Influence of augmented reality technology upon pupils' knowledge about human digestive system: The results of the experiment*

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Abstract: Applying information technologies in the educational process is the main direction of modern education. However, "moving" information communication technologies to schools is the primary purpose of discussions held by pedagogical and scientific society as this is a very problematic field (Lamanauskas, 2006). Most of the researches show that the virtual learning environment help to achieve higher learning results. However, pupils' questioning in Lithuania, Germany, Romania, Malta and Czech (Lamanauskas, Vilkonis & Klangauskas, 2007; Lamanauskas & Vilkonis, 2007; Bilek, Zemanova & Turčani, 2007) showed that most of the respondents prefer real learning environment or combine real and virtual environments while learning natural sciences. The latest scientific research shows that along the real and/or virtual teaching/learning environment, a combined environment can also be acceptable. The introduced environment can be created using augmented reality technology (ART), i.e. augmenting real objects found in the environment and usual material visuals with virtual information in the real space. In Siauliai University, a pedagogical experiment was done, and it aims at establishing effective teaching/learning platform based on augmented reality technology (ARTP) influence upon the learning results. 110 pupils of the 7 th form of comprehensive school took part in the experiment. The analysis of the research data shows that pupils' achievement after use of ARTP in the experimental group significantly improved while completing some tasks.

Key words: information communication technologies; virtual/real learning environment; combined real and virtual environments; augmented reality technology

1. Introduction

Applying information technologies in the educational process is the main direction of modern education (Slabin, 2002). However, "moving" information communication technologies to schools is the primary purpose of discussions held by pedagogical and scientific society as this is a very problematic field (Lamanauskas, 2006). Most of the researches done in the world (Evaluating information and communications technology: Perspectives for a balanced approach, 2001; SITES, 2001; Zajanciauskiene, 2007) show that the virtual learning environment help to achieve higher learning results. The use of ICT (Informationand Communications Technology) in the educational process had a positive impact on the learners of different age groups, the students with ordinary and special needs dealing with different subjects. However, ICT's influence upon pupils' teaching/learning achievement and their attitude should not be assessed tendentiously or unilaterally. Students' questioning in

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Lithuania, Germany, Romania, Malta and Czech (Lamanauskas, Vilkonis & Klangauskas, 2007; Lamanauskas & Vilkonis, 2007) showed that most of the respondents prefer real learning environment or combine real and virtual environments while learning natural sciences. The latest scientific research shows that along the real or virtual teaching/learning environment, a combined environment can also be acceptable (Adams, 2005; Billinghurst, 2002; Azuma, 1997; http://net.educause.edu/ir/library/pdf/ELI7007.pdf). The introduced environment can be created using augmented reality technology (ART), i.e. augmenting real objects found in the environment and usual material visuals with virtual information in the real space. M. Adams (2005) states that augmented reality technology is one of ten most important human technologies that should be very useful for learning. Augmented reality is created putting into practice the display of a computer which affects the user's senses and provides additional information. A virtual view or text can be inserted into the vision field of the user. Nevertheless, information can be received through other senses such as hearing or touching. Thus, the core of augmented reality is formed from the visuals that can be observed adopting a special devise (for example, stereo glasses are used for watching a view through the semi-clear screen). The final result of such observation is the wholeness of real and virtual information. Currently, applying different approaches, a number of various AR technologies have been created[1]. Although augmented reality technology is not new, its potential in education is just beginning to be explored.

In 2007, a group of scientists from the University of Siauliai conducted research focused on how the teachers of sciences and the experts providing assistance with teaching/learning evaluated the efficiency of a lately created teaching/learning platform based on augmented reality technology (ARTP). The investigation established that if applied at school, the ARTP could make the learning process of different target groups more effective and help the gifted learners and those with low motivation and special educational needs (Vilkonienė, et al., 2007; Vilkoniene, et al., 2008). Moreover, research revealed that a part of teachers believed that when using the ARTP, students with learning difficulties should treat the learning process as a game and therefore find studying easy and attractive. Considering the results of the above-mentioned research, the pedagogical experiment, which aimed at determining effectiveness of ARTP's influence upon the learning results, was done in Siauliai University in January-February, 2008. Nevertheless the object of the research is quite narrow (pupils in the seventh form knowledge and abilities in the sphere of human digestive system), the researches of this character recently get a special importance because in the scientific literature providence that AR technology will reach educational institutions in this decade appear (Kaufmann, 2003).

2. The methodology of the research

Till applying of ARTP in all groups of the pupils who took part in the research traditional verbal, material visual (human digestive system model), printed (the illustrations and texts of the textbook and the other books) teaching/learning means were used. During the experiment, different manipulative sanctions were being applied in two groups: in the first (hereafter-E1)—ARTP, in the second (hereafter-E2)—computer teaching program

[1] In order to examine the possibilities of using ART for learning purposes in comprehensive school, in 2006, the ES 6FP project ARiSE (Augmented Reality in School Environments) was launched. The technology produced by the ARiSE project is aimed at creating conditions for the users not only to observe a combined view but also to directly interact with the real world (real objects). It is likely that in this case, the approach *learning by doing* can be implemented in a more effective way. Firs learning module "*The Human Digestive System*" for the first prototype of the new learning platform based on ART focused on teaching/learning biology was created in the first year of work on the project.

(hereafter-CTP). Both ARTP and CTP were treated as not the main teaching/learning aids which let visualize teaching/learning material and deepen understanding of teaching/learning material more effectively, and also stimulate learning motivation and involvement in subject. At that time when the pupils of the groups E1 and E2 were deepening their knowledge by the help of the manipulative aids, the pupils of the auditorial groups were using the same traditional teaching/learning aids as before—textbooks, accessory information sources (encyclopedias, the Internet, teacher's help, etc.).

To evaluate the researched features till the application of the manipulative means and the changes of the features after influence in the interval of 3 weeks pupils' knowledge and ability testing was done (pre-test and post-test). The stimulus material of the test was made of 4 tasks which showed pupils' ability that is thinking critically, reproducing and applying knowledge. The tasks were formulated so that they would involve 4 different topics planned in biology teaching programme: the organs of digestive system, the digestive tract, resolution of alimentary stuff, resorption of alimentary stuff. In order to do as thorough data analysis as it is possible, not only general task accomplishment result but also every "step" of the task was evaluated. Different tasks were made of different number of "the steps" (from 3 to 11) which illustrated particular pupils' abilities and knowledge. It was tested if the pupils knew each organ: mouth, throat, gullet, stomach and etc. The tasks of the test were evaluated in two stages. In the first stage, every step of the task was evaluated in two ranks: "don't know" and "know in full". In the second stage, general task result was evaluated in three ranks: 1—the task was not done (it was done wrongly), 2—the task was done not in full (there is some blemish), 3—the task was done in full (right). The research data were processed applying SPSS software. To analyze the data both expositive (comparative and absolute frequency, datum of shift and scatter) and analytical (Wilcoxon's test – to compare two dependent grips, Mann's and Whitney U-test—to compare two independent grips, Kruskal-Wallis Test—to compare three or four independent grips), statistics were used.

3. Characterization of the pupils who took part in the research

In total 114 seventh—formers took part in the research. This age range was chosen considering the natural sciences contents of Lithuanian Comprehensive School. Exactly the pupils in the seventh form get to know with the human digestive system and its organs, the digestive tract, they have out the processes of alimentary stuff resolution and resorption. Aiming at homogeneity of experimental and auditorial groups during the experiment, there was spotted the non-stochactic handy pupils' grip sampling—4 classes of the seventh formers from one school were chosen (identical environment, the same subject teacher and the same teaching/learning methods apart application of manipulative sanction).

After completely equal positions of the starting auditorial groups had been set, the two above-mentioned groups were approached as one. Thus, all the pupils of four classes made 3 groups: 2 experimental groups (E1 and E2)—57 pupils in them and 1 auditorial group (A)—57 pupils in it.

4. The results of the research

The first diagnostic section shows that after application of the traditional and common to all the groups teaching/learning methods pupils' learning results in the sphere of human digestive system are similar in all groups (see Table 1—pre-test).

Table 1 Comparison of generalized pre-test and post-test results of all exploratory groups

Task	Kruskal-Wallis test					
	Pre-test (E1, E2, A1, A2)			Post-test (E1, E2, A)		
	χ^2	*df*	*p*	χ^2	*df*	*p*
Organs of digestive system	5.155	3	0.16	11.081	3	0.00**
Digestive tract	4.199	3	0.24	13.017	3	0.00**
Digestion process	3.366	3	0.33	16.027	3	0.00**
Resorption process	3.783	3	0.28	18.286	3	0.00**

Note: ** $p<0.01$.

Mann-Whitney test used for two unrelated grips showed that both auditorial groups A1 and A2 are homogeneous, no statistically significant differences between pre-test results of these groups were determined (organs of digestive system: $p=0.58$; digestive tract: $p=0.63$; digestion process: $p=0.26$; resorption process: $p=0.21$). Because of this reason, analyzing the research data away the two auditorial classes were approached as one auditorial group A.

While comparing three exploratory groups (E1, E2 and A) in pairs, during the first measurement statistically significant difference between groups E1 and A was determined only in one position: organs of digestive system (see Table 2, Pre-test). The analysis of frequencies show that 42.9 percent of the pupils in the group E1 know all the organs of human digestive system and their place in the organism, 57.1 percent know it partially. The research data in group A are following: 20.8 percent know it in full and 79.2 percent know it partially. There were no pupils who did not do the task in any of the above-mentioned groups. Considering the research data and the fact that no significant differences between groups E1 and E2 were determined, it can be said that only the auditorial group A minutely segregated (only in one sphere) from all three pupils' groups—pupils in this group knew the organs of human digestive system and their dislocation place in the organism worse. However, this difference did not significantly influence the homogeneity of all the groups.

The second diagnostic section shows that after application of the manipulative sanction the testing results in three exploratory groups (E1, E2, A) diverged significantly (see Table 1, post-test). Comparing the groups in pairs (Mann-Whitney Test), statistically important differences between groups E1/K and E1/E2 were pointed out in all positions, i.e. Organs of digestive system, digestive tract, digestion process and resorption process (see Table 2).

Table 2 Comparison of the generalized pre-test and post-test results among the groups

Task	Test	Mann-Whitney test					
		E1/A		E1/E2		E2/A	
		U	*p*	U	*p*	U	*p*
Organs of digestive system	Pre-test	578.000	0.03*	300.000	0.10	705.000	0.88
	Post-test	463.500	0.00**	256.500	0.03*	683.500	0.47
Digestive tract	Pre-test	685.500	0.52	280.500	0.06	574.000	0.09
	Post-test	474.500	0.00**	223.500	0.00**	763.500	0.95
Digestion process	Pre-test	667.500	0.29	315.500	0.15	667.500	0.51
	Post-test	457.000	0.00**	188.500	0.00**	699.000	0.43
Resorption process	Pre-test	646.000	0.20	309.000	0.16	667.500	0.50
	Post-test	345.000	0.00**	114.000	0.00**	590.000	0.24

Notes: * $p<0.05$; ** $p<0.01$.

While comparing the results of fulfillment of each step of the task in different pairs of the groups, most of

statistically significant differences were determined between groups E1/A (see Table 3). In the table it is seen that above-mentioned differences were recorded while identifying a few organs of digestive system (mouth, duodenum, small intestine), pointing salivary glands as the organ which does not partake in digestive process directly, pointing in which organs (mouth, duodenum) particular alimentary stuff is separated and pointing in which organs which stuff is suck up (small and large intestine).

Table 3 Comparison of the thorough post-test results among the groups

Task	The step of the task	Mann-Whitney test					
		E1/A		E2/A		E1/E2	
		U	*p*	U	*p*	U	*p*
Organs of digestive system	Throat	686.500	0.28	714.000	0.56	351.000	0.68
	Mouth	621.000	0.02*	676.000	0.26	337.500	0.15
	Salivary glands	609.000	0.07	738.500	0.96	297.000	0.09
	Gullet	730.000	0.79	727.500	0.77	351.000	0.64
	Liver	715.500	0.31	742.000	0.98	351.000	0.31
	Stomach	728.500	0.60	729.000	0.48	351.000	0.31
	Pancreas	731.000	0.85	731.000	0.85	364.500	1.00
	Duodenum	581.500	0.02*	628.500	0.17	229.500	0.00**
	Large intestine	715.500	0.31	632.000	0.02*	297.000	0.02*
	Small intestine	580.500	0.00**	739.500	0.96	283.500	0.01*
	Rectum	719.000	0.76	738.500	0.96	351.000	0.76
Digestive tract	Salivary glands	414.000	0.00**	756.000	0.87	202.500	0.00**
	Liver	708.000	0.39	745.500	0.75	324.000	0.31
	Pancreas	637.500	0.06	751.500	0.81	310.500	0.12
Digestion process	In mouth	455.000	0.00**	713.500	0.53	194.000	0.00**
	In stomach	685.000	0.34	537.500	0.01*	210.000	0.00**
	In duodenum	433.500	0.00**	736.500	0.71	221.500	0.00**
Absorption process	In small intestine	309.000	0.00**	639.500	0.58	121.500	0.00**
	In large intestine	416.500	0.02*	661.000	0.71	213.500	0.05

Notes: *p<0.05; **p<0.01.

Between the groups E1/E2 the situation is similar: there was recorded the same number of positions in which statistically significant differences were determined and only a few of them do not coincide with the above-compared pair. The differences between groups E2/A are worth to be emphasized. In this pair there were recorded considerably fewer statistically significant differences (only in 2 positions), but the reason of these differences is worse test results of group E2 (see Table 4). It implies that computer curriculum used in group E2 did not significantly influence pupils' knowledge.

Thorough analysis (of each step of the task) of absolute and relative rates of the testing results illustrates the reasons of statistically significant differences in the end of experiment (post-test), which occur between different pairs of the groups (see Table 4). In the table it is seen that fulfilling most of the tasks group E1 distinguishes for its better results. Thus, it is fair to think that all statistically significant differences between groups E1/A and E1/E2 occurred namely because of better group E1 pupils' knowledge and ability to apply it.

It is obvious that pointing different organs of digestive system and digestive tract and their dislocation in human organism, group E1 which was using ART better knew namely these organs and glands which are not visually seen in various printed illustrations or visual means traditionally used at school (dummies and moulages), i.e. salivary glands, duodenum, small intestine and pancreas. Besides, E1 is the only group in which all the pupils (100%) identified mouth as digestive organ. Pointing organs which partake in segmentation and resorption processes group E1 showed signally better results in all the tasks (Table 4).

Table 4 Thorough results of post-test (N/%)

Task	The step of the task	E1			E2			A		
		Don't know	Know partially	Know in full	Don't know	Know partially	Know in full	Don't know	Know partially	Know in full
Organs of digestive system	Throat	4/14.8	-	23/85.2	3/11.1	-	24/88.9	4/7.3	-	51/92.7
	Mouth	-	-	27/100	2/7.4	-	25/92.6	9/16.4	-	46/83.6
	Salivary glands	3/11.1	-	24/88.9	8/29.6	-	19/70.4	16/29.1	-	39/70.9
	Gullet	2/7.4	-	25/92.6	3/11.1	-	24/88.9	5/9.1	-	50/90.9
	Liver	-	-	27/100	1/3.7	-	26/96.3	2/3.6	-	53/96.4
	Stomach	1/3.7	-	26/96.3	-	-	27/100	1/1.8	-	54/98.2
	Pancreas	4/14.8	-	23/85.2	4/14.8	-	23/85.2	9/16.4	-	46/83.6
	Duodenum	2/7.4	-	25/92.6	12/44.4	-	15/55.6	16/29.1	-	39/70.9
	Large intestine	-	-	27/100	5/18.5	-	22/81.5	2/3.6	-	53/96.4
	Small intestine	-	-	27/100	6/22.2	-	21/77.8	12/21.8	-	43/78.2
	Rectum	7/25.9	-	20/74.1	8/29.6	-	19/70.4	16/29.1	-	39/70.9
Digestive tract	Salivary glands	6/22.2	-	21/77.8	18/66.7	-	9/33.3	39/68.4	-	18/31.6
	Liver	4/14.8	-	23/85.2	7/25.9	-	20/74.1	13/22.8	-	44/77.2
	Pancreas	2/7.4	-	25/92.6	6/22.2	-	21/77.8	14/24.6	-	43/75.4
Digestion process	In mouth	4/14.8	1/3.7	22/81.5	17/63.0	-	10/37.0	31/54.4	2/3.5	24/42.1
	In stomach	8/29.6	1/3.7	18/66.7	17/63.0	4/14.8	6/22.2	23/40.4	2/3.5	32/56.1
	In duodenum	6/22.2	10/37.0	11/40.7	16/59.3	6/22.2	5/18.5	36/63.2	12/21.1	9/15.8
Absorption process	In small intestine	-	6/28.6	15/71.4	10/38.5	9/34.6	7/26.9	20/37.7	13/24.5	20/37.7
	In large intestine	1/4.8	-	20/95.2	5/19.2	2/7.7	19/73.1	13/24.5	3/5.7	37/69.8

Tentative analysis of the testing results showed that in some positions statistically significant pre-test and post-test result differences (i.e. organs of digestive system: p=0.02; digestive tract: p=0.03; absorption process: p=0,00; in the sphere digestion process pupils' knowledge also changed, though the change was not so big to consider it as statistically meaningful: p=0.05) appear because of the marked improvement of experimental group pupils' knowledge and abilities (Vilkoniene, 2008). Thorough analysis (of each step of the task) of the results which is presented here gives possibility to see which pupils' knowledge and abilities changed significantly during the experiment (see Table 5). Wilcoxon Signed Ranks Test showed that at the end of the experiment pupils in group E1 knew salivary glands, duodenum and small intestine signally better. It is worth to emphasize that during the second testing pupils of this group pointed rectum signally worse (during pre-test: knew 92.9% pupils in the group, did not know—7.1%. Vis-a-vis: the results of post-test, Table 4). The situation conspired this way can be explained so that while using ARTP in the contents of Biology lesson rectum was not being emphasized.

Whereas, the test results of the group E2, which was deepening knowledge while using computer teaching programme, significantly differ only in one position: knew salivary glands better (Table 5). Similar situation showed up while evaluating the test results of the group A: significant differences were recorded in 2 positions. Pointing salivary glands (organs of digestive system) knowledge and abilities of the last-mentioned pupils' group improved. However, pointing the stuff which is separated in duodenum (resorption process) statistically significant difference appeared due to the fact that during the second testing pupils in group A completed this task signally worse (during pre-test: knew in full—20.8% pupils in the group; knew partially—39.6%; did not know—39.6%; during post-test: knew in full—15.8%; knew partially—21.1%; did not know—63.2%).

On the ground of absolute and comparative analysis, it can be stated that in some positions statistically significant pre-test and post-test result differences appear because of the marked improvement of pupils' knowledge and abilities.

Table 5 Pupils' knowledge and abilities change after application of manipulative influence

Task	The step of the task	Wilcoxon test					
		E1		E2		A	
		Z	*p*	Z	*p*	Z	*p*
Organs of digestive system	Throat	-0.577	0.56	-0.707	0.48	-0.707	0.48
	Mouth	-1.732	0.08	-1.414	0.15	-1.069	0.28
	Salivary glands	-2.714	0.00**	-2.309	0.02*	-3.153	0.00**
	Gullet	-1.000	0.31	0.000	1.00	-0.447	0.65
	Liver	-1.000	0.31	-1.000	0.31	-1.000	0.31
	Stomach	-1.000	0.31	-1.000	0.31	0.000	1.00
	Pancreas	-0.378	0.70	-1.134	0.25	-0.832	0.40
	Duodenum	-3.317	0.00**	-0.816	0.41	-1.508	0.13
	Large intestine	-1.414	0.15	-1.414	0.15	0.000	1.00
	Small intestine	-2.236	0.02*	0.000	1.00	-1.667	0.09
	Rectum	-2.000	0.04*	0.000	1.00	-1.667	0.09
Digestive tract	Salivary glands	-2.714	0.00**	-1.265	0.20	0.000	1.00
	Liver	0.000	1.00	-0.577	0.56	-1.155	0.24
	Pancreas	-1.000	0.31	0.000	1.00	-1.213	0.22
Digestion process	In mouth	-0.702	0.48	-0.090	0.92	-1.095	0.27
	In stomach	-2.762	0.00**	-0.914	0.36	-1.402	0.16
	In duodenum	-1.344	0.17	-1.265	0.20	-2.183	0.02*
Absorption process	In small intestine	-2.179	0.02*	-0.537	0.59	-0.339	0.73
	In large intestine	-2.984	0.00**	-0.933	0.35	-1.875	0.06

Notes: *p<0.05; **p<0.01.

5. Generalization

It approves finding of the previous researches (Winter & Pemberton, 2008; Vilkoniene, et al., 2008; Vilkoniene, 2008; Balog & Pribeanu, 2007; Billinhurst, 2007) that AR technology can be effectively applied in comprehensive school. A few facts which clarified in the research let us think so:

(1) Comparing the post-test results of fulfillment of each step of the task in different groups' pairs, most of statistically significant differences were determined between E1 and the other two groups: between E1/A–in eight positions, between E1/E2–analogically. Between groups E2/A statistically significant differences were determined only in two positions (small intestines and their dislocation and segmentation process in stomach);

(2) The reason of the differences determined between groups E2/A is worse group's E2 test results. It implies that computer teaching programme used in group E2 made insignificant influence upon pupils' knowledge and abilities;

(3) Thorough analysis of absolute and relative rates of the testing results of each task step shows that fulfilling most of the tasks group E1 characterizes in better testing results;

(4) Pointing different organs of digestive system and digestive tract and their dislocation place in human organism group E1 which was using ART better knew namely these organs and glands which are not visually seen in different printed illustrations or visual aids traditionally used at schools (dummies, moulages), i.e. salivary glands, duodenum, small intestine and pancreas. Naming the organs which partake in segmentation and resorption processes group E1 showed signally better results in all the tasks;

(5) E1 was the only group in which all the pupils (100%) identified mouth as a digestive organ;

(6) Inasmuch, while using ARTP in the contents of Biology lesson rectum was not being emphasized, during the second testing pupils in the group E1 pointed *rectum* and its dislocation place signally worse.

Summarizing the presented facts, it is possible to state that:

(1) While studying human digestive system ARTP used along with the traditional verbal, material visual and printed teaching/learning aids positively influenced teaching/learning about human digestive system results;

(2) Additionally applied computer teaching program marginally influenced the changes of pupils' teaching/learning results.

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