.

I. The experimental group will achieve better post-test results than the control.
II. There will be significant differences between the experimental and the control group in the total number of scores achieved in the post-test and pre-test.
III. The visualisation elements of the teaching unit will have an impact on better understanding of the selected chemical concepts.

The comparisons of the relative answer frequencies of students who solved a particular pre-test and post-test item correctly within the experimental and the control group are presented in Figs 1 and 2. The impact of the teaching unit visualisation elements on the understanding of chemical concepts is illustrated by the analysis of one test item (Fig. 3).

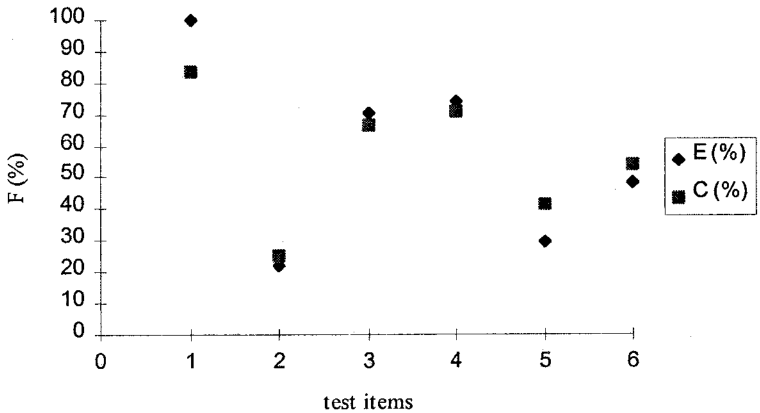

FIG. 1. Relative answer frequencies of students who solved a pre-test item for the experimental and the control group.

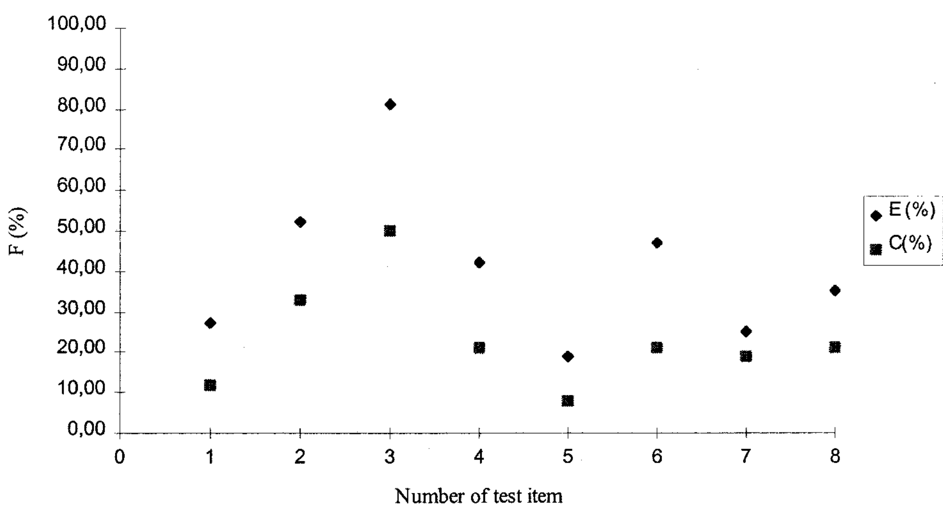

FIG. 2. Relative answer frequencies of students who solved a post-test item correctly for the experimental and the control group.

Discussion

The first part of the discussion refers to the results presented in the appendix, Table AI. The validity of the different hypotheses was tested by the chi-square test.

I. *Students' perception of the difficulties of chemical concepts depends on average study grade and chemistry grade, but does not depend on gender.*

This hypothesis was tested with five questions, 1–5 (appendix Table AI)

1. In your opinion should there be more hours of chemistry; are there enough hours; are there too many hours of chemistry?
The perception of the number of hours of chemistry depends on gender; female opinion is that there are too many chemistry classes at school.

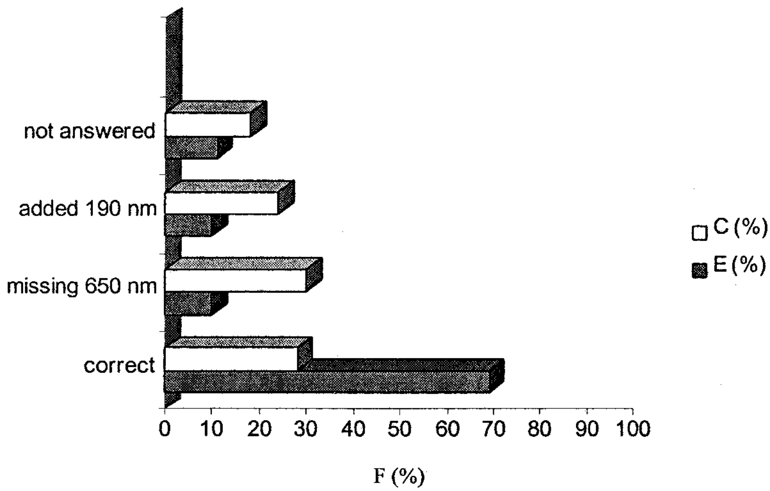

FIG. 3. Final test results for the first part of the test item.

2. In your opinion chemistry concepts are; easy to learn, very difficult to learn, not too hard to assimilate?
Regardless of the average study grade and the grade in chemistry, the prevailing opinion is that chemistry is a difficult school subject, but the perception of difficulty depends on gender. For males chemistry is perceived as less difficult than for females.

3. Which activities do you find attractive for learning chemistry?
Activities which challenge learning and support a positive attitude towards chemistry do not depend on the average study grade, grade in chemistry or gender. Students like experiments and they are also attracted to solving chemical problems.

4. What are the reasons that make chemistry a dull and uninteresting subject?
The reasons why chemistry is a dull and uninteresting subject differ according to gender. Females think that they have to learn concepts which are not related to everyday life situations, while males think that chemical concepts are presented in too much detail.

5. Who do you ask for help if you don't understand chemistry concepts?
When chemical concepts are not understood, students' reasons for seeking help depend on their average study grade, and on gender. Females with better than average study grades seek help from their school teachers, while males with lower average study grades seek help elsewhere.

Based on the chi-square test results for questions 1–5, it can be concluded that average class grade and chemistry grade have only a minor effect on the perception of the difficulties of chemical concepts; much greater differences were detected between gender. Therefore the hypothesis can be rejected.

II. *Students with better average study grades and chemistry grades will have fewer problems in understanding concepts presented in the multimedia teaching unit.*
This hypothesis was tested with question 6 (appendix Table AI).

6. How did you find the presentation of concepts in this multimedia teaching unit: very clear, clear, not clear—difficult to follow?
Based on chi-test values, this hypothesis can be rejected. The majority of students, regardless of average study grade, the grade in chemistry, or gender, found some parts of the multimedia teaching unit difficult to follow.

III. *The majority of students, regardless of their grade in chemistry, average study grade and gender, will be challenged to carry out experiments presented in the teaching unit; likewise in the wet laboratory.*

This hypothesis was tested with question 7 (appendix Table AI).

7. Do you wish to carry out the experiments shown in the multimedia teaching unit in the wet laboratory?
This depends on the grade in chemistry, but not on the average study grade or gender. The better the grade in chemistry, the less challenged are the students to repeat the experiments in the wet laboratory. We can conclude that students with a better grade in chemistry perceive the laboratory work as repetitive and dull. The hypothesis can be rejected.

IV. *The attractiveness of different multimedia elements and students' perception of their interconnections depends on their average study grade, grade in chemistry, and gender.*

This hypothesis was tested with questions 8 and 9 (appendix Table AI).

8. Which topic do you find most interesting?
Again, the attractiveness of different topics does not depend on the average study grade, grade in chemistry, or gender. Students found two topics the most interesting: Oxygen—the life supporting gas, and Interaction of light with matter.

9. What has particularly attracted you in the multimedia teaching unit?
Students, regardless of their average study grade in chemistry or gender, were attracted by movies, animations, colours and sound. Females were more sensitive to colours, and males to sound. The hypothesis can be rejected; only slight differences between gender can be noted.

V. *Students with lower average study and chemistry grades will need the teacher's guidance in working independently with the multimedia unit.*

This hypothesis was tested with question 10 (appendix, Table AI).

10. Did you miss the teacher's explanations while working with the multimedia teaching unit?
Regardless of the average study grade, grade in chemistry, or gender, students' opinion is that they do need—at least to some degree—the teacher's explanation. The hypothesis can be rejected.

Part 2 of the Study—Measuring the Effect of the Multimedia Tutorial Teaching Unit on Student Understanding of Selected Chemical Concepts

The results of the pre-test are displayed in Fig. 1. On average, the experimental group was better by 2.7% than the control group. According to the value of the chi-square test

(0.936; 5 = 1.2856), there are no significant differences between the performances of the experimental and the control group according to the scores achieved in the pre-test.

Based on the results, all three hypotheses tested can be accepted as valid. The results presented in Fig. 2 reveal that the experimental group was doing better in the post-test than the control group. The experimental group achieved on average 20.5% better results than the control group. Also, the chi-square test (8.83E–05; 1) = 15.367 shows that there are significant differences between experimental and control groups in the total number of scores achieved in the pre- and post-tests. The better results of the experimental group can be attributed to an improved understanding of selected chemical concepts. The results presented in Fig. 3 indicate that visual presentation of the chlorophyll spectrum and the written explanation about absorption, as well as animation of the absorption phenomena shown on the CD-ROM, have contributed significantly to a better understanding of the phenomenon, and that students were able to apply their knowledge in solving the question about the absorption maximums of chlorophyll in the visible light spectrum. As a result, 69% of students from the experimental group gave correct answers while only 28% from the control group answered correctly. There were only 10% wrong answers from the experimental group related to the question of the absorption maximum at 650 nm (nanometres), while there were 30% wrong answers in the control group. In addition, 14% more students from the control group thought (incorrectly, since it does not come within the visible light spectrum) that chlorophyll would absorb light at 190 nm.

Conclusions

In this study, the effects of the interactive multimedia tutorial unit on students' perception of the new learning environment and their understanding of chemical concepts were evaluated. As for the instruments, a structured interview and a questionnaire were used in the first part of the study, while for measuring student performance a pre- and a post-test were used. Based on the findings it is possible to conclude the following:

- Chemistry can be considered a difficult and not very popular school subject and no significant differences in these perceptions can be obtained regarding the grade in chemistry or average study grade. Females think that the chemical curriculum is too theoretical and not enough attention is given to interrelating chemical concepts with real life experiences, while, on the other hand, the prevailing opinion among the males is that the explanation of concepts is often unnecessarily too detailed.
- In spite of this negative attitude towards chemistry, there are many techniques which, if properly introduced in the classroom, can be considered as a good tool for the development of more positive student attitudes towards chemistry. Among the various techniques, students especially stressed the importance of chemical experiments and their enjoyment at being involved in solving problems. Therefore, these techniques should be used more often than they are.
- Computerised systems, like multimedia tutorials, can be regarded as challenging for students. But at the same time students were also very honest and critical, saying that in spite of the vivid presentation of the concepts they would still need the teacher's explanation and guidance in order to gain the maximum benefit from the new learning environment. Therefore, multimedia should be used in teaching with a certain degree of caution, and only after a short introduction has been given of the concepts presented

in the unit. Also, students need guidance when working independently with multimedia units in focusing their attention on the most important features of the presentation, especially when phenomena at microscopic level are presented.
- Students found the two most attractive parts of the multimedia teaching unit to be 'Oxygen—the life supporting gas' and 'Interaction of light with matter', which differ most from the textbook presentations of these concepts; at the same time, in both units these concepts are presented at the macroscopic level, while those parts describing phenomena at microscopic level were considered to be difficult.

Nevertheless, regardless of the mixed feelings about the new learning environment, the multimedia teaching unit has promising effects on the students' acquisition of knowledge. Not only were the results achieved by the experimental group better in the post-test as a whole. Also, the students were more competent in solving test-items where higher categories of knowledge were tested, such as understanding phenomena at a microscopic level and relating them to the macroscopic observations, combined with the capability of analysing data and extending their knowledge beyond the standard school framework. All these can be attributed to the interaction with the new learning environment.

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Appendix

TABLE AI. Perception of the multimedia teaching unit—experimental group

Dependent variables: questions	Independent variables										
	Grades in chemistry				Average study grade					Gender	
	Poor f(%)	Good f(%)	Very good f(%)	Total	Poor f(%)	Good f(%)	Very good f(%)	Excellent f(%)	Total	Male f(%)	Female f(%)
General attitude towards chemistry as a school subject											
1*. In your opinion:											
• there should be more hours of chemistry	0	0	0	0	0	0	0	0	0	0	0
• there are enough hours of chemistry	7.41	11.10	7.41	25.92	0	3.7	14.82	7.41	25.93	14.81	11.11
• there are too many hours of chemistry in comparison with other subjects	40.74	25.93	7.41	74.08	14.81	29.63	25.93	3.7	74.07	14.81	59.27
Total	48.15	37.03	14.82	100	14.81	33.33	40.75	11.11	100	29.62	70.38
χ^2 test		(0.368.2) = 2.046					(0.130; 3) = 5.645			(0.064; 1) = 3.431	
2*. In your opinion chemistry concepts are:											
• easy to learn	7.41	3.7	0	11.11	3.7	3.7	3.7	0	11.1	11.11	0
• very difficult to learn	25.93	22.22	3.7	51.85	3.7	18.52	22.22	7.41	51.85	11.11	40.78
• assimilable	14.82	11.11	11.11	37.04	7.42	11.11	14.82	3.7	37.05	7.4	29.6
Total	48.16	37.03	14.81	100	14.82	33.33	40.74	11.11	100	29.62	70.38
χ^2 test		(0.526.4) = 3.192					(0.918; 6) = 2.018			(0.018; 2) = 8.021	
3*. What activities do you find attractive for learning chemistry:											
• experiments	22.22	14.83	3.7	40.75	3.7	11.11	18.52	7.42	40.75	11.11	29.63
• successful problem-solving	11.11	11.11	11.11	33.33	0	11.11	18.52	3.7	33.33	14.82	18.52
• good grade	11.11	3.7	0	14.81	7.41	3.7	3.7	0	14.81	3.7	11.11
• none	3.7	7.41	0	11.11	3.7	7.41	0	0	11.11	0	11.11
Total	48.14	37.05	14.81	100	14.81	33.33	40.74	11.12	100	29.63	70.37
χ^2 test		(0,481, 6) = 5,505					(0.342; 9) = 10.101			(0.516; 3) = 2.281	

4*. What makes chemistry dull and not interesting:											
• too detailed presentation of concepts	14.81	22.22	7.41	44.44	0	11.11	25.94	7.41	44.46	25.93	18.52
• learning of concepts not related to life	18.53	3.7	3.7	25.93	3.7	11.11	11.11	0	25.92	0	25.93
• not enough practical examples	7.41	7.41	0	14.82	3.7	3.7	3.7	3.7	14.81	0	14.81
• dull teacher presentation of concepts	7.41	3.7	3.7	14.81	7.41	7.41	0	0	14.81	3.7	11.11
Total	48.16	37.03	14.81	100	14.81	33.33	40.75	11.11	100	29.63	70.37
χ^2 test		(0.663.6) = 4.103					(0.256; 9) = 11.301			(0.024; 3) = 9.414	
5*. Who do you ask for help if you don't understand chemical concepts?											
• teacher	0	0	3.7	3.7	0	0	0	3.7	3.7	0	7.44
• peers	37	33.38	11.11	81.49	11.11	22.22	40.75	7.41	81.49	14.81	62.94
• others	11.11	3.7	0	14.81	3.7	11.11	0	0	14.81	14.81	0
Total	48.11	37.08	14.81	100	14.81	33.33	40.75	11.11	100	29.62	70.38
χ^2 test		(0.124; 4) = 7.241					(0.039; 6) = 13.244			(0.003; 2) = 11.470	
Teaching unit: understanding of the teaching unit											
6. You found the presentation of concepts in the teaching unit:											
• very clear	11.11	7.41	3.70	22.22	3.70	7.41	11.11	0.00	22.22	11.11	11.11
• clear	33.34	25.93	11.11	70.38	7.41	25.93	25.93	11.11	70.38	18.52	51.85
• not clear—difficult to follow	3.70	3.70	0.00	7.4	3.70	0.00	3.70	0.00	7.4	0	7.41
Total	48.15	37.04	14.81	100	14.81	33.34	40.74	11.11	100	29.63	70.37
χ^2 test		(0.979; 4) = 0.444					(0.655; 6) = 4.160			(0.344; 2) = 2.136	

TABLE AI.—*continued*

Dependent variables: questions	Independent variables										
	Grades in chemistry				Average study grade					Gender	
	Poor f(%)	Good f(%)	Very good f(%)	Total	Poor f(%)	Good f(%)	Very good f(%)	Excellent f(%)	Total	Male f(%)	Female f(%)
Students' perception of the learning environment											
7. Do you wish to repeat the experiments shown in the teaching unit in the wet laboratory?											
• yes	37.04	14.81	0.00	51.86	11.11	25.93	14.81	0.00	51.85	14.81	37.05
• no	11.11	22.23	14.81	48.14	3.70	7.41	25.93	11.11	48.15	14.81	33.33
Total	48.15	37.04	14.81	100	14.81	33.34	40.74	11.11	100	29.62	70.38
χ^2 test	$(0.017; 2) = 8.4143$				$(0.056; 3) = 7.569$					$(0.901; 1) = 0.016$	
8. Which topics in the CD-ROM unit especially attracted your attention?											
• oxygen—a life supporting gas	29.63	11.11	3.7	44.44	7.41	14.81	18.55	3.7	44.47	11.11	33.33
• interaction of light with matter	18.52	14.82	7.41	40.75	7.41	14.81	14.81	3.7	40.73	11.11	29.64
• bromination of hydrocarbons—an example of a simple photochemical reaction	0	7.41	3.7	11.11	0	3.7	3.7	3.7	11.1	7.41	3.7
• light-dependent reaction of photosynthesis	0	3.7	0	3.7	0	0	3.7	0	3.7	0	3.7
Total	48.15	37.04	14.81	100	14.82	33.32	40.76	11.1	100	29.63	70.37
χ^2 test	$(0.389; 6) = 6.317$				$(0.936; 9) = 3.593$					$(0.467; 3) = 2.547$	

9. What was particularly attractive in the CD-ROM unit?											
• videos and animation	14.81	7.41	3.7	25.92	7.41	3.7	11.11	3.70	25.92	7.41	18.52
• colours	14.81	3.7	3.7	22.21	3.70	7.41	3.7	7.41	22.22	0	22.23
• new learning environment	7.41	7.41	3.7	18.55	0	11.11	7.41	0	18.54	3.7	14.81
• detailed interpretation of concepts	3.7	7.41	0	11.11	0	7.41	3.7	0	11.11	3.7	7.41
• sound	3.7	7.41	3.7	14.81	3.7	0	11.11	0	14.81	14.81	0
• nothing	3.7	3.7	0	7.4	0	3.7	3.7	0	7.4	0	7.41
Total	48.13	37.04	14.8	100	14.81	33.33	40.73	11.11	100	29.62	70.38
χ^2 test		(0.941; 10) = 4.127					(0.573; 15) = 13.381			(0.022; 5) = 13.114	
10. Did you miss the teacher's explanations?											
• yes	11.11	7.41	7.41	25.93	3.7	3.7	11.12	7.41	25.93	7.41	18.52
• occasionally	29.63	22.22	3.7	55.55	3.7	25.93	25.93	0	55.56	11.11	44.44
• not at all	7.41	7.41	3.7	18.52	7.41	3.7	3.7	3.7	18.51	11.11	7.41
Total	48.15	37.04	14.81	100	14.81	33.33	40.75	11.11	100	29.63	70.37
χ^2 test		(0.730; 4) = 2.033					(0.160; 6) = 9.251			(0.237; 2) = 2.883	