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Analyzing the Impact of Using Interactive Animations in Teaching

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Abstract: This study intends to measure the impact of interactive animations on the students' performance. Two courses from Subotica Tech were included, the subjects "Analog and Digital Electronics" and "Microcontrollers". The experiment lasted over a period of tree years, and it involved the formation of two groups in every academic. Both groups' members participated in traditional frontal teaching, but the experimental group could use interactive Flash animations built from selected parts of those courses as supplementary tool. At the end of the semester, the exam marks were analyzed with a Two-Sample T-Test. The results show that learning with properly created interactive animations could have positive effects on most students' academic performance.
Keywords: distance education and telelearning, improving classroom teaching, interactive learning environments, simulations, media in education.

1 Introduction

In the era of modernization in the teaching process, when the use of novel information technologies aims to achieve easier, faster and more efficient knowledge transfer in education, the application of interactive animations has become more and more important. The questions arises as to what the reasons are which have made interactive animations a vital part of modern e-curricula, and whether there is empirical evidence to support claims that using multimedia and interactivity in e-curriculum has positive impact to cognitive development and academic achievement at students. In the first part of this paper, authors analyze characteristics of the interactive animations. The second part presents some research done with interactive animations developed at Subotica Tech. The e-contents are compiled from selected parts of the course "Analog and Digital Electronics" and "Microcontrollers" at Subotica Tech.

The thorough investigation by Sekular and Blake [1] into how students take in information, how they learn pointed out that the learning process takes place primarily by way of sight, and since it is the most vital of our senses, it is also the most highly-developed one. It enables a person to gather information from one's surroundings, analyze these and then decide how to process based on the deduced data. In terms of teaching, it is by seeing that students will best grasp a complicated string of steps as it helps transform a vague idea into an image in their brains.

Kraidy [2] started that, if the aim is to increase the amount of information to be processed by students within a set time frame, then giving them visual information to work with will help them reach this goal.

Graphical representations are defined as visual aids that act as supplement to any other textual information and will concentrate learners' attention [3]. Such representations will have maximum effect when accompanying some learning material that is (relatively) new to the learner [4]. This is especially the case with computer animation that is designed to aid long-term learning in the form of focusing learners on certain objects in the beginning.

The research of Rieber [5] portrayed that abstractions connected with time transitions in a process can be decreased by implementing animations to convey ideas and processes that change over time. Dual-coding theory by Paivio, [6] [7] offers an explanation as to why graphics are so effective: retaining memory over a long time is made easier if a combination of verbal and visual cues is used. This makes animations a distinctively significant support of visualizing material for long-term memorization. Animation and narration further support dual-coding [8].

What makes animations stand out is movement, as opposed to static, still images, and this demonstrates the various relationships within and along a certain process. By Goldstein, Chance, Hoisington and Buescher [9] movement will be remembered longer than static images. According to Gordin and Pea [10] and also Brodie, Carpenter, Earnshaw, Gallop, Hubbold, Mumford, Osland, Quarendon [11] visualization is a vital part in the acquisition of scientific topics, since important relationships between concepts will be pointed out for learners.

It was demonstrated by research results that animations are more effective learning tools that static images, and this was further supported by lesson plans incorporating lectures as well as different learning inputs [12]. Based on the dual-coding theory [7] it may be asserted that learning will be the most effective if there are lectures alongside animations, since they together form a base of reference that will help learners fully understand the knowledge that was conveyed through the animations. Lectures will cue the students, but actual studying happens through the animations [13].

2 Interactive Animations

One of the tendencies in education is the continually growing amount of learning content which must be acquired by the student. Almost every generation's curricula are extended by a certain amount of new, updated or revised material. With this swelling of learning contents, another issue arises, namely that the time which is intended for learning these amount of contents is growing ever shorter for each subsequent generation. Besides that, students are no longer interested in the foundations of some complex system, and how it is compiled, but rather, they want to know how the system works and how it can be managed. In accordance with these tendencies the educators have been searching for learning tools which can help the students acquire knowledge.

As animation are able to unambiguously portray changes over time (temporal changes), they are extremely suitable for using them in process and procedure teaching. Animations are applied to show dynamic content, and they reflect alterations in position (translation), as well as form (transformation) which form the basis of learning this kind of topic [14].

