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Towards more efficient e-learning, intelligence and adapted teaching materials

Janko Žufić *jzufic@unipu.hr*
University of Juraj Dobrila in Pula
Department of Pre-School and Primary School Teaching
I.M. Ronjgova 1, Pula, Croatia

Damir Kalpić *damir.kalpic@fer.hr*
University of Zagreb
Faculty of Electrical Engineering and Computing
Unska 3, Zagreb, Croatia

Abstract

This article presents results of a research project in which we attempted to determine the relationship between efficient e-learning and teaching materials adapted based on students' intelligence structure.

The project was conducted on approximately 500 students from 23 classes in nine elementary schools, with ten teachers of History, Informatics and several licensed psychologists. The e-teaching material in History was prepared for students in the eighth grade of elementary school.

Students were tested for their intelligence structure divided into groups in accordance with the most prominent component obtained for each of them. Each of the groups was subsequently given teaching materials adapted to their most prominent intelligence component. The results have shown that the use of the adapted teaching materials yielded better results, with improvement amounting to 6-12% compared to those obtained with e-materials not adapted to students' intelligence structure.

Keywords: adaptive teaching e-materials; structure of intelligence; more efficient e-learning, most prominent intelligence factor, 2-sigma problem

1. Introduction

While creating e-teaching materials, teachers strive to create such content that would be logical and understandable to their students. However, they often simply copy teaching materials from the existing textbooks, not taking into account the fact that e-learning is a different medium, which requires a different learning paradigm. The development of technology has led to the development of information systems for e-education, which are gradually adopting standards of pedagogy, didactics, psychology and methodology present in traditional education.

Adaptive educational systems offer an advanced form of an environment that attempts to satisfy different needs of students [9]. The system is dynamically adapting in order to create optimal conditions that will support students in learning. Rassmunsen [24] concludes that the educational system can determine student's learning habits, and that it can be adapted for more efficient teaching of a student. Colors of the text and background can either help or hinder learning and memorization [30]. Studying individual differences and styles of learning partially explains why some students are more successful than others.

Apart from learning habits, another area that needs to be studied is whether there is a need to create different teaching e-learning materials for students or student groups, and if so, based on which criteria?

Among other potential causes, intellectual abilities could be instrumental to success for students whose difference in intelligence and levels of ability are measurable [22]. However, it is problematic that even psychologists do not agree on the definition of intelligence. According to [29], intelligence is the most visible and the most relevant part of cognitive functioning, and the most important trait of a person as a whole. Gardner, who is the founder of the theory of multiple intelligences [12], [13], [14], defines intelligence as a "*biopsychological potential that can be activated in cultural surrounding for the purpose of resolving a problem or creation of a product that has value in that culture*." In some cultures, intelligence means the ability to form a logical conclusion, in others the ability to persuade, while in third the ability to listen well [4], [5], [25].

In efficient e-learning, the goal that needs to be achieved is defined by Bloom's 2-sigma problem, which motivates researchers to find a modus of teaching that will be as efficient as the tutor-style teaching. Bloom evaluated the efficiency of teaching under a traditional master learning group and a tutor system of teaching. In his research, the traditional type of learning was the least efficient, while the tutor approach to teaching was the most efficient[1] [6].

Meta-analyses so far have given some interesting results. For example, Kulik [20] analyzed results of 97 studies, and concluded that the difference between the traditional teaching and e-teaching is minimal. Most meta-analyses support the conclusions of Kulik's study [21], [28], with an exception of Fletcher's meta-analysis, which showed a higher efficiency of modern tutorial systems compared to traditional teaching [11].

While examining published research studies, we noticed that the connection between intelligence and adaptation of teaching materials in regard to the efficiency of e-learning has not been well researched. While there are many studies researching the relationship between text position on the monitor and its perception by the computer user, effects of serial positioning in visual working memory [26], position of theoretical units [18], type of information coding [7], [8], [10] and organization of material in long-term memory [3], [23], [27] no theoretical model or research has addressed the practical issue faced by e-teaching materials designers, such as whether there is a form of preparation/organization of e-teaching materials that would increase the efficiency of learning. Therefore, we conducted a research project to empirically determine the connection between e-learning efficiency and adaptive teaching materials created in accordance with student's structure of intelligence.

The goal of this study is two-fold. The first goal is to determine if there is a connection between adaptive teaching materials (created based on the structure of students' intelligence) and more efficient learning. The second goal is to determine whether there is a difference in learning efficacy using traditional learning methods and learning with the assistance of a computer.

For that purpose, we established two null-hypotheses: the initial null-hypothesis H_{0a} for the first goal is that there is no difference between learning efficacy in learning using adapted teaching materials compared to that using general, non-adapted teaching materials. The initial null-hypothesis for the second goal of our study H_{0b} is that there is no difference between learning efficacy in learning with the assistance of a computer compared to traditional learning.

2. Methodology

To achieve the stated goals of our research, we:

a) Measured the intelligence (quotient) of all the students who participated in the study, and established the dominant factor of intelligence for each student;

b) Divided students into five groups: first, the control group, which learned using traditional methods with a teacher; second, which learned using a computer and general e-materials (this group is experimental with respect to the first, and control with respect to the

[1] The difference in the final achievement, using standard deviation, was: the results of the students in the tutored group were better by 2-sigma, while those achieved by the students in the master learning group were better by 1-sigma than those by students in the traditional learning group.

third, fourth and fifth group); the third, fourth and fifth group consisted of students whose dominant factor of intelligence was verbal, non-verbal and mathematical-logical, respectively;

c) Created e-teaching materials adapted to the most prominent factor of intelligence for the third, fourth and fifth group, and general e-teaching materials for the second group;

d) Conducted teaching of the students using computers and web pages containing adapted materials for the experimental groups, or using traditional methods and a teacher for the control group;

e) Tested acquired knowledge following a learning course;

f) Performed data analyses using statistical tools in order to draw the conclusion of the study.

2.1. Participants in research project

2.1.1. Students

The study included 23 classes of eighth-grade students of elementary schools in Pula, Medulin and Pazin, with a total of 509 students. This population of students was chosen because in the Republic of Croatia, over 99% of all students attend public schools, and distribution of the intelligence quotient (IQ) is normal with median of 100. In high school or higher education institutions the distribution of IQ would be shifted to the left or right, depending on the type of school and students.

All students learn Informatics and are well-acquainted with information technology. The study was conducted at the beginning of the school year, lasted two weeks, and had an equal number of boys and girls aged approximately 14.

Students and their parents had been informed about the study, and voluntary testing of the intelligence quotient was conducted upon obtaining parents' written approval. Students who did not bring the approval to participate in the study, who were not psychologically tested, or those who did not wish to participate in learning using computers, were included in the control (*Cont*) group, which had regular classes with their History teachers.

Learning on computers was conducted during regular History classes. All the students (including those who learned with a History teacher and those who learned using computers) were told that this was a regular course, and that following the course they would take an achievement test. They were also told that the achieved grades would have the same relevance as all the other grades received in the History course. Each class had between 16 and 29 students, but the *Cont* group consisted of only five to eight students in each class. History teachers followed their standard course curriculum.

All the students in the study were learning Informatics, and were familiar with information technology since they had had a minimum of four years of Informatics at the time of the study. Furthermore, participation in the project required a very low level of computer skills (e.g. using the keyboard, mouse and monitor navigation fields). Table 1 shows the average success[2] in History and general success from the fifth to the seventh grade.

	Fifth grade	**Sixth grade**	**Seventh grade**
History	4,03	3,96	3,79
General grade point average	4,29	4,29	4,14

Table 1. Average success for the History course and general grade point average.

2.1.2. Psychologists and Teachers of History and Informatics

[2] Grades are between sufficient (2) and excellent (5). Insufficient grade (1) is a non-passing grade, and was therefore excluded from evaluation of grade averages.

Nine teachers of History and ten teachers of Informatics were involved in the study, each in their own school. Teachers of Informatics were familiar with using the system for distant learning, Moodle[3].

Five licensed psychologists employed in the schools in which the study was conducted also participated in the study. Two schools did not have their own psychologist, and testing was conducted by a psychologist from a neighboring school. All the teachers of History and Informatics, as well as the psychologists who were involved in the project received a honorarium.

2.2. Structure of intelligence and psychological testing

The authors of the project adopted the widely-accepted three-stratum theory of structure of intelligence by Carroll [29]. That theory integrates two well-tested and influential concepts of intelligence structure – Spearman's model of g-factors and Cattell's model of fluid and crystallized intelligence.

Psychologists tested verbal, non-verbal and mathematical-logical factors of intelligence. These factors are directly connected with learning. Two psychological tests were used: Non-verbal incomplete strings test [16] and Verbal test of intelligence KI-4, which contains four sub-tests, Incomplete links, Incomplete nouns, Fast calculations and Non-belonging terms.

All the tests are valid for this population, and are objective and standardized. The tests are not available to public, and subjects had no access to them prior to testing.

For the non-verbal component of intelligence, we used the Non-verbal incomplete strings test. This type of test measures fluid intelligence and determines a factor of intelligence that is independent on culture and education. The test consists of 30 problems, and is solved by circling one of the five provided answers. For each correct answer the subject receives one point, questions that are not answered receive no points, and for each incorrect answer 0.2 points are deducted from the score.

For the verbal factor of intelligence we used the Test of intellectual abilities KI-4, the sub-test Incomplete nouns, which tests subjects' vocabulary and dominantly belongs to the factor of crystallized intelligence.

For the mathematical-logical factor of intelligence, we used the sub-tests Fast calculations, Incomplete strings and Non-belonging terms. The sub-test Fast calculation demands a fast use of the four basic calculation operations and a heightened concentration. It is saturated primarily with the factor of concentration-calculation, followed by the factor of crystallized intelligence. The sub-test Non-belonging terms is a test of verbal-logical thinking, and according to the analysis, it is primarily saturated with the factor of logical thinking, and to a lesser extent with the factor of crystallized intelligence. The sub-test Incomplete strings is one of Thurston's tests, and according to Horn's factorial analysis, it is saturated primarily with the factor of logical thinking, followed by the factor of concentration-learning, and somewhat with the factor of crystallized intelligence [17].

Psychological testing was conducted by licensed psychologists, under controlled conditions and observing all the standard rules that must be present to make testing valid and objective.

2.3. Division of students into groups

The total number of students participating in the project was 509 (48.2% boys and 51.8% girls). Following the psychological testing (undertaken by 462 students, or 90.8% of all students), students were divided into three sub-groups based on testing results: the first sub-group was composed of students with the predominant *verbal* factor of intelligence (177 students, 38.3%); the second of those with the predominant *non-verbal* factor of intelligence

[3] Moodle (abbreviation for *Modular Object-Oriented Dynamic Learning Environment*) is a free and open-source e-learning software platform, also known as a Course Management System, Learning Management System, or Virtual Learning Environment (VLE).

(150 students; 32.5%); and the third with the predominant *mathematical-logical* factor of intelligence (135 students; 29.2%). From these three subgroups we formed 5 groups.

The first of them was the control group (*Cont*), which consisted of 170 students. This group was composed of students who did not participate in the psychological testing or did not wish to learn by using computers, as well as of proportional, randomly chosen subjects from the initial three groups. The control group *Cont* had learned by a traditional method of teaching with their History teacher. The main reason for the introduction of the control group *Cont* was to compare learning efficacy between students who use traditional learning methods with students who use computer-based learning. In the group using the traditional method of teaching, the teacher worked with a small group (five to eight students) and had many interactions, creating an efficient teaching modality similar to the tutoring system of teaching, while the computer-based teaching had the advantage of using teaching materials adapted to the students.

The second group, *Univ*, was composed of a proportional number of students (n=76) from the initial three psychological groups. This group was experimental (along with the third, fourth and fifth group) in regard to the first group, and control in regards to the third, fourth and fifth group. The *Univ* group was created in order to establish whether there is a difference in computer-based learning efficiency when materials are adapted to the student's most prominent factor of intelligence compared to learning efficiency when teaching materials are identical for all students (i.e., when teaching materials were not adapted to the student's factor of intelligence).

The third group, *Verb*, was composed of students with the dominant verbal factor of intelligence (n=85).

The fourth group, *NoVerb*, was composed of students with the dominant non-verbal factor of intelligence (n=81).

The fifth group, *ML*, was composed of students with the dominant mathematical-logical factor of intelligence (n=79).

In formation of the third, fourth and fifth group, we did not pay attention to the number of students in each group, but rather to the dominant factor of intelligence, which resulted in an unequal number of students in these groups.

During group formation, we did not pay attention to students' general success or specific History grades from previous years of their education. Following the formation of the groups and conclusion of the research project, average grades for History and general grade point averages for previous years of education were calculated for each group (shown in Table 2).

Subject	**Group**	**Fifth grade**		**Sixth grade**		**Seventh grade**	
		Mean	st dev	Mean	st dev	Mean	st dev
History	*Count*	3.73	1.10	3.61	1.14	3.42	1.09
	Univ	3.91	0.97	3.92	1.02	3.79	1.07
	Verb	4.30	0.95	4.33	0.88	4.11	0.97
	NoVerb	4.16	1.09	3.96	1.00	3.82	1.06
	ML	4.36	0.79	4.34	0.88	4.19	0.89
General success (grade point average)	*Count*	3.94	0.80	3.95	0.84	3.78	0.81
	Univ	4.29	0.79	4.33	0.70	4.17	0.80
	Verb	4.43	0.74	4.46	0.62	4.32	0.75
	NoVerb	4.43	0.71	4.42	0.75	4.32	0.85
	ML	4.68	0.53	4.64	0.51	4.47	0.69

Table 2. Average grades for general success and History (shown by group)

2.4. Teaching materials and their presentation

Schools in the Republic of Croatia have the right to choose which teaching materials or publishers they will use. In the schools where the project was conducted, materials used in the study were published by three different publishers (Školska knjiga, Profil and ALFA). History teachers used their standard materials, while one History teacher and one Informatics teacher

created teaching materials based on the materials that were common to all of the three publishers. The teaching unit used in the research project was *"Croatian history 1921-1928"*.

2.4.1. Preparation of teaching materials

In the preparation of the teaching materials, we paid attention to the practical recommendation presented by Gardner [13] and Armstrong [2], as well as to the contents that are adaptable for e-learning. It is important to mention that the teaching material for *each* of the groups contained *all* elements in each teaching unit.

Table 3, created based on the existing recommendations [1], [12], [13], [14], [15], [19] and on the elements the authors used in preparation of the teaching materials shows

Dominant factor of intelligence		***Verb*al**	**Mathematical-logical**	**Non-*Verb*al**
Characteristics		- efficient use of words, either verbally or in writing - rich vocabulary - expressive speech - rich linguistic expression	- logical thinking, easy observation of logical structure and relationships, as well as cause-consequence correlations - ability to categorize, classify, conclude and generalize	- correct observation of spatial relationships - feel for colors, lines and shapes - ability to visualize
Centers of interest		- reading corner - language laboratory and a corner for writing (computer, paper and pens)	- scientific center (materials for experiments)	- visual media center (computer graphics) - space for visual thinking (charts, graphs, puzzles, collections of pictures)
Learning style	**Thinking through**	- words	- deduction	- pictures
	They like…	- reading, writing, telling stories, playing word games etc.	- experimenting, asking questions, solving problems etc.	- drawing, doodling, shaping, imagining pictures
	They need…	- books, tapes, writing materials - diaries, conversations (dialogs, discussions, debates), stories and similar content	-materials for experimenting and deduction - visits to scientific museums, observatories etc.	- art, video materials, slides, creative games, puzzles, pictorials, illustrated books
Teaching strategy	**Recommendations**	- telling stories - writing a diary - writing tasks	- classification, categorization - heuristic method - scientific thinking	- visualization - use of different colors - drawing ideas - graphic symbols
	Structure of the prepared teaching materials and their presentation (percentages of the content type are approximate)	- teaching materials in essay form, with fewer pictures, schemas and additional explanations - 85% text - 1 (10%) table - 1 (5%) geographical and historical chart - structure of the text was not relevant (0 elements), low use of colors (2 colors), no graphic symbols - students had use of pen and paper	- an overview of the material with a detailed explanation of certain terms - 65% text - 8 (25%) tables - 2 (10%) geographical and historical charts - good structure (8 elements), - low use of colors (2) and graphic symbols	- A picture or a schema at the start of the teaching unit to attract attention - different colors of the text and different text size with explanations - graphic symbols - 50% text - 25 (30%) pictures, - 9 (20%) geographical and historical charts - lots of colors - 4 colors and additional accentuation of text - no attention to text structure (1-2 elements)

		E-teaching materials for the group *Univ* contained a combination of the mentioned materials, with approximately 70% text, 11 (15%) pictures, and 7 (15%) geographical and historical charts. Two colors and elements of text accentuation were used.

Table 3. Basic characteristics, interests, learning styles, teaching strategies and modes of teaching material use for a particular student group.

the basic characteristics, central interests, learning styles with structure of the teaching materials, and teaching strategies used in preparation of the teaching material for each of the factors of intelligence, i.e., group of students. Each teaching material consisted of eight teaching units and four short tests were conducted after every second teaching unit presentation. At the end of the study, the students approached a comprehensive test, which covered the entire teaching material. The students were encouraged during their learning on computers to learn until the tests were passed with at least 95% success rate. Students were able to take both short tests and the final test multiple times.

The adapted teaching materials were created in collaboration with a professor of History, and the prepared adapted teaching materials were reviewed for professional, teaching and methodological accuracy by an experienced professor of History. In her review, the professor noted that the prepared teaching materials were *"…innovative, adapted for the students' age, didactically and methodologically modern, easy to navigate even for students whose knowledge of the information technology is poor..."*

2.4.2. Web courseware tools and presentation of the teaching material

We chose the web courseware Moodle version 1.7 because it is used at the University Juraj Dobrila in Pula, which was the leader of the project, and because the program is available in Croatian, is reliable and easy to use and contains a very good statistical apparatus for follow-up of students' activity.

Moodle has multiple modes of presentation of teaching materials. We chose a form of presentation based on lessons. For needs of this project, we prepared four types of teaching materials, one for each group of students, containing the same teaching contents, but with a different form of teaching material. Each course had its own students, and each student could approach only the course for which s/he had applied.

Each lesson (Figure 1) contained four teaching units (several short texts, pictures and geographical maps). Following each unit, students were prompted to fill a questionnaire containing 5-10 questions (Figure 2). Students had the immediate feedback information related to the accuracy of their answer as soon as they provided it. In case of an incorrect answer, the student was directed to repeat the teaching unit and repeat the test. Continuation to the next teaching unit was dependent on complete accuracy of all the answers to the test. Types of questions in the questionnaire were: single choice, multiple choices, completion of a sentence by writing a year, or 1-2 missing words.

Figure 1. Screenshot of the content of a History lesson

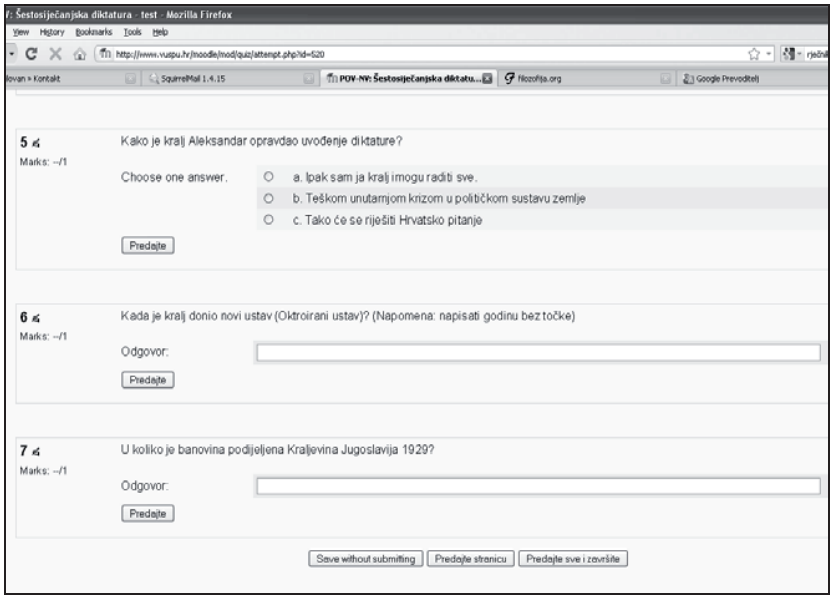


Figure 2. Screenshot of a questionnaire

The students' learning was scheduled in double periods. Following the teaching, no student group would use the teaching materials either at school or at home. None of the groups use standard teaching materials or systems for distant learning either.

2.5. Acquired knowledge testing

The final test of acquired knowledge contained 16 questions, and it was identical for all the students in all groups. The testing was conducted during a History class, following the termination of the learning process (typically after 4-6 days). The test was in a written paper form, with sufficient time to answer all the questions, and the maximum time of 30 minutes for the entire test. Six of the questions required an answer containing one or two words (question group T), another six required writing a number or a date (question group B), three questions required encircling one or more of the provided answers (question group Z), and one question required a longer written answer (question group O). The students were tested

under controlled conditions, individually, without help, notes or textbooks. Each correct answer was awarded 1 point, while incorrect answers and unanswered questions carried 0 points. The maximum number of points was 16, and each test was graded on a 1 to 5 scale of success (1 being the worst, and 5 the best).

2.6. Statistical data analyses

Initial statistical data analyses were conducted using statistical functions in the Microsoft Excel® program package. For general description analyses, we evaluated means, standard deviation of t-values with the associated probability. In certain cases the variance analyses and calculation of the Fisher F coefficient (with its associated probability) were calculated using the STATISTICA program package, version 8, in order to reach valid conclusions.

3. Results

3.1. Results of the achievement test

A total of 491 students approached the test (96.5%). Eight students (2.5%) who used computer-based learning achieved less than 12.5% of total points, and their results were excluded from the analyses due to an evident lack of interest and motivation for participation in the project. All tests were evaluated by the same person, and evaluated based on strict criteria. The complete results by group and relationship of success between groups *Univ* and *Cont* are shown in Table 4.

Type of question	Group		*Cont*	*Univ*	*Verb*	*NoVerb*	*ML*	Total
	Number of students		170	73	81	80	79	483
B Writing a date or a number [N=6]	Achieved points - $\overline{X}$		3.494	3.452	4.154	3.888	4.114	3.765
	Achieved points [%]		58.24	55.53	69.24	64.79	68.57	62.75
	Standard deviation, SD		1.967	1.720	1.555	1.613	1.481	1.744
Z Single or multiple choice [N=3]	Achieved points - $\overline{X}$		2.253	2.664	2.709	2.694	2.715	2.538
	Achieved points [%]		75.1	88.8	90.3	89.8	90.5	84.68
	SD		0.822	0.493	0.431	0.460	0.458	0.646
T Writing one or two words [N=6]	Achieved points - $\overline{X}$		3.954	4.272	4.656	4.464	4.77	4.339
	Achieved points [%]		65.9	71.2	77.6	74.4	79.5	72.31
	SD		2.020	1.720	1.512	1.532	1.368	1.744
O Descriptive answer [N=1]	Achieved points - $\overline{X}$		0.218	0.219	0.333	0.281	0.297	0.261
	Achieved points [%]		21.8	21.9	33.3	28.1	29.7	26.09
	SD		0.388	0.382	0.440	0.427	0.442	0.413
Total for all types of questions [N=16]	Achieved points - $\overline{X}$		9.16	10.61	11.84	11.33	11.90	10.90
	Achieved points [%]		57.25	66.31	74.00	70.78	74.37	68.14
	SD		4.45	3.586	3.167	3.165	3.086	3.79
	Average grade		2,59	3,07	**3,62**	3,40	**3,62**	
	SD		1,610	1,494	**1,410**	1,337	**1,352**	
	Achieved results compared to the *Univ* group	Better results by points [%]	-13.7	-	**11.59**	**6.79**	**12.16**	-
		t-value	1.170	-	**2.260**	1.387	**2.381**	-
		P	0.234	-	**0.025**	0.167	**0.0185**	-
		Fisher F-value	1.372	-	**5.109**	1.740	**5.675**	-
		P	0.243	-	**0.025**	0.189	**0.018**	-

		Better results by grade[4] [%]	-15,6	-	**17,91**	10,75	**17,92**	
		t-value	0.063	-	**0.020**	0.149	**0.018**	
	Achieved results compared to the *Cont* group	Better results by grade [%]	-	13.70	**19.34**	14.16	**19.94**	-
		t-value	-	1.170	**3.483**	**2.621**	**3.572**	
		P	-	0.243	**0.001**	**0.009**	**0.000**	
		Fisher F-value	-	1.372	**12.137**	**6.547**	**12.771**	-
		P	-	0.243	**0.001**	**0.011**	**0.000**	-
	All experimental groups [$\overline{X}$ =11,44] compared to the control *Cont* group [$\overline{X}$ =9,92]							
	Success enhanced by 15.27% t-value=2.48 [P=0.014] Fisher F-value=18.08 [P=0.000]							

Table 4. Complete results of the final achievement test by group and type of questions[5]

Table 5 presents a comparison of the test results by type of question and by group for boys and girls. Table 6 presents comparative results of the acquired knowledge between the *Univ* group, which did not use adapted teaching materials, and other experimental groups, which used the adapted teaching materials, based on the type of questions, for boys only. Table 7 presents the relationship between results and types of questions.

				***Verb* [N=81]**				***NoVerb* [N=80]**				***ML* [N=79]**			
Type of question →				T	Z	O	B	T	Z	O	B	T	Z	O	B
		$\overline{X}$		4.66	2.71	0.34	4.15	4.46	2.69	0.28	3.88	4.77	2.72	0.30	4.11
***Univ* [73]**	T	4.27	%	9.1				4.44				**11.7**			
			t	1.11	-	-	-	0.87	-	-	-	**2.29**	-	-	-
			p	.268				.386				**.024**			
	Z	2.66	%		1.91				1.12				2.26		
			t	-	0.11	-	-	-	1.36	-	-	-	1.17	-	-
			p		.916				.177				0.240		
	O	0.24	%			39.4				27.3				36.4	
			t	-	-	1.33	-	-	-	0.47	-	-	-	0.76	-
			p			.185				.642				.448	
	B	3.45	%				20.3				12.5				**19.1**
			t	-	-	-	1.71	-	-	-	1.24	-	-	-	**2.19**
			p				.090				.218				**.030**

Table 5. Results comparison by group for different types of questions[6]

	Verb [N=45]				NoVerb [N=38]				ML [N=32]			
	T [6]	Z [3]	O [1]	B [6]	T [6]	Z [3]	O [1]	B [6]	T [6]	Z [3]	O [1]	B [6]

[4] Grades were formed based on points achieved in the test: insufficient (1) between 0 and 7.5 points (<50% of the total points); sufficient (2) from 8 to 9.5 (50-62.5% of total points); good (3) from 10 to 11.5 (62.5-75% of total points); very good (4) from 12 to 13.5 (75-82.5% of total points) and excellent (5) from 14-16 points (>82.5% of the total).

[5] Statistically significant values are marked in bold.

[6] % - in the table marks the improvement of the experimental group compared to the *Univ* group for a particular type of questions.

		$\overline{X}$														
				4.12	2.49	0.33	3.66	4.55	2.88	0.33	3.84	4.61	2.63	0.33	3.85
Univ [N=27]	T [6]	3.25	%	29.5	-	-	-	**40,0**	-	-	-	**26,0**	-	-	-
			t	1.64				**2.63**				**2.47**			
			p	.106				**.011**				**.017**			
	Z [3]	2.46	%	-	1.21	-	-	-	**17.1**	-	-	-	6.91	-	-
			t		0.13				**2.54**				0.85		
			p		.899				**.014**				.399		
	O [1]	0.06	%	-	-	**450**	-	-	-	**450**	-	-	-	**450**	-
			t			**2.68**				**2.74**				**2.53**	
			p			**.009**				**.008**				**.015**	
	B [6]	2.54	%	-	-	-	**44.1**	**-**	**-**	**-**	**51.2**	**-**	**-**	**-**	**51.6**
			t				**2.23**				**2.87**				**2.70**
			p				**.029**				**.006**				**.009**
	Total [16]	8.31	t	1.93				**3.32**				**2.73**			
			p	.059				**.002**				**.009**			
				t=3.03 p=.003 ($\overline{X}$ =11.14 for groups *Verb*, *NoVerb* and *ML*)											

Table 6. Result comparison for different types of test questions by groups (boys)

				Boys															
				Univ [N=27]				*Verb* [N=45]				*NoVerb*[N=38]				*ML* [N=32]			
Type of question				T [6]	Z[3]	O[1]	B[6]	T [6]	Z[3]	O[1]	B[6]	T [6]	Z[3]	O[1]	B[6]	T [6]	Z[3]	O[1]	B[6]
		$\overline{X}$		3.25	2.46	0.06	2.54	4.12	2.49	0.33	3.66	4.55	2.88	0.33	3.84	4.61	2.63	0.33	3.85
Girls	***Univ* [N=46]**	T [6]	4.69	t	**3.11**	-	-	-	1.45	-	-	-	0.40	-	-	-	0.20	-	-	-
				p	**.003**				.150				.690				.844			
		Z [3]	2.62	t	-	0.84	-	-	-	0.76	-	-	-	**210**	-	-	-	0.01	-	-
				p		.401				.450				**.039**				.944		
		O [1]	0.35	t	-	-	**2.96**	-	-	-	0.16	-	-	-	0.17	-	-	-	0.11	-
				p			**.004**				.871				.867				.915	
		B [6]	3.88	t	-	-	-	**3.01**	-	-	-	0.54	-	-	-	0.10	-	-	-	0.07
				p				**.004**				.593				.925				.945
	***Verb* [N=36]**	T [6]	5.00	t	**3.77**	-	-	-	**2.18**	-	-	-	-	-	-	-	-	-	-	-
				p	**.000**				**.032**											
		Z [3]	2.62	t	-	0.89	-	-	-	0.76	-	-	-	-	-	-	-	-	-	-
				p		.376				.448										
		O [1]	0.35	t	-	-	**2.91**	-	-	-	0.18	-	-	-	-	-	-	-	-	-
				p			**.005**				.855									
		B [6]	4.24	t	-	-	-	**4.07**	-	-	-	1.40	-	-	-	-	-	-	-	-
				p				**.000**				.165								
	***NoVerb* [N=42]**	T [6]	4.34	t	**2.12**	-	-	-	-	-	-	-	0.52	-	-	-	-	-	-	-
				p	**.038**								.604							
		Z [3]	2.57	t	-	0.56	-	-	-	-	-	-	-	**2.52**	-	-	-	-	-	-
				p		.580								**.014**						
		O [1]	0.23	t	-	-	1.80	-	-	-	-	-	-	-	0.96	-	-	-	-	-
				p			.078								.341					
		B [6]	3.70	t	-	-	-	**2.52**	-	-	-	-	-	-	-	0.35	-	-	-	-
				p				**.014**								.729				
	***ML* [N=47]**	T [6]	4.96	t	**4.34**	-	-	-	-	-	-	-	-	-	-	-	1.07	-	-	-
				p	**.000**												.288			
		Z [3]	2.73	t	-	1.65	-	-	-	-	-	-	-	-	-	-	-	0.83	-	-
				p		.105												.409		

		O [1]	0.28	t	-	-	**2.21**	-	-	-	-	-	-	-	-	-	-	0.51	-
				p			**.031**											.609	
		B [6]	4.16	t	-	-	-	**4.03**	-	-	-	-	-	-	-	-	-	-	0.82
				p				**.000**											.418

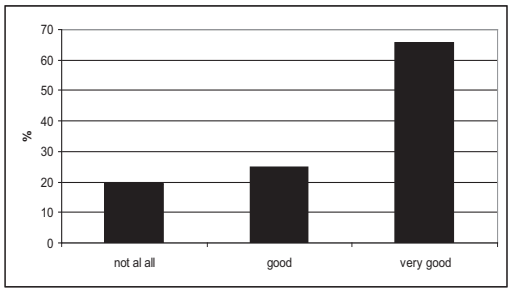
Table 7. Comparison of the results of acquired knowledge by type of question and by group for boys and girls

3.2 Feedback information received from students upon study termination

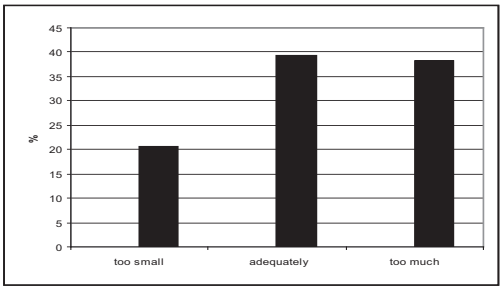
Immediately following the achievement test, students had an opportunity to provide feedback using an anonymous questionnaire in which they wrote their comments. Answers were in numerical form (from 1 to 5), with space at the end of the questionnaire for verbal comments regarding the project.

In their reply to the question "How did you like learning History using a computer?," the majority of students (65.6%) reported it was "interesting" or "super-interesting," while 19.6% of the students replied that they did not like it. In their reply to the question "How do you evaluate the quantity of the material you had to learn?," 39.2% reported it was "adequate", 20.6% said "small" or "too small," and 38.1% reported it was "large" or "too large." Regarding the final achievement test, 15.8% of the students judged that it was difficult, 43.2% that it was adequate, and 41% that it was easy. When asked "Is this type of learning appropriate for you?", 30.6% of the students replied negatively, 17.5% replied that it is adequate, and 51.6% that it is entirely appropriate for them. We also established what was particularly appealing to the students in computer-based learning. Approximately half of the students (51.5%) stated that short tests during the learning process were particularly helpful because they would receive feedback, while 42.3% of the students pointed out that they are satisfied with the use of information technology in education. Furthermore, 52.6% of the students stated that they particularly liked having short breaks after fulfilling their learning obligations. Responding to the question related to the aspects they did not like, 41.2% of the students reported that they missed having a teacher who would lead them in their learning process. In their evaluation of technical difficulties associated with the project, 85.6% of the students stated that they did not have any or only very few technical difficulties. In the last question students were asked to give an overall grade to the entire project. The majority of the students gave the project an excellent or a very good grade (61.8%), while 19.5% of the students gave it an insufficient or sufficient grade.

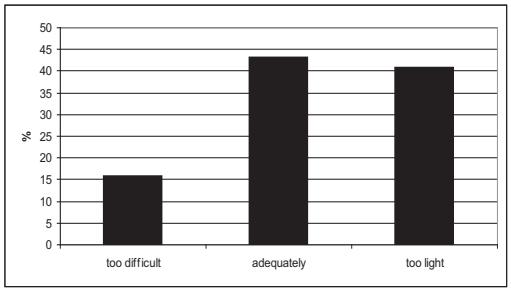
Students' comments at the end of the questionnaire expressed their satisfaction with the project as well as the wish to have similar projects in the future. In some cases the comments contained the idea of combining teaching modalities (1. Occasionally computer-based teaching, and occasionally traditional teaching; or 2. Having a portion of the same school hour with a teacher, and another portion using computer-based learning).



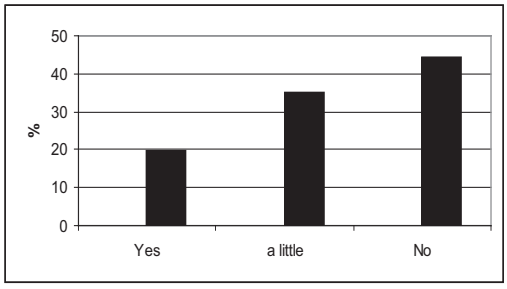
Graph 1. "How did you like learning History through computers?"



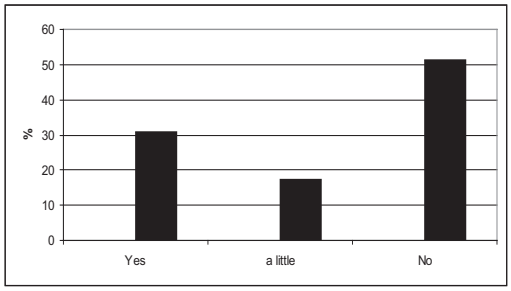
Graph 2. "How do you evaluate the quantity of material you had to learn?"



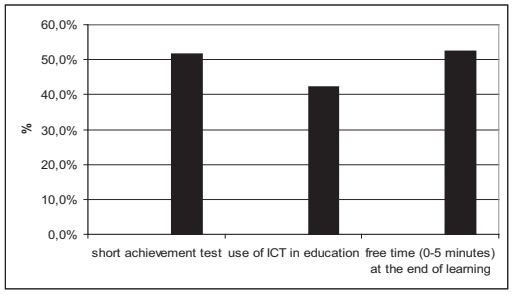
Graph 3. "How difficult was the final test?"



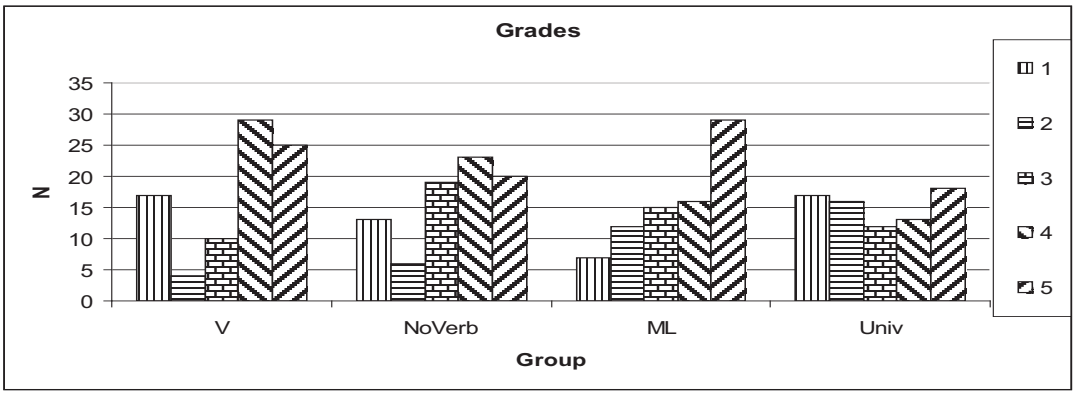
Graph 4. "Did you miss a teacher during computer-based learning?"



Graph 5. "Do you think that this form of teaching is appropriate for you?"



Graph 6. "What did you like in computer-based learning?"



Graph 7. Grades by group

3.2. Analysis of results

Analysis of success (Table 2) in students' previous years of education showed that the achieved success (in History, as well as general success) had been gradually, albeit not significantly, declining. Such results are expected, and can most likely be accounted for by a more demanding school curriculum, as well as the fact that students had entered puberty, and their interest in school had to diminished.

The basic question we attempted to answer by this research was whether the use of teaching materials adapted to the students' factors of intelligence would achieve better results in e-learning. Final results (Table 4) showed that for the groups with adapted teaching materials improvement in results amounted to 11.84% for the *Verb* and 12.16% for the *ML* groups, with a statistically significant difference ($p<0.05$ by t-test and Fisher test) compared to the control group that used teaching materials not adapted to the students' factor of intelligence (*Univ*). The *NoVerb* group had improved its results by 6.74% in regard to the control *Univ*. While comparing average grades, the difference is even more remarkable, with

the 17.9% difference in success for the *Verb* and *ML* groups, and 10.75% for the *NoVerb* group compared to the *Univ* group. The distribution of the grades is shown in Graph 7.

When the results are compared to the control group *Cont*, which had learned by using a traditional method, the difference is even larger: 18.34% for the the *Verb* group, 14.16% for the *NoVerb* group, 19.94% for *ML* and 13.70% for *Univ*. All the differences except that for the *Univ* group are statistically significant. Comparison of results between all the groups learning by means of computers and the control group *Cont* shows that the computer learning was significantly (15.72%) more efficient than the traditional form of learning.

It is evident that the difference in success between the *NoVerb* and the *Univ* groups was relatively small (6.74%). The reasons for these results are in a relatively small difference in the teaching materials between the two groups. Table 3 shows that the *NoVerb* teaching material had a total of 34 pictures and geographical charts, while in the *Univ* group there were 18 pictures and charts/maps. The number of colors in the *NoVerb* group was 4, and 2 in the *Univ* group, while other elements were similar. Therefore, similar results were not unexpected.

A comparison of average grades (calculated as noted in footnote #4 and shown in Graph 7) has shown an even larger increase in the average grades in all three groups compared to the control group (17.9% for *Verb* and *ML* groups, and 10.8% for the *NoVerb* group).

Our initial null-hypothesis H_{0a}, which states that there is no statistically significant difference in learning efficacy between adapted and general teaching materials, is therefore rejected for the groups *ML* and *Verb* at the level of significance $p<0.05$, while it is accepted for the *NoVerb* group. Therefore, we conclude that there is a statistically significant difference in learning efficacy when using adapted teaching materials in comparison with the non-adapted teaching materials.

The second goal of our study was to determine whether there is a difference in learning efficacy between traditional learning modalities and computer-based learning. We compared the achieved results in experimental groups (computer-based learning) compared to the control *Cont* group, which learned using traditional modality (Table 4). The observed differences were even greater than when comparing adapted to non-adapted materials. The differences in results with resepect to the control group *Cont* were 19.3% for the *Verb* group, 14.2% for *NoVerb*, 19.9% for *ML* and 13.7% for the *Univ* group. All the differences except the results for the *Univ* group are statistically significant ($p<0.05$ by t-test and Fisher test). A comparison of the combined results achieved by the experimental groups regarding the control group *Cont* indicates a 15.7% higher efficiency of learning in computer-based learning ($p<0.05$).

Therefore, the second null-hypothesis H_{0b}, which states that there is no statistical difference in learning efficacy between students using traditional learning methods and those who used computer-based learning, is rejected at the level of significance $p<0.05$, and we conclude that there is a statistically significant difference in learning efficacy between traditional and computer-based learning.

The analyses results of the groups with the adapted teaching materials and the *Univ* group by the type of questions reveals that the groups with the adapted teaching materials had generally better results, from a modest 1.12% for the choice-type questions in the *NoVerb* group, to a significant 39.4% for descriptive questions in the *Verb* group, although only two of the achieved values were statistically significant ($p<0.05$; T and B type of questions in the *ML* group).

The final testing was conducted using identical types of questions as those used during tests following each teaching unit, with an addition of a descriptive question. The authors considered preparation of special parallel questions, different for each of the groups. However, due to the concerns that this type of questions would lead to testing under different conditions, the authors abandoned this idea. Therefore, the questions were identical for all students who participated in the project.

Although learning efficiency by students' gender was not the focus of the research, Table 7 indicates that there are differences in learning efficiency by gender. The analysis shows that girls had generally better test results than boys, and the difference is often statistically

significant. Better results for girls are noticeable when the results for girls in all four experimental groups, and in three types of questions (T, O and B) are compared with the results for the boys in the *Univ* group (non-adapted teaching materials). Other comparisons showed no statistically significant differences. The reason for these results could be in the well-known fact that girls mature earlier (physically and cognitively), and tend to be more careful and more responsible in comparison with boys of the same chronological age. As a result, they are likely to be more learning-oriented, and did not use the learning-allotted time for unauthorized surfing over the Internet. This area requires additional research, and if the achieved results confirm our observations, then girls in particular should be encouraged to use computer-based learning.

The comparison among girls in different groups showed no significant differences, but Table 6 suggests that there is a significant difference among boys in nearly all segments. We observed that boys who used the adapted teaching materials achieved better results, and out of possible 12 categories, nine were statistically significant. The results achieved among boys placed in different groups show that the adaptation of teaching materials leads to better results.

In terms of different types of questions in the test, Table 4 shows differences in the percent of the achieved points. The lowest number of points was achieved in questions requiring descriptive answer (average of 26.9% of total available points for the question), a higher number of points (62.8%) for questions requiring insertion of a number or a date, an even higher number of points (72.3%) for questions requiring insertion of one or two words, while the highest number of points (84.7%) was achieved in single- or multiple-choice questions. These results were expected, and should be taken into account in the design of teaching materials. According to the results shown in Table 5, there are no statistically significant differences between the groups with adapted vs. non-adapted teaching materials in terms of the types of questions in the test, with the exception of T and B types of questions for the *ML* group.

It is important to mention some elements that may have influenced the achieved results. Given the fact that teaching was conducted simultaneously in 23 classes during the same week, the project leader could not be present in all the teaching locations. Testing was conducted by History teachers. It is uncertain how motivated the students were to write the test to the best of their abilities. However, the authors believe that potentially poorer results did not influence the relationship between groups, but only the average success in the entire population.

The survey conducted at the end of the project gave some interesting insights. The amount of teaching materials had been well chosen. The final test may not have been sufficiently difficult, although that was expected since the students would take tests with feedback throughout the learning process. One third (30.6%) of the students reported that computer-based learning was not appropriate for them. This percentage is not too high, and may arise from the fact that this was the students' first encounter with this form of learning. The greatest deficiency of this type of learning for this age group was the lack of a teacher with whom they could interact in real time. That is also the greatest deficiency in online learning in general, and many researchers and authors recommend mixed modalities, or an introductory "face-to-face" workshop during in which students will be introduced to online learning. The students particularly liked two things: a) short tests with feedback throughout the learning process; and b) the fact they were free to use the last few minutes as they wished if they successfully learned the teaching materials and passed all of the short tests. Instructions also had a highly motivating effect on the students, and should be taken into account during preparation/design of the e-teaching materials. The final evaluation given by the students was above average: 61.8% of all the students evaluated it as excellent or very good, while only 19.8% gave it an insufficient or sufficient grade.

4. Conclusions and suggestions for future research

In this research project we attempted to answer the question whether there is a difference in the efficacy of the e-learning if the teaching materials are adapted to the students' most prominent factor of intelligence.

We found that the results among students who learned over the computer with adapted teaching materials were better than the results of the students who did not use adapted teaching materials.

Furthermore, it was noted that the difference in results is particularly noticeable among boys, while among girls the difference was much smaller. However, girls generally achieved better results than boys.

The authors consider that future research should determine the elements and the rules (such as the number of pictorial and graphic elements, the ratio between text and visual elements, the number of colors, and the position of text) that would contribute to achievement of better results among students using adapted teaching materials.

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