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DEVELOPING STUDENTS' VISUAL LITERACY IN A VIRTUAL MODELLING ENVIRONMENT

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***Abstract**: This study investigates the influence of virtual modelling activity on the development of students' visual literacy. An experiment was conducted using learning environment "Cell World" in order to enhance students' skills of analysing and translating visual information. The participants were 190 Estonian secondary school students who applied the models of protein synthesis and genetic code. A pre- and post-test was designed and completed to measure students' visual literacy. Results of the study indicated that students' skills in analysing visual information were higher after the application of the models. The students' ability to translate information across different representations also developed statistically significantly. This study therefore provides additional evidence that introducing manipulative learning objects in instructional settings can significantly improve learner's visual literacy.*

***Keywords:** visual literacy, virtual modelling, web-based learning environments*

I. INTRODUCTION

This study addresses the ways in which secondary school students' visual literacy can be improved through virtual modelling activity in a web-based learning environment. Visual literacy can be defined as a set of learned abilities that enable people to interpret visual messages accurately and also, to effectively create such visualisations [1; 2; 3; 4]. The way in which students perceive and understand visual images is one of the crucial issues for the field of visual literacy [5].

Various attempts have been made to distinguish different visual literacy skills [6; 7]. The present study concentrates on students' skills in analysing visual information and their ability to translate information across different visual representations. Translation, or visual association, can be defined as the ability to link visual images that depict a unifying theme [1]. According to Ainsworth [8], translation involves mechanisms of processing, mapping between and moving across external representations. The process of translation presumes the comprehension and conversion of relationships between different external representations [9]. In the process of teaching science, various types of external representations are used, such as diagrams, physical or virtual models, static and dynamic visualizations, etc. Thus, successful translation across different external representations is a challenging issue when communicating scientific knowledge to learners. Results of previous studies however, indicate that learners often perform poorly in translation tasks; for example, the study conducted by Wilder and Brinkerhoff [10] revealed students' difficulties in translating between biomolecular visualizations and graphs.

Several authors have stressed the educational value of scientific modelling. According to the theoretical framework for designing multimedia proposed by Reed [11], the manipulation, rather than simply the perception, of objects has a crucial role in the learning process. This proposition is also supported by empirical studies about the effect of interactivity in computer-based learning [12], according to which interactive manipulation using multimedia materials can significantly enhance deeper learning. The design of the virtual modelling environment "Cell World" implemented in this study therefore emphasizes the role of object manipulation in instruction.

The following research questions were set to the study:

1) What are secondary school students' initial skills of analysing visuals and translating information across different visuals?

2) How does the virtual modelling activity in the learning environment "Cell World" influence students' visual literacy skills?

II. METHODS

2.1. Learning environment

The virtual learning environment "Cell World" (http://bio.edu.ee/models) was devised in the Science Education Centre at the University of Tartu. The "Cell World" learning environment enables learners to explore complex microscopic processes that take place in cells, such as molecular genetics, respiration, photosynthesis, etc. In the present study, the models of protein synthesis and genetic code were used. The topic of genetics was selected as it is conceptually one of the most challenging themes in biology and students' conceptions of genetic processes tend to be poor [13].

The main activity for students in the environment is the virtual construction of biological processes. Each model consists of two main parts: on the left side of the screen is the store of movable objects, and on the right side, the desk with animation (see Figure 1). Users must choose the correct molecule from the store and add it to the desk so that the animation of the process can continue.

Figure 1. Screenshot of the model of protein synthesis of the virtual learning environment "Cell World"

2.2. Participants

In order to fulfil the aims of the study, an experiment was conducted in which 190 students (aged 17-18) from the 11th year of nine Estonian secondary schools participated. The students were not novices in the domain of genetics as the topic of the protein synthesis was already studied some weeks before the intervention.

2.3. Procedures

The study was conducted in four lessons. In the first lesson, students filled in an individual pre-test in 20 minutes. The pre-test aimed to measure students' initial level of visual literacy skills –

that is, their analysis of visual representations and ability to translate information across the different representations.

In the next stage of the study, participants applied the learning environment “Cell World” individually for 2 x 45 minutes. In the first lesson, students used a model of protein synthesis, and in the second one, a model of genetic code was used.

In order to assess the development of students’ visual literacy skills, a 20 minute post-test, identical to the pre-test, was filled in after the intervention. This post-test was completed on average ten to fourteen days after the model application.

2.4. Data collection

Students’ visual literacy skills – the analysis and translation of visual information – were assessed on the basis of three different representations in the pre- and post-tests.

In the first representation, students’ skills in analysing visual information were assessed. The representation was a screenshot of the model of protein synthesis that was applied in the study (see Figure 1). The students’ assignment was to analyse the picture and name all the components depicted on the image.

In order to measure students’ skills in translating information across different visual representations, two additional representations were included in the pre- and post-test (see Figure 2).

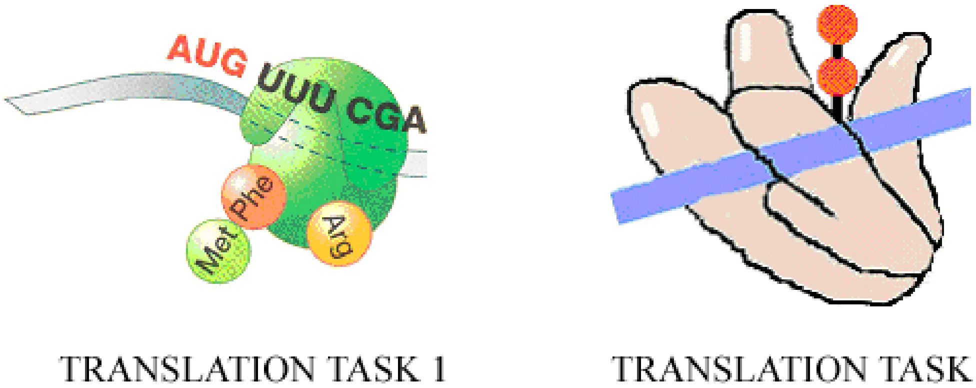

Figure 2. The representations of translation tasks in the pre- and post-test

The second representation (translation task 1) was familiar to students from the textbook that they had previously used in the classroom for learning about protein synthesis. The students’ task was to compare the first, model-based representation with the second representation and translate the information across these by marking all the same components on the second picture.

The third representation (translation task 2), on the other hand, was taken from a textbook that was unfamiliar to students. Again, in order to assess students’ skills in translating visual information, students had to compare the first, model-based representation, with the third, and mark the same objects on the third image.

Students’ responses in the pre- and post-test were coded in the following way. For each correct component, students were scored with one point, and for missing or incorrect answer, no points were given. For the comparison of pre- and post-test scores, the Wilcoxon Signed Ranks test was implemented with SPSS software.

III. RESULTS AND DISCUSSION

The aim of this study was to clarify skills held by secondary school students in analysing and translating information across different representations, and what effect the application of the virtual modelling environment would have on the development of these visual literacy skills. At first, students’ initial level of visual literacy was assessed on the basis of the pre-test answers (Table 1).

Table 1. Students' (n=190) initial visual literacy skills according to the pre-test data

Components	Analysis (Representation 1)		Translation (Representation 2)		Translation (Representation 3)	
	Mean (%)	SD	Mean (%)	SD	Mean (%)	SD
Ribosome	0.60 (60%)	0.49	0.31 (31%)	0.46	0.26 (26%)	0.44
mRNA	0.49 (49%)	0.50	0.32 (32%)	0.47	0.24 (24%)	0.43
Peptide	0.67 (67%)	0.47	0.16 (16%)	0.37	0.18 (18%)	0.39
Amino acid	0.65 (65%)	0.48	0.38 (38%)	0.49	0.24 (24%)	0.43
Peptide bond	0.65 (65%)	0.48	0.23 (23%)	0.42	0.22 (22%)	0.41
Codon	0.35 (35%)	0.48	0.23 (23%)	0.42	-	-
Nucleotide	0.35 (35%)	0.48	0.13 (13%)	0.34	-	-
Hydrogen bonds	0.36 (36%)	0.48	-	-	-	-
tRNA	0.56 (56%)	0.50	-	-	-	-
Anticodon	0.65 (65%)	0.48	-	-	-	-
Total	5.17 (52%)	3.30	1.52 (22%)	1.95	1.14 (23%)	1.71

Table 1 demonstrates that in the analysis task, students gained an average of 5.17 points out of 10 (52%). Most students were able to correctly name five or six components of the model-based representation. In the pre-test translation tasks, students were less successful: in Representation 2 the mean score was 1.52 out of 7 (22%). Interestingly, in the unfamiliar textbook representation, students' skills in translating visual information were approximately the same, as the total score for Representation 3 was 23% (mean score 1.14 out of 5).

Overall, the objects that students most often named were the same in both translation tasks (see Table 1). In the familiar textbook representation, the most often named components were amino acid (38% of students), mRNA (32%), and ribosome (31%), as for the unfamiliar textbook representation, students received the highest scores by correctly naming ribosome (26% of participants), mRNA (24%) and amino acid (24%). This suggests that students had most initial knowledge about these components.

In Table 2, the results of the post-test are presented, which represent students' visual literacy skills after the application of the modelling environment.

Table 2. Students' (n=190) visual literacy skills after model application according to the post-test data

Components	Analysis (Representation 1)		Translation (Representation 2)		Translation (Representation 3)	
	Mean (%)	SD	Mean (%)	SD	Mean (%)	SD
Ribosome	0.87 (87%)	0.34	0.65 (65%)	0.48	0.61 (61%)	0.49
mRNA	0.76 (76%)	0.43	0.63 (63%)	0.49	0.50 (50%)	0.26
Peptide	0.93 (93%)	0.26	0.51 (51%)	0.50	0.50 (50%)	0.15
Amino acid	0.92 (92%)	0.28	0.73 (73%)	0.45	0.47 (47%)	0.70
Peptide bond	0.88 (88%)	0.33	0.49 (49%)	0.50	0.48 (48%)	0.57
Codon	0.68 (68%)	0.47	0.53 (53%)	0.50	-	-
Nucleotide	0.70 (70%)	0.46	0.32 (32%)	0.47	-	-
Hydrogen bonds	0.85 (85%)	0.36	-	-	-	-
tRNA	0.84 (84%)	0.37	-	-	-	-
Anticodon	0.75 (75%)	0.44	-	-	-	-
Total	8.17 (82%)	2.29	3.85 (55%)	2.25	2.93 (59%)	1.87

As can be seen from Table 2, the average score for the model-based representation in the post-test was relatively high – 8.17 points out of 10 (82%). Also, the scores for translation tasks were higher than in the post-test –3.85 points (55%) for the Representation 2 and 2.93 points (59%) for the Representation 3. The results indicated that although the scores for the analysis task were very high, a large proportion of students were still unable to correctly associate different representations. For instance, 93% of students could correctly identify peptide on the model-based representation. However, only 51% and 50% of students respectively could transfer this information into Representations 2 and 3. These results confirm previous findings, in which students performed poorly in translation tasks as it is cognitively challenging to compare and map information presented in different representations [9; 10; 14].

The Wilcoxon Signed Ranks test was applied to the comparison of pre- and post-test data in order to clarify the development of students' visual literacy skills (Table 3).

Table 3. Development of students' (n=190) visual literacy skills according to the pre- and post test results analysed with the wilcoxon signed ranks test

Skill	Max	Pre-test		Post-test		Z	p
		Mean (%)	SD	Mean (%)	SD		
Analysis (Representation 1)	10	5.17 (52%)	3.30	8.17 (82%)	2.29	-10.39	<0.001
Translation (Representation 2)	7	1.52 (22%)	2.05	3.85 (55%)	2.28	-10.27	<0.001
Translation (Representation 3)	5	1.14 (23%)	1.71	2.93 (59%)	1.87	-9.21	<0.001

According to the Wilcoxon Signed Ranks test results, it can be concluded that students' skills in analysing the model-based representation improved significantly as a result of the model application (Z=-10.39; p<0.001).

The comparison of pre- and post-test data indicated that after application of the model, students also achieved higher scores in translating information across different representations. For associating model-based representation and Representation 2, students' average score increased from 1.52 (22%) in the pre-test to 3.85 (55%) in the post-test. On the basis of the Wilcoxon Signed Ranks test, this development was statistically significant (Z=-10.27; p<0.001). Students' abilities to translate visual information across model-based representation and Representation 3 demonstrated a similar improvement with an average of 1.14 (23%) in the pre-test and 2.93 out of 5 (59%) in the post-test (Z=-9.21; p<0.001). Table 4 also demonstrates the pre- and post-test differences for each of the components presented in the representations.

Table 4. Comparison of students' (n=190) pre- and post-test results with the wilcoxon signed ranks test

Components	Analysis (Representation 1)		Translation (Representation 2)		Translation (Representation 3)	
	Z	p	Z	p	Z	p
Ribosome	-6.76	<0.001	-7.61	<0.001	-7.14	<0.001
mRNA	-6.53	<0.001	-7.00	<0.001	-6.95	<0.001
Peptide	-6.20	<0.001	-7.78	<0.001	-6.29	<0.001
Amino acid	-6.57	<0.001	-7.38	<0.001	-8.79	<0.001
Peptide bond	-5.91	<0.001	-6.06	<0.001	-8.53	<0.001
Codon	-6.98	<0.001	-6.00	<0.001	-	-
Nucleotide	-7.27	<0.001	-5.09	<0.001	-	-
Hydrogen bonds	-9.64	<0.001	-	-	-	-
tRNA	-7.02	<0.001	-	-	-	-
Anticodon	-6.38	<0.001	-	-	-	-

Thus, it can be concluded that, when comparing the pre- and post-tests, the components were all statistically significantly more marked in the post-tests. It is therefore evident that the virtual modelling activity in the environment “Cell World” had a positive effect on learners’ skills in analysing visual information, and the ability to map and translate information across different representations. This follows previous research where the development of students’ representational skills after computer-based visualization activities has also been demonstrated [10].

IV. CONCLUSIONS

The present study explored ways in which students’ visual literacy can be improved through virtual modelling activity. More specifically, we were interested how students analysed visuals and to what extent they were able to translate information across different representations.

According to the pre-test data, students’ initial skills in translating information across different representations were significantly lower than their skills in analysing a single representation. This outcome confirms previous findings that the translation of visual information is a cognitively demanding process and students are often not able to associate the components of visual representations.

The comparison of students’ pre- and post-test data demonstrated that the students’ skills in analysing visual representations developed statistically significantly as a result of the intervention. Moreover, the skills of translating information across different representations also developed significantly. The results of the current study therefore provide strong evidence that introducing manipulative learning materials in instructional settings can effectively improve students’ visual literacy.

Acknowledgments

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