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E- Learning in Chemistry: To Use It or Not to Use It?

[1]Margareta Vrtačnik, [2]Rahela Čemažar

[1]University of Ljubljana, Faculty of Natural Sciences and Engineering

[2]University of Ljubljana, Faculty of Education

Abstract

The paper presents the results of a study on the impacts of e-learning chemistry concepts. The purpose was to find out whether students are able to learn new chemistry concepts using e-learning exclusively and later apply newly acquired knowledge, and what are their attitudes towards e-learning. Specially designed learning objects (LOs) were prepared and students were working in Moodle e-learning environment. Prior to the experiment students' pre-knowledge was tested, followed by post-knowledge test and a structured interview, where also their performance and feelings were tested. The results were analysed quantitatively and qualitatively. The study shows that learning chemistry by using technology may result in actual learning of new and difficult concepts, however the learning effect primarily depends on student prior knowledge. On the other hand student attitudes towards e-learning are positive.

Key words*: e-learning, learning objects (LOs), chemistry, students' attitude, chemistry knowledge*

Povzetek

Članek obravnava raziskavo o vplivih e-učenja na razumevanje zahtevnih kemijskih pojmov. Namen študije je bil dobiti odgovore na vprašanja:ali so učenci sposobni razumeti in naučiti se zahtevnih kemijskih pojmov ter kasneje to znanje tudi pravilno uporabiti ter ugotoviti njihove občutke pri tovrstnem učenju. Učenje je potekalo v učnem okolju Moodle s posebej izdelanimi učnimi objekti. Rezultate smo merili s primerjavo rezultatov pred-testa in po-testa, odgovore pa smo preverjali tudi prek strukturiranega intervjuja. Kvalitativna in kvantitativna analiza rezultatov kaže, da so učenci sposobni usvojiti novo znanje dokaj težkih kemijskih pojmov izključno s pomočjo e- tehnologije uspešno le ob pogoju, da imajo ustrezno predznanje. Delo v e-učnem okolju so učenci pozitivno sprejeli.

Ključne besede*: e-učenje, učni objekti (UO), kemija, odnos dijakov, znanje kemije*

1. Introduction

Most researchers on e-learning agree that that e-learning is undoubtedly a powerful and valuable extension to traditional educational initiatives which will change education tremendously within the next years **[1,2]**. Thus, a fair amount of research and development programs into the ways to improving the impact of e-learning have been carried out and are still ongoing. These programs traditionally focus on two different views of e-learning: technological issues on the one hand and general educational issues on the other **[1]**. However, in spite of all these efforts, there is still much controversy whether computer-supported learning is better than learning in conventional environments such as in a classroom or from a text book. Mayer **[3]** correlates this controversy with the fact that studies and reports which promote e-learning are rather doctrine-based, very often not built on research evidence.

Specific reports on the impacts of e-learning on students' performance in different study disciplines are relatively rare. One exception are the Fisher Family Trust reports on how e-learning improves pupils exam grades. The Trust carried out an independent research running in four consecutive years on the relationship between e-learning and its contribution to pupils' performances. The results refer to the performance of primary and secondary grade pupils in the United Kingdom, who are using an online exam practice programme (SAM Learning, created by SAM Learning, Ltd.). SAM Learning is cross-curricular, covering more than 15 subjects at primary (KS2, KS3) and secondary (GCSE) level and encourages independent e-learning by students, with nearly 60% of being used outside school hours. Independent evidence shows that 10+ task hours, using SAM Learning, improves GCSE by 4.6%, KS3 pupils who achieve L5+ by 3.6%, and KS2 pupils who achieve L4+ by 2.6% [4].

Since research evidence on the impact of e-learning on students knowledge and performance, particularly in chemistry teaching/learning are non-existent, we decided to conduct an empirical research in which we focused on the impact of e-learning organic chemistry concepts on students performance and also their feelings, such as acceptance, resistances and fears during working with e-learning units.

The Department of Chemical Education of Informatics, Faculty of Natural Sciences and Engineering, University of Ljubljana, Slovenia, has a long-time experience in working with Slovenian chemistry teachers and students. Our recent engagement in the international European project SLOOP (Sharing Learning Objectives in an Open Perspective) offered a chance to design a series of e-learning units, the so called learning objects. As for the topics we selected two from the 3rd grade high-school chemistry curriculum: Mechanisms of organic reactions, and Proteins. These two topics were specifically selected because they cause many difficulties to teachers. They claim that mechanisms are too difficult to be taught at the high school level, while proteins should not be taught at all since they are not related to student life experiences according to their opinion. Thus, we were challenged to developed six learning objects on organic reaction mechanisms and four learning objects on proteins. Additionally, we developed two LOs on hydrocarbons for lower secondary school students.

We took the task with great enthusiasm and motivation, yet we were not sure how this new e-learning approach would be accepted by students: will the student be really able to learn new concepts, and how would they feel when working alone in a new learning environment. For this reason we decided to conduct a research to find the answers to these two questions.

2. Background

The theoretical part of organic chemistry course for high schools is primarily focused on meeting three goals: (1) to introduce bonding and stereochemistry of organic molecules, including types of isomerism found in these molecules, (2) to describe and explain the reactivity of organic molecules in terms of functional groups, (3) to introduce the basic concept of organic reaction mechanisms.

Experience has shown that in particular, the concept of reactivity in relation to the concept of reaction mechanisms is extremely difficult for an average high-school student to cope with. Consequently, chemistry is regarded as one of the least popular school subjects. According to our research on student affinity towards chemistry [5] which included 201 high-school students, this subject was graded by 3 on the scale from 1 to 5. One of the reasons why reactivity is such a problematic topic because this concept is very poorly defined in the majority of textbooks and teachers are not experienced enough to find suitable strategies to build a firm bridge between the observable data of wet-experiments with rational explanations of experimental results on the sub-microscopic level. Therefore, the LOs to be developed within the SLOOP project were a good challenge to try to design such units for students, where by using visual aids, they should be able to better understand the concepts of reactivity and organic reaction mechanisms on the sub-microscopic level. The idea was that these LOs should be used as a complementary material to organic chemistry textbooks and to teacher explanations of these concepts in the class room.

3. LOs design approach

The first step in developing the LOs was designing an expert concept map, showing the relation of concepts on which the concept of reactivity is based (Figure 1). The central term in the concept map is electronegativity.

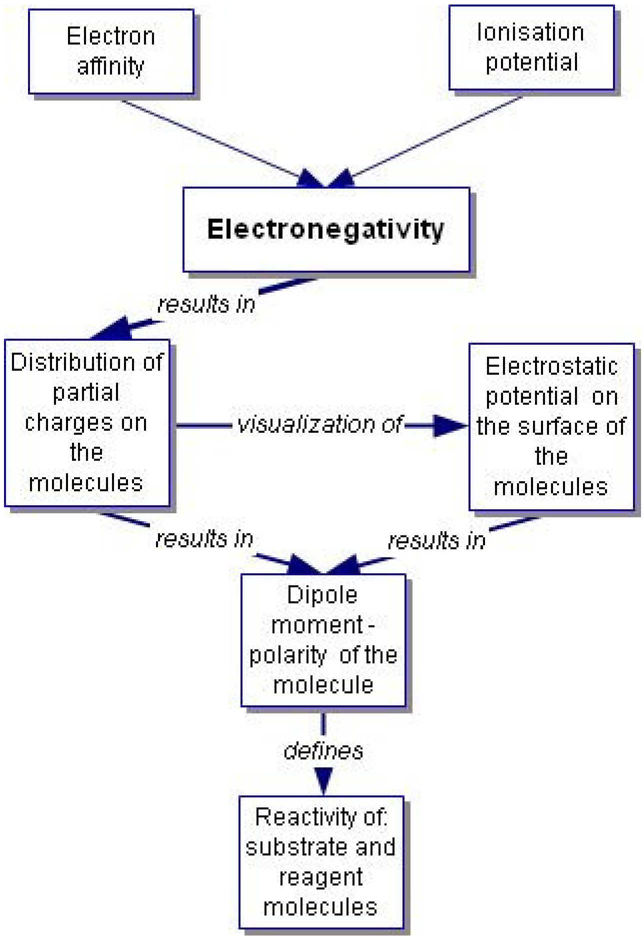
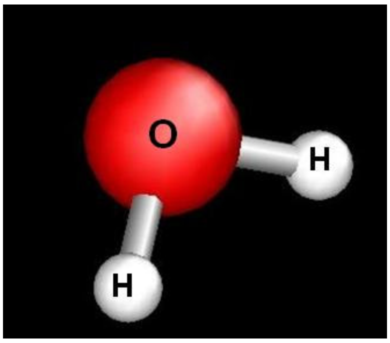


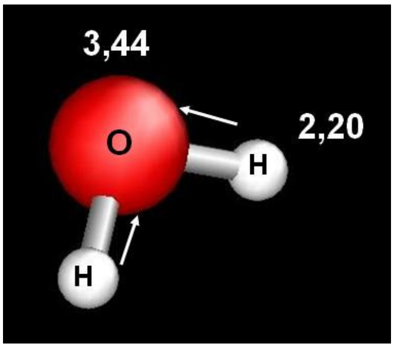
Figure 1: The expert concept map on "reactivity"

The first LO was experimental. The central part contains some experiments with sodium and water, ethanol, acetone, and hexane. We expected that knowing the reaction of sodium with water, students would be able to detect the differences and similarities of the reactions of sodium with ethanol, acetone and hexane and correlate observations with the structure of the molecules.

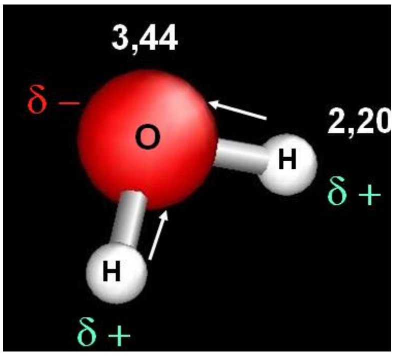
The second LO was designed as a theoretical basis, explaining the reasons for differences and similarities in reactivity of water, ethanol, acetone and hexane. This approach is presented on Figure 2.



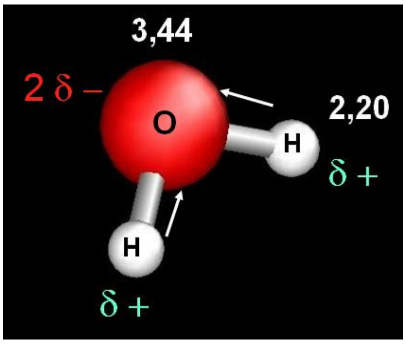
Model of water molecule



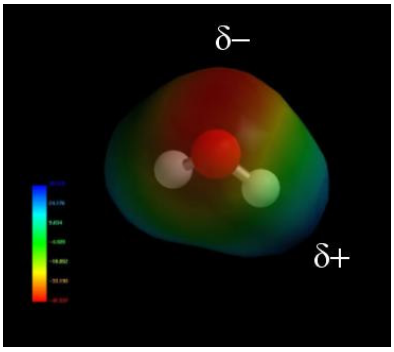
Values of EN from Pauling's scale



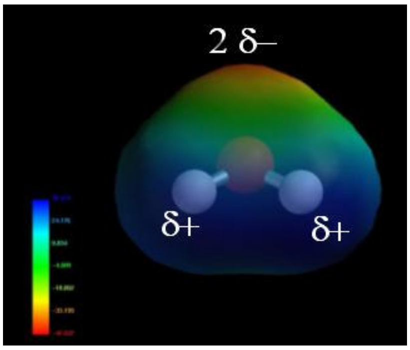
Formation of partial charges on oxygen and hydrogen atoms



Water molecule is electrically neutral, hence the sum of partial charges must be 0.



Distribution of electrostatic potential on the surface of water molecule: red colour denotes negative potential, blue positive potential – deficiency of electrons. View 1



Distribution of electrostatic potential on the surface of water molecule: red colour denotes negative potential, blue positive potential – deficiency of electrons. View 2

Figure 2: Explaining the polarity of a water molecule

In the subsequent step students are given a chance to practice the correlation between electronegativity of atoms and electron density distribution through a series of exercises. At the end of the LO students can assess the learning impact of the unit, taking a self-evaluation knowledge test.

4. Research Design

Our research was designed in such a way as to get the answers to the following research questions:

1. Does the approach we used in the LOs enable students to acquire deeper understanding of the concept to later apply the knowledge on electronegativity of atoms for predicting the polar or non-polar nature of molecules and their reactivity, and whether the students possess sufficient pre-knowledge to cope with the concepts presented through the LOs.
2. What are their general and more specific attitudes toward e-learning and how can e-learning contribute to the improvement of classical teaching approach in the classroom?

The research design is presented in Figure 3.

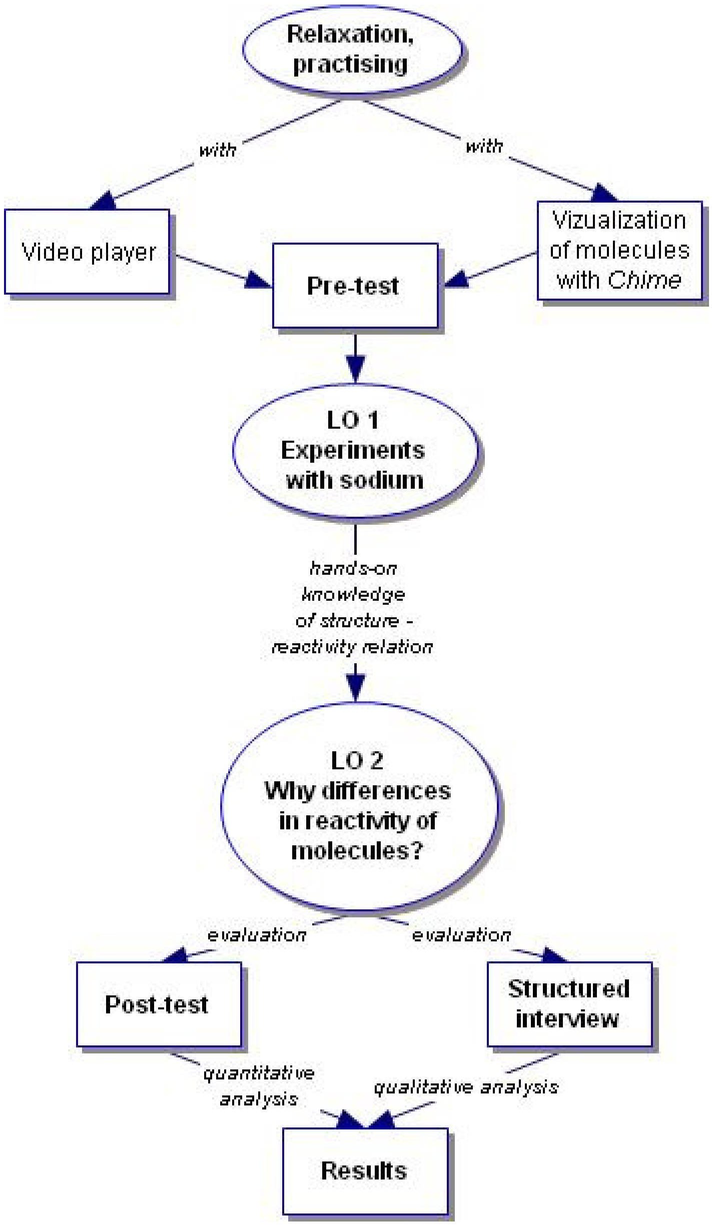


Figure 3: Research plan

Students were tested individually in the period from March to May 2007. Each session started by creating a relaxed and informal atmosphere, e.g. small talk, offering refreshments, etc. Students could also practise computer skills for working with videos and using *Chime* plug-in for virtual model presentation. Following this they took a computer-based interactive pre-test, and then proceeded to work with the two LOs. After a short break they took the post-test. After approximately a week the same students came back for a structured interview. The results were analysed quantitatively and qualitatively.

4.1 The sample

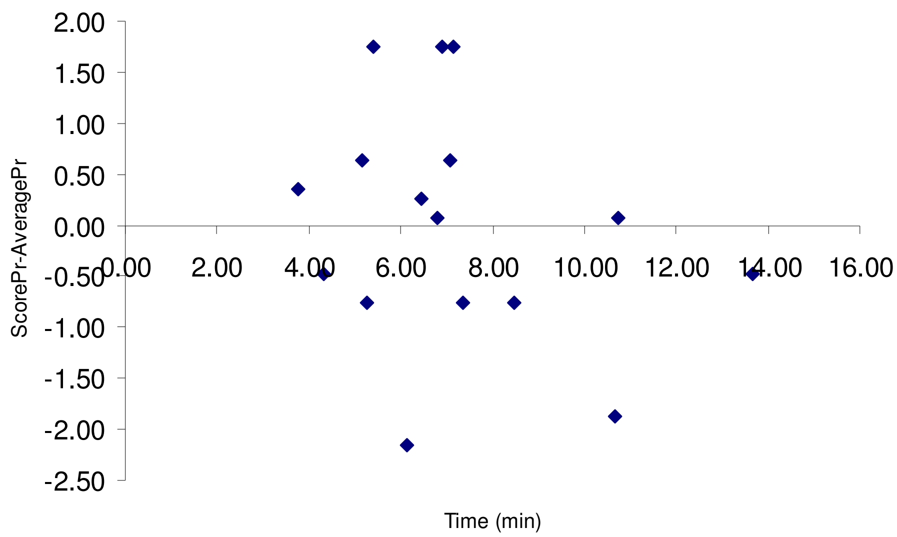
There were 16 high-school students (3rd or 4th graders) age 17 – 18 years from the Ljubljana region, who volunteered to take part in this research..

4.2 Instruments

The instruments for evaluating the impact of LOs on students' knowledge and attitudes toward e-learning were: pre-test, post-test and structured interview. We also used TV camera for shooting the students' while working with this new teaching media. The pre-test and post-test were designed by using the "Quiz" option installed in the Moodle learning management system which allowed for automatic collection of the results. Both tests were composed of nine test items, mainly multiple-choice questions with only one correct answer, or multi-correct answers.

4.3 Results & Analysis

The students understanding of concepts were tested with pre-test and after the experiment with post-test. The average time the students needed to complete the pre-test was 7.21 minutes, and the average scores achieved 8.26 (out of ten scores). Nine students achieved above average results at the pre-test and seven below the average. The differences between students' scores achieved in the pre-test and average scores (ScorePt-AveragePt) and time that each student spent working with the pre-test are presented in Graph 1.

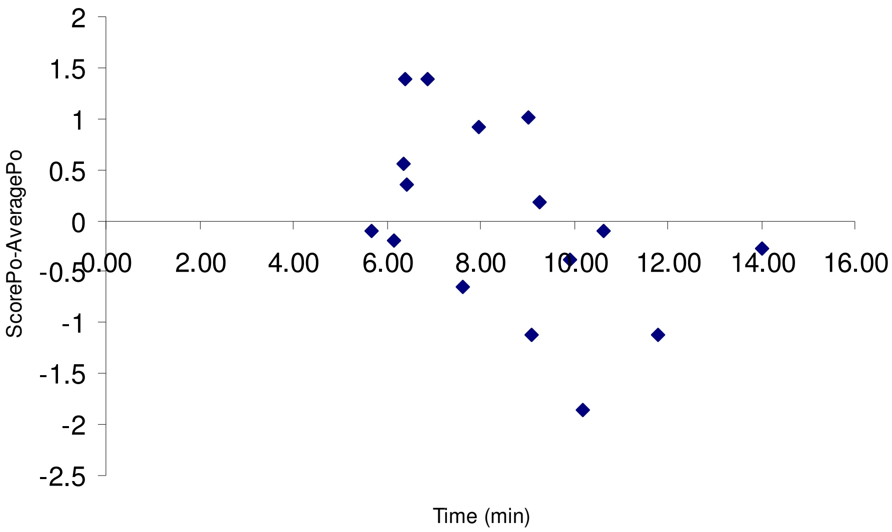


Graph 1: Time used by students to solve the pre-test vs. the difference between the scores achieved and the average scores at the pre-test

Above average scores were achieved by students who needed from 4 to 11 minutes to complete the pre-test. The highest scores were achieved within 5.5 to 7.5 minutes by those who were able to finish the pre-test in time. The results below average were noticed within a slightly more scattered time range, i.e. 4 to 13 minutes. Three students gave too general definitions of alcohols, five students confused rational formula of aldehyde propanal with keton acetone or gave general name aldehyde. Nine students were not able to recognize all correct answers from the picture of molecular models of hydrocarbons. Four students did not recognize the molecule of acetone as polar one and four students had problems with the selection of the right balanced equation of the reaction of sodium with water. The results of the pre-test are in accordance with our expectations: to successfully work with both LOs students needed appropriate pre-knowledge.

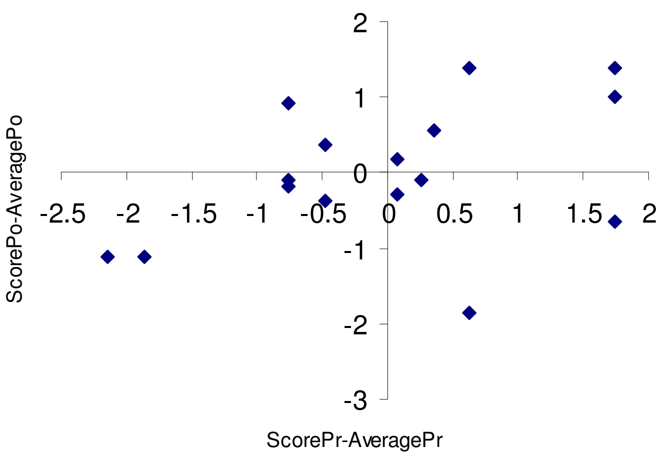
On the average students needed 8.6 minutes to complete the post-test. The average scores achievement was 8.34 (maximum was 10). Students spent 1.39 minutes more time to complete the post-test but the differences in the average scores achieved between the post test and the pre-test are negligible. Graph

2 indicates that students who achieved the scores above the average solved the post-test in a narrow time-span, between 6 to 9 minutes, while those students whose results at the post-test were below average, needed between 6 to 14 minutes to finish the test. Seven students achieved results above average in the post-test, and 9 students below the average. This situation was just the opposite in the case of the pre-test.



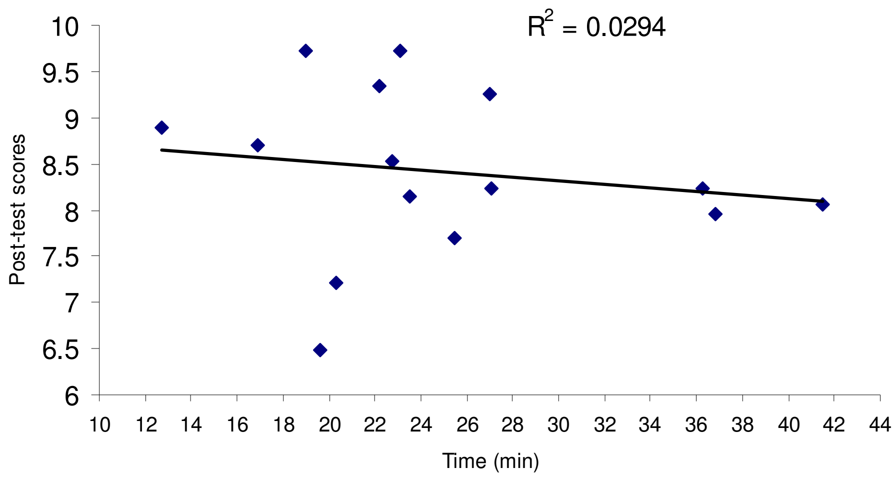
Graf 2: Time needed to complete the post -test vs. the difference between the scores achieved at the post-test and average scores at the post-test

Learning effects of both LOs can be partially deduced from Graph 3.



Graf 3: Differences between the Scores and Post Test Average vs. Scores and Pre Test Average

Five students who achieved above average results in the pre-test, also achieved above average results at the post-test; two students, who were below average at the pre-test, achieved above average results at the post-test. It is possible to conclude that those seven students learned the concepts presented in LOs at a satisfactory level and were later able to use this newly acquired knowledge. Two students, whose results were above average at the pre-test, achieved below average results in the post-test. For these two students we can conclude that although they had enough pre-knowledge to be successful in learning concepts presented in LOs, they did not pay enough attention to the content presented and probably did not follow the e-learning units carefully enough. Two students, whose pre-test results were far below the average, managed to decrease this difference during the post-test. In spite of the fact that their results were still below the average, the difference between their post-test results diminished. The results of other students were close to the average. From the analysis of the mistakes at the post-test, we can conclude that the majority of students (12 or 13 from the total of 16) did not grasp the concepts of electronegativity, electrostatic potential and their relations with types of reaction sites in molecules. They were also unable to learn from the LOs how to use Pauling scale of electronegativity of atoms for predicting the type of bonds between atom pairs. These results are not in concordance with our expectations, however, for us it is an important message, which is to improve the second LO. The lessons learned from this part of the research results was that only the best students were able to learn difficult concepts on their own through the e-learning environment, without teacher's help. These students are internally motivated and do not need any additional external encouragement. If we compare the results of the post-test with the time students spent working with both LOs we got another important indication, namely that time does not necessarily correlate with their achievements in the post-test (Graph 4). On the contrary, as can be seen from the trend line on Graph 4, more time spent resulted in lower achievements. The best scores were achieved by those students who completed the units within 19 to 28 minutes.



Graph 4: Time spent for working with LOs and the scores achieved at the post-test

5. Analysis of the structured interview

Fifteen students took part in the structured interview. The interview consisted of six parts: general questions about the use of computer at home and at school, students' feelings when working with LOs, their satisfaction with the results of the pre-test, reviewing the level of students understanding of concepts presented in the first LO, and about the second LO and their satisfaction with the post-test results.

5.1 General part of the structured interview

The results revealed that the majority of students (9/15) never use computer in the classroom, five said that computer is only occasionally used in the classroom, and one student claimed that computer is used in the classroom at least once a week. The majority (14/15) of students also said that computer is never used during chemistry lessons (only in one case the teacher uses PowerPoint presentations for lecturing). We can conclude that computer is a natural companion of students' life, but teachers are still reluctant to use it, either due to the lack of computer skills or the lack of computer technology available at schools.

5.2 Students' feelings in working with LOs in Moodle environment

Thirteen students of 15 were relaxed and felt safe working with LOs in Moodle environment; two students felt some fear and unease at the beginning because they did not know what to expect, however, they soon adapted to the new learning environment, and the fear disappeared. They found the wealth and diversity of elements included in the LOs very attractive (10 /15 answers).

As for the negative features of working in this new learning environment, six students found no distractors, six students missed teacher's explanations or a hard copy of the material presented on the computer screen.

5.3 Pre-test

In the pre-test 13/15 students stated that the test is simply part of the research design for analysing the impact of e-learning on their feelings and knowledge.

5.4 Understanding concepts included in the first LO

For the first LOs we expected that while observing reactions of sodium with four structurally different solvents, students would intuitively develop the notion of a correlation between structure and reactivity. Analysing their answers we can conclude that students are generally good observers; the only problem was with observing the formation of a suspension in the reaction of sodium with acetone. However, when they were presented with explanations of the observable facts, we often detected model thinking. For example, students always correlated the colour change of the indicator phenolphthalein with the formation of hydroxide ions, although water was not present. Three students also had insufficient pre-knowledge of acids and bases, since in the case of the reaction of sodium with water they correlated the colour change of the indicator with the formation of sodium ions.

5.5 Understanding concepts from the second LO

With a set of tasks and questions we wanted to get a deeper insight into students' understanding of correlations between the concepts of electronegativity, polarity, distribution of electron density on the surface of molecule and the meaning of electrostatic potential on the surface of a molecule.

In the first task student were presented with the model of water molecule and the Pauling scale of electronegativity. They were asked to find the electronegativity of oxygen and hydrogen atoms, to calculate the difference and to assign the number of valence electrons on oxygen atom and the number of unshared electron pairs on oxygen atoms. Then, using a water molecule, they had to point out which atom attracts the electrons of the covalent bond and tell the result of this attraction. Then they had to say whether the picture of electrostatic potential on the surface of the water molecule confirms their answers. Seven (7) students who achieved 8.06 – 9.72 scores at the post test answered all questions correctly without any help. Two students with post-test scores below average (6.42 and 7.22) were not able to answer questions without substantial help. Basic concepts were not clear to them, they did not understand the meaning of electronegativity, and they did not differentiate between electonegativity and electrostatic potential. Other student were able to answer the questions correctly with minor help.

In the second task the student were presented with a physical model of 1-chlorobutane molecule, a picture of the distribution of electrostatic potential on the surface of the molecule, and the Pauling scale of electronegativity. The questions we asked were similar to the questions about water molecule, with an additional question, which type of the reagent would preferably react with the carbon atom to which chlorine atom was attached. We expected that students, using a picture of electrostatic potential distribution on the surface of 1-chlorobutane molecule, would be able to deduce the nature of the reagent (with negative electrostatic potential). Five students, who previously gave correct answers in the case of water molecule, answered correctly also in this task. Those five students were joined by two student who needed help in the case of water molecule, but they obviously learned from this direct help and gave all correct answers in the case of 1-chlorobutane molecule. Three students made only one mistake in answering questions: they selected a wrong type of the reagent which should react with 1-chlorobutane molecule. By the mistakes they made in answering questions five students proved that they did not understand concepts presented in the second LO to such un extent that they would be able to apply their knowledge without some help from the teacher. Students were also asked to self-evaluate their capability in using the Pauling scale of electronegativity for predicting the distribution of electron density and polarity of the molecule. On the scale 1 – 5, two students assessed themselves with the highest score (5), nine students were more cautious and graded themselves with 4 (among them were also the students who achieved the poorest results at this part of the structured interview). Four students chose grade 3, and interestingly, among those students was also a student who was even overcritical: he answered all questions correctly without any help, and achieved 9.26 scores at the post-test. All but one students (14/15) claimed that the picture of electrostatic potential on the surface of 1-chlorobutane molecule helped them in answering questions about the properties and reactivity of the molecule. The student who claimed that this picture did not help, was the one whose achievements at the post-test were the lowest, explaining that her visualization capabilities are very poor and therefore pictures did not help her very much to better understand the concepts.

5.6 Post-test

In this section of the structured interview we wanted to find out the level of difficulty of the post-test. 14 students decided that the post test was adequate for their level of understanding of the concepts presented in both LOs. One student said that that the post test was too difficult and his result confirmed his claim (his achievement was below the average - 7.69). Nine students said that the results from the post test met their expectations and gave a series of explanations, e.g.: “My result was expected because the post test included such items which were directly related with the concepts taught through the LOs.” Another student gave the following explanation: “I understood the concepts presented, but to achieve better results I should work through the LOs once again.”, and yet he got 9.72 scores out of 10 at the post test. Five students were only partially satisfied with their post-test results but were critical enough and blamed themselves for the outcome. One student was disappointed with the results (7.22), claiming that “I could be better but I made some stupid mistakes”. 13 students assessed e-learning units as a valuable supplementary material for learning chemistry; one student would replace traditional chemistry classes with e-learning, and one student rejected e-learning, explaining that “I do not want to learn alone, I need somebody to encourage me, and answer my questions”.

6. Conclusions

Our research results prove that e-learning approach in chemistry may result in actual learning of new and difficult concepts, but the learning effect primarily depends on students’ prior knowledge. Only one third of students (5), who took part in this research, actually learned new concepts to such an extent to apply newly acquired knowledge in a new learning situation without any help during the structured interview. Those students also achieved scores above the average in the post-test. With other students some misunderstanding or even the lack of some basic chemistry concepts was noticed during the structured interview (the concepts of chemical bond, valence of electrons, spatial arrangement of atoms in molecules, bases and acids, etc.).

We are particularly glad that students felt relaxed and safe when working with LOs in the Moodle environment and that even those who had some fear at the beginning quickly adapted to the new environment. They also assessed the structure of LOs very high. Thus, on the one hand these findings are very encouraging for us, but on the other raise a great responsibility. In designing new LOs special attention should be paid to interactivity and versatility of LOs and quality of visual elements so that students working with LOs would learn new concepts and be motivated and challenged.

7. Acknowledgements

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Strokovni življenjepis

Margareta Vrtačnik *currently holds the position of professor of chemical education and informatics at the University of Ljubljana, Slovenia. She took B.Sc. in chemistry, and M.Sc. in chemical education, and a Ph.D. in chemistry, all at the University of Ljubljana. She taught chemistry at a high school in Ljubljana before joining the staff of the University of Ljubljana in 1977, being successively assistant, assistant professor, and associate professor, prior to her current position. She spent a study year at the University of Maryland, USA, working with Professor Marjorie Gardner, a prominent chemical educator. Her chemical research has been on the biodegradation and photolysis of organic pollutants in the atmosphere, development of expert systems, structuring of chemical knowledge and QSAR studies. Her chemical education research is into the development of information and communication technologies to support critical thinking, including the use of visualization tools to promote visual literacy in chemistry. Professor Vrtačnik has also been centrally involved in the UNESCO programme to support university-industry cooperation. She was four years a vice-dean at the Faculty of Natural Sciences and Engineering, University of Ljubljana, currently she is presiding the University Commission for Undergraduate Study Programmes.*

***Margareta Vrtačnik** je redna profesorica kemijskega izobraževanja in kemijske informatike na UL, Naravoslovnotehnična fakulteta. Ima magisterij iz kemijskega izobaraževanja in doktorat iz kemije. Predno se je l. 1977 zaposlila na UL, je poučevala kemijo na I. gimnaziji v Ljubljani. Leta 1981 je bila na študiju na univerzi Maryland pri ugledni profesorici za področje kemijskega izobraževanja Prof. Marjorie Gardner. V sklopu dejavnosti UNESCO mednarodnega centra za kemijske študije je kot vabljena predavateljica gostovala na vrsti univerz in bila vključena v projekte s področja kemije in sorodnih disciplin ter kemijskega izobraževanja. Bila je nosilka bilateralnih, aplikativnih in temeljnih projektov ter sodelovala kot aktivna raziskovalka v mednarodnih projektih s področja university-industry cooperation. Njeno kemijsko raziskovalno področje je študij biorazgradnje in fotolize organskih onesnaževal ob podpori metod QSAR. Njeno raziskovalno področje na področju izobraževanja pa obsega zlasti razvoj in vrednotenje IKT pripomočkov za podporo kritičnemu mišljenu ter vizualni pismenosti, ki sta za bodoče naravoslovce ključna. Štiri leta je bila prodekanica na NTF ter predsednica študijske komisije, trenutno se ji izteka mandat predsednice komisije za dodiplomski študij, UL.*

***Rahela ČEMAŽAR** je absolventka izobraževalne smeri kemija-bilogija na Pedagoški fakulteti v Ljubljan in zaključuje diplomsko delo pod mentorstvom M. Vrtačnik. V sklopu diplomskega dela je bila vključena v raziskavo o vrednotenju učinka kemijskih učnih objektov na znanje kemije in odnosu dijakov do e-učenja.*

***Rahela ČEMAŽAR** she is finishing her undergraduate studies at the Faculty of Education,University of Ljubljana. She is preparing her diploma work on the effects of chemistry learning objects (LO) on knowledge and attitudes of high school students towarsd e-learning under the supervison of M. Vrtačnik.*