Unlike static pictures, temporal changes are shown in animations directly (instead of indirectly by some awkward auxiliary markings including arrows and motion lines). The application of animations, as opposed to static graphics, makes these extra markings unnecessary, thus stripping down the displays and making them attractive, lively and easily understandable [15]. Furthermore, there is no need for the learner to process these auxiliary markings and what changes they try indicate. Interpreting the markings and the inferences may actually surpass the level of graphical skills that the learner possesses. Yet with animations, these displays immediately show all information concerning the changes, thus no extra mental depiction is required.

Learning can be facilitated by animations in two ways. On the one hand, their function is to affect the learner, raise their interest and keep up motivation. The entertainment industry implements this same function in their animations. On the other hand, though, animations also have the function to facilitate comprehension and memorization of a given content. The knowledge-building process is thus supported and this cognitive function is essential to effective learning.

Superficially, it may seem that animations are the perfect candidates to be applied in presenting dynamic content. Nevertheless, there is no unambiguous research evidence supporting this. Some researchers have conducted comparisons of how effective static and animated displays are in education by using a number of content domains. Although there have been positive results where animations have proven to be rather effective, these results have been countered by other investigations that have found no positive, and even negative effects of using animations. On the whole it is safe to say that animations are not by definition more effective than static graphics. Instead, the specific features of certain animations and their method of application is crucial in what kind of effect they will have on knowledge acquisition.

2.1 Do Animations Make Learning Faster?

Animations play an important role in computer-based learning environments. So far, however, it has not been sufficiently resolved under which conditions and in which respect animations do actually lead to better learning outcome. Well-designed animations are likely to be a real asset to the teacher. They will speed up the learning process and make it easier to grasp and memorize the material. It especially comes in handy when the teacher is trying to explain a difficult subject. The question arises: Why is a subject perceived as difficult? It may either be because it requires a certain amount of imagination. For example, in our animations we visualized a clock signals, a values and shapes of the input and output voltage signals, a states and changes of the microcontroller internal registers etc. With the help of computer animations both the teaching and learning process will be made less difficult, it will take less time and it will be livelier.

However, what then explains the fact that sometimes animations are not educationally effective as one would expect them to be? A possible answer would be that students are unable to "compute" the information seen in the animation adequately. If a complex subject is to be presented with animation, it may result in an equally complex animation, thus leaving students feeling overwhelmed. This is supported by the role of visual perception and cognition in human information processing. The perceptual and cognitive systems of humans have their limits for information processing. Once the presented animation reaches or oversteps the learners' information processing limits, the learning process may no longer be effective. Also negative effects come forward if the new information being presented in animations is faster than the speed of how fast the learner is capable of processing that effectively.

Replacing current static graphics with animations without careful consideration is not likely to result in improved learning; instead animations should be accompanied by textual explanations, and let the learner have control over the speed of the animation. Such user-controllable animations will enable learners to "customize" the animations by varying the playing speed and direction, labels and audio commentary to suit their own personality. The controllable animation can be realized with interactive animation. The interactivity within the animation could mean the own playing speed and walk-through, different amount of auxiliary explanations etc.

Besides the visualization of the curriculum, this kind of animation offers another advantage: the possibility of modeling and simulating systems. This means that knowledge acquisition can take place also by changing the model's parameters, or otherwise experimenting with the system. So, when using interactive simulations besides the previously mentioned advantages, some new ones can be defined:

- The model offers the possibility for analyzing and doing experiments with those systems, which cannot be done in real life.
- The models enables studying of certain fast occurrences in a much slower mode, or time-consuming events in a much shorter time span than in reality.
- The model makes it possible to focus on the vital characteristics of the learning content being taught.
- The model offers the users the freedom of experimentation without any consequences.

2.2 The Advantages of Flash Animations

The developing environment provided by the packet Adobe Flash CS3 (and its prior versions) was used by the authors as the tool of choice for creating these interactive animations. In a simplified form, this software tool is an application for creating vector sketches and animation, with the option of adding this interactive feature. Naturally, the Flash developing environment offers many more options, but it also includes very straight-forward ways of creating animations. The fact that it is rather easy to create interactive animations is a crucial aspect, as in such a case it is not a pre-requisite for the subject teacher to be highly educated in information technologies. This type of animation can be used for presenting the material in theoretical classes, but also for creating a fully electronic curriculum for consolidating the material previously taught in practices, as well as for independent work outside the classes.

Practice shows that creating effective interactive animations still requires the close cooperation of the teacher and the expert for Flash technologies. Successful acceptance of the animations by the students primarily depends on the course teacher. It is their task to determine the following:

- Goals that are to be achieved with this animation,
- The content that is to be shown,
- Which elements of the learning material are to be represented statically (with an image), and which will take the forms of animation or interactive animation (simulation),
- Guidelines (design of the outlook, which controls are to be used, the user's options within the system, etc.) based on which the application will be developed.

The task of the "Flash expert" is to realize the requirements of the teacher as best as possible. The programmability of the animation thus comes in really handy for the expert. When developing the Flash application of the programs that may be used is Action Script (the current version is 4), an object-oriented programming language. With the help of this language every element of the animation (lines, colors, sound, etc.) can be controlled, calculations can be made using the entered parameters, and finally, the results can be presented, and actually used to draw new objects or their trajectories, as well as communicate with the server, among others.

It is safe to say there is no such task in creating an animation that an experienced Flash programmer cannot solve. In fact, this is the real advantage of this tool, as it can meet all the requirements irrespective of school age or learning material. Besides the listed advantages of a Flash animation, it is also rather easy to distribute this application. There are two most commonly used formats for saving this animations: the executive (*.EXE) format, which starts in its in-built player; and the standard (*.SWF) format for playing in a web browser or in the FlashPlayer player (it can be downloaded easily from the Internet). What is characteristic of these two formats is the small file size, which is a vital factor when distributing the application via the Internet. Another benefit of the Flash animation is that it is a single file, there are no separate sound files, and the images do not comprise a separate module. All this ensures that there is no special installation procedure, only the file to be saved and started, which makes it an accessible program for even the somewhat computer-wary users.

Besides the so-called technical advantages, with the use of adequate design techniques, the Flash-type animation could gain further benefits. One of those benefits is the result of how a Flash animation is developed: most often the parts of a Flash animation are drawn, and there is little use of images from the real world. The advantage of drawing, i.e. of creating vector objects for animation is that the drawn objects are represented in a simpler form, with less detail than, for example, if they were shown in a bitmap format. This means once the educator has abstracted the material for the students there is yet another simplification of the learning material. But there are other design techniques which could lead to more effective learning process, for example:

- Using the "Inserting and removing fragments" technique. The complexity and information load of the animation interface can be regulated by inserting or removing objects or pieces of information form it.
- Using the "Dimming fragments" technique. With this technique one can differentiate between important parts of the animation and those which serve as additional information. The dimmed elements look like as if they are melting into the background.
- Using background (blurred) animation to attract and keep user's attention on the interface.

Also, in these projects the following design aspects were used:

- Minimize the number of visual elements, thus making it easy to follow the presented process.
- Minimal amount of lateral information used solely for presenting the essence as simply as possible.
- " Data entry by keyboard was not incorporated. The reason for this is that the data entry option does not always mean an advantage in the learning process: they may cause the user to be preoccupied with trying to crash the application by entering invalid formats and values.

As a result of these design techniques, the system will show a straight-forward form, using only the vital details, leading directly to a better and easier understanding of the model, and the user cognitive load is kept on adequate (i.e. low) level.

Are these the only reasons why the animation should be used in teaching? No, they are not. There are problems which occur in educational communication called information barriers, and the Flash animation will yield some solutions to this problem. Some of these barriers can be classified in the following way:

- perceptual barriers – each subject in the communication process feels and interprets events occurring to them differently, depending on their psychological, cultural and social status,

- psychological barriers – the same word or event will have a different meaning for different persons,
- social barriers – these barriers become apparent by the different social statuses of the subjects in the educational communication,
- cultural barriers – these arise in communication due to the different cultural backgrounds of the subjects participating in the communication process,
- semantic barriers – barriers of this type appear when interpreting written contents, speeches, images, and other, thus the way the message is read will change the content itself,
- media barriers – this information barrier occurs when the there are different communication media used on educational communication. It is well-known fact that each carrier has their own markings, which may be helpful as well as distracting in communication,
- physical barriers - informational barriers come up in educational communication when transferring the message, i.e. in the channels of connection.

How and where do information barriers occur when there are PCs used in the teaching process? Some of possible sources of problems are described below:

- experience shows that old programs which exclusively use the keyboard for interaction will be accepted to a lesser extent due to the fact that using the keyboard is more complicated than using the mouse,
- programs (simulations) designed using too much detail will be harder to accept because first the users have to make out what is on the screen and only then move on to the explanation of the modeling system,
- if there are too many options for simulation set up, result saving, parameter input, etc, where the users might 'become disoriented', then, according to Murphy 's Law, they probably will.

3 Practical Applications

The following section describes interactive animations which have been successfully in use as an auxiliary teaching tool at Subotica Tech - College of Applied Sciences [16]. Unfortunately, the advantages of the animations as described before are difficult to transfer to paper only with the help of images. The applications have been designed as interactive tutorials for presenting the functioning of some of the basic systems of analogue and digital electronics (Figure 1.) and microcontrollers (Figure 9. and 10.). For the Microcontrollers course two e-contents (interactive Flash simulation) were developed. They presents exercises for three out of fourteen lessons, but these three lessons count as "difficult", for example they cover the following themes: using the microcontrollers built in timer/counter in different modes, setting and using interrupts, communication through serial port, controlling analog to digital signal (and vice versa) conversion etc. The e-content for the Analogue and Digital Electronics there are altogether 19 simulations classified into 5 groups/exercises. Through these simulations the students can practice approximately about 40% of curriculum's theory. For example, "Exercise 1" contains simulations on the topics: Sources of alternating signals, Voltage splitter, Passive voltage adder, RC low-pass filter, RC high-pass filter. Figure 1. shows the screenshot of Exercise 3 and the accompanying simulation entitled "Pojačavač sa zajedničkim" (Common emitter amplifier). The design of the

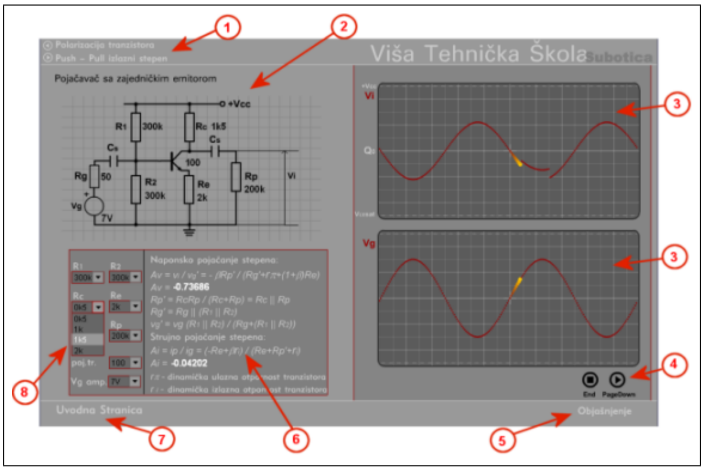

Figure 1: Representation of the exercise "Common emitter amplifier"

application shown in this image is followed through in the rest of the simulations, as well: the upper left corner contains the sketch of the system, below are the system parameters which can be altered in the simulation, while the "oscilloscope" is situated in the right side of the screen, showing the change of the signal over time. In this part of the application, by clicking on the link labeled "Objašnjenje" (Explanation) the theoretical background comes up in text form.

Below is a detailed description of the content and functions of the elements on the screen:

1. Links for transition to the next/other simulation within this exercise.
2. Sketch to be simulated. The parameters listed next to the components are changing depending on values of the checkboxes under the sketch.
3. Representation of the shape of voltage signal at the input and output. Part of the image marked with the arrow 3 shows the shape of output voltage, while the one marked 4 shows the input voltage. These shapes of signals are constantly redrawn. The lighter point on the line shows the current voltage value. The break in the line is the consequence of the change in RC components on the sketch during the simulation.
4. Buttons for starting and stopping the simulation.
5. The button for calling up the background explanation for how the sketch functions.
6. The list of equations used for calculating the necessary parameters of the sketch and the results of the calculation/estimation.
7. The return button leading to the introductory page where the exercises can be chosen.
8. Values of the sketch components. These parameters can be changed by choosing values from the checkboxes. Each change has affects the listing of calculated values based on the new parameters and the change of signal shape at the output ("upper canal of the oscilloscope").

The following image (Figure 2) shows the simulation "Decade counter" with the help of which students can learn the logic of the synchronