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VISUAL LITERACY AND SUFFICIENT CONTEXTUALIZATION ELEMENTS AS PREREQUISITES FOR EFFECTIVENESS OF WEB-BASED LEARNING OBJECTS AS COGNITIVE TOOLS

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***Abstract**: The current study investigated the development of students' understanding of chemistry and their ability to translate visual information into verbal form and across representation due to application of two interactive web-based models and worksheets. 100 grade 8 students applied two web-based models during two lessons and filled in a pre- and a post-test. The results of the study show that students' understanding of chemistry developed statistically significantly. On the basis of the comparison of the pre- and post-test results a significant development was found in students' ability to translate visual information into verbal form and across two models. It is concluded that the applied methodology was successful for developing students' visual literacy skills and that improved visual literacy provides evidence of a more coherent understanding of the content.*

***Keywords:** learning objects, contextualization elements, visual literacy, cognitive tools*

I. INTRODUCTION

Cognitive tools could be defined as computational applications that are designed to support, extend and enhance thinking processes [1]. Representations of different kinds are also supposed to ease the cognitive load of their observers, however that is not always the case.

The aim of an educational representation is to communicate a specific message from an expert to a novice. According to Jakobson's communication model [2], there are six factors of communication that are needed for communication to occur: context, addresser, addressee, contact, common code and message. Although the model was developed to describe verbal acts of communication, it has a more general field of application, as it involves a common code. In communication, we are not limited to using words and can actually use anything that functions semiotically, e.g. in instruction different kinds of visual representations are widely used to communicate knowledge.

While there is a growing trend of attracting digital resources into the learning process, it is not the media itself that influences learning, but rather a teaching method that is designed into a particular media presentation [3]. Therefore, it is concluded by Clark that media and their affordances have important influence on learning indeed, but only in cases when they embody adequate instructional methods. Methods are defined as "the provision of cognitive processes or strategies that are necessary for learning but which students can not or will not provide for themselves". We find more evidence for this from Mayer's cognitive theory of multimedia learning (CTML) [4], which has a strong emphasis on the traits of cognitive processes. According to the cognitive theory of multimedia learning, it is important to design multimedia instruction which takes into consideration the patterns according to which the human mind works. The CTML focuses on five cognitive processes in learning with multimedia: the selection of relevant words from the presented text or narration, the selection of relevant images from the presented illustrations, the organization of the selected words into a coherent verbal representation, the organization of selected images into a coherent pictorial representation, and the integration of the pictorial and verbal representations and prior knowledge.

According to Lotman's notion of autocommunication [5], the shift of context results in a situation when the same initial message acquires a different meaning for the receiver. In our study, we applied two interactive web-based models in which learning objects of varying level of complexity were used. The main goal of our research was to find out if students were able to translate visual information of one model into that of the other one. It would provide us with evidence that due to the application of two models students acquire a more coherent understanding of two chemistry domains.

Our research questions were:

1) Does students' understanding of the content domains develop due to the application of interactive models and worksheets?
2) How do interactive models develop students' skills of translating visual information into verbal form and across the models?

II. METHODS

2.1. Sample and Procedure

The sample was composed of 100 students of the 8th grade (aged 14–16) of two Estonian schools. The participants had learnt both chemistry topics (chemical bonding and oxides) before the study during the same school-year.

The study was conducted in three lessons. In the first lesson, the students filled in a 15-minute pre-test and afterwards worked half an hour with a model of Chemical Bonds and a worksheet. In the second lesson the students worked with a model of Oxides and a worksheet. A week later the students were given 15 minutes to fill in a post-test.

2.2. Interactive Chemistry Models

Two interactive web-based models (Chemical Bonds and Oxides) were used in the study together with student worksheets. The model of Chemical Bonds (located at http://bio.edu.ee/flash/keemside/index.htm) is based on Bohr's atomic structure. The model enables learners to select atoms of different elements and observe the patterns of electron motion at the formation of either covalent or ionic type of chemical bonding.

The model of Oxides (located at http://mudelid.5dvision.ee/oksiidid) is more simplified and abstract. Learning objects (LOs) used in this model are not familiar to learners as that kind of atom representations are not used in textbooks, Bohr's structures are preferred. This model enables learners to compile oxides of metals and non-metals matching different elements with oxygen.

The models used in this study were equipped with help files and theory sheets. The help file introduces the main affordances of a model. The theory sheets serve as contextualization elements [6] for the LOs in the models. The mechanisms of formation of different types of chemical bonding and oxides were not described and were intended to be discovered by learners on their own applying the models.

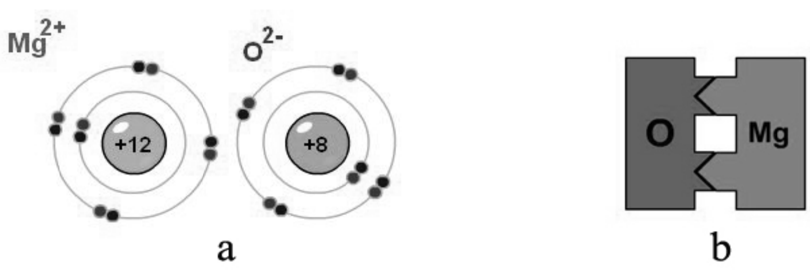

Figure 1. Learning objects in the models of Chemical Bonds (a) and Oxides (b)

2.3. Student Worksheets

Workflow with models was organized via student worksheets [7]. Two separate worksheets were composed for models of Chemical Bonds and Oxides. Learners were provided with specific instructions and tasks which they had to follow in a prescribed order and answer content-specific questions in-between and during the tasks.

On the worksheet for model Chemical Bonds, learners were asked to describe what happens to the electrons when a chemical bond is formed and also to mark oxidation numbers of the elements participating in the process. Such tasks were meant to help learners to create referential connection between the symbolic and sub-microscopic levels of representation of oxidation numbers. On the worksheet for model Oxides, learners were provided with tasks involving LOs from the model of Chemical Bonds and they were asked to map referential features of those onto LOs of the model at hand. This method was used in order to foster development of coherent understanding of the chemistry domains which is possible only when learners are able to translate visual information from language of one presentation into that of another using adequate content-specific context.

2.4. Pre- and Post-test

Participants of the study filled in a pre-test before and a post-test after the treatment. The questions and tasks in both tests were the same but placed in a different order in the post-test. Some of the chemical compounds were substituted with analogical ones in the post-test.

In order to answer our first research question about the development of students' understanding about chemistry, we asked 9 questions about chemical bonding and 4 questions about oxides. In the field of chemical bonding, the students were asked to determine the type of chemical bonding in different compounds and to reason their decision-making. In the field of oxides, the students were asked to determine oxidation numbers of several compounds. All together the answers to these content-specific questions would help us to see if the students' understanding of chemistry had developed due to the application of interactive models.

In order to answer the second research question about the students' visual literacy skills, we had two types of questions. Four questions investigated how well the students' were able to translate visual information into verbal form. The students' were supposed to verbalize the different types of LOs they saw on the computer screens (Figure 1) into the language of chemical symbols. In the tests we had 4 questions on translating visual information into verbal form and 5 questions dealt with the translation of LOs of the model of Chemical Bonds into LOs used in the model of Oxides.

The pre- and post-test answers were coded as follows: 0 – incorrect or unanswered; 1 – correct answer. For further statistical analysis MS Excel and PASW 18.0 packages were used. Wilcoxon Signed Ranks test of PASW was used to measure students' development on the basis of pre- and post-test scores.

III. RESULTS AND DISCUSSION

3.1. Understanding of chemistry

Since the study was related to chemistry domains, firstly we examined if the students' understanding of chemical bonding and oxidation numbers had developed due to the application of interactive models and worksheets. For this we compared the pre- and post-test answers using Wilcoxon Signed Ranks Test. We found (Table 1) that the students were able to determine the type of chemical bonding better, as the number of correct answers had doubled in the post-test. The development of understanding in the field of bonding was statistically significant ($Z=-7.6$; $p<0.001$).

Table 1. Development of students' (n=100) understanding of chemistry on the basis of the pre- and post-test results

Domain	Max. points	Pre-test (%)		Post-test (%)		Z	p
		Mean (%)	SD	Mean (%)	SD		
Determination of bonding	4	2.03 (51)	1.62	3.67 (92)	0.99	-6.8	<0.001
Reasoning of bonding	5	1.74 (35)	1.81	3.76 (75)	1.69	-7.2	<0.001
Understanding of chemical bonding (Total)	**9**	**3.77 (42)**	**3.14**	**7.43 (83)**	**2.37**	**-7.6**	**<0.001**
Oxidation numbers in F_2	1	0.06 (6)	0.24	0.15 (15)	0.36	-2.7	<0.01
Oxidation numbers in CuO	1	0.36 (36)	0.48	0.65 (65)	0.48	-4.9	<0.001
Oxidation numbers in NaF	1	0.21 (21)	0.41	0.45 (45)	0.50	-4.2	<0.001
Oxidation numbers in CO	1	0.23 (23)	0.42	0.52 (52)	0.50	-4.9	<0.001
Understanding of oxides (Total)	**4**	**0.86 (22)**	**1.13**	**1.77 (44)**	**1.30**	**-6.2**	**<0.001**

Next, we examined the development of students' understanding in the field of oxides and this was also statistically significant ($Z=-6.2$; $p<0.001$). Thus, the application of the model Chemical Bonds and the model Oxides together with accompanying worksheets can be recommended as an effective method of improving grade 8 students' understanding of chemistry.

3.2. Translation of visual information into verbal

Specific attention was paid to the students' skills to translate visual information into verbal form. They had to translate the models' learning objects into verbal signs. Almost half (Table 2) of the students coped with this task in the pre-test.

Table 2. Development of students' (n=100) skills to translate visual information into verbal information on the basis of the pre- and post-test results

Domain	Max. points	Pre-test (%)		Post-test (%)		Z	p
		Mean (%)	SD	Mean (%)	SD		
Chemical formula of F_2	1	0.44 (44)	0.50	0.86 (86)	0.35	-6.1	<0.001
Chemical formula of CuO	1	0.65 (65)	0.48	0.86 (86)	0.35	-3.4	<0.01
Chemical formula of NaF	1	0.52 (52)	0.50	0.85 (85)	0.36	-4.7	<0.001
Chemical formula of CO	1	0.35 (35)	0.48	0.73 (73)	0.45	-5.4	<0.001
Translation of visual information into verbal (Total)	**4**	**1.96 (49)**	**1.25**	**3.30 (83)**	**0.87**	**-7.0**	**<0.001**

Comparing the results of the pre- and post-test, a statistically significant development was found, as 83% of students succeeded in this type of tasks. This finding shows that after applying the models in two lessons the students could orient better within the realms of sub-microscopic and symbolic levels of representation. The fact that the students could externalize their understanding about LOs using language of chemical symbols shows that the instructional treatment was in good accord with what we know about cognitive processes involved in multimedia learning.

3.3. Translation of visual information across the models

Concerning students' visual literacy we focused on their skill to translate visual information from the learning objects of one model to that of the other model. As in textbooks Bohr-like representations are usually implemented the students are more used to them. In the pre- and post-tests the students were asked to complete a figure by drawing the missing objects using the box-shaped LOs from the Oxides model (Figure 1b). The same process of formation was depicted in an earlier task with Bohr's structures. The students had to match the common context of the figures and express the missing content using a specific graphical language of box-shaped LOs. Although this task seems to be very logical and simple at first sight, the pre-test results (Table 1) showed that just 34% of the students were able to complete the drawing correctly. However, in the post-test the percentage of students who coped with this task has doubled (69%).

Table 3. Development of students' (n=100) skills to translate visual information across the models on the basis of the pre- and post-test results

Domain	Max. points	Pre-test (%)		Post-test (%)		Z	p
		Mean (%)	SD	Mean (%)	SD		
Representation of a single electron in F atom	1	0.22 (22)	0.42	0.67 (67)	0.47	-6.7	<0.001
Quantity of chemical bonds	1	0.51 (51)	0.50	0.83 (83)	0.38	-5.2	<0.001
Relation between "legs" and chemical bonds	1	0.38 (38)	0.49	0.79 (79)	0.41	-6.1	<0.001
Completing a figure	1	0.41 (41)	0.49	0.54 (54)	0.50	-2.2	<0.05
Representation of paired electrons	1	0.20 (20)	0.40	0.62 (62)	0.49	-6.5	<0.001
Translation of visual information across the models (Total)	**5**	**1.72 (34)**	**1.55**	**3.45 (69)**	**1.53**	**-7.5**	**<0.001**

These results show that although the students were presented with both types of visual information in the tests, the majority of them were not able to translate the information prior to the treatment. The reasons for this could be that although the students saw different visual representations, it did not automatically mean that they were able to put the LOs into a domain-specific context. This is supported by both semiotic and visual literacy theoretical frameworks [8] and is interpreted as a need for active processing of visual stimuli. Thus, in order to understand a particular LO, the students need to put it into a specific context and only then a visual stimuli becomes meaningful. Although both Bohr-like representations as well as box-shaped LOs were supplied with chemical symbols beside them, it was still insufficient for the students to perceive them in the context of chemistry on the sub-microscopic level. One reason for this could be absence of domain-specific coherent pictorial and verbal internal representations in the students' long-term memory [4] and, therefore, their inability to place incoming information into a proper context. However, after the application of models and worksheets, the students performed significantly better and so it can be concluded that the treatment was sufficient to support them in processing visual information of LOs in a more active manner. Probably the students benefited the most from the learning tasks in which they were told to concentrate their attention on specific parts of the LOs in a prescribed order. According to the significant development of students' ability to translate visual information across models, it can be concluded that the applied methodology was successful for developing students' visual literacy skills and providing them with cognitive support.

IV. CONCLUSIONS

The current study aimed at investigating the development of the ability of students to translate visual information into verbal form and across representations due to the application of interactive models and worksheets. The results of the study show that students' visual literacy skills developed statistically significantly. Therefore, it can be concluded that the method applied could be recommended as a sufficient treatment for developing students' visual literacy. The fields of domain-knowledge and the models are intersecting and, thus, form a basis for effective knowledge acquisition when a learner is interacting with the models. Although these overlapping areas exist, it should be made evident for students via the contextualization elements. Supportive contextualization elements are thus crucial cognitive tools. While the intersecting areas are important, they do not by themselves elicit development of understanding. The areas of model content, which do not overlap with content knowledge already possessed by a learner, are the ones where learning could potentially take place. The results of the study also show that students' understanding of chemistry developed statistically significantly as well. This could be concluded from students' answers to the content-specific questions in the pre- and post-tests. The development of students' ability to translate information across two models provides us with evidence that students' understanding of the domains became more coherent after the treatment.

Acknowledgements

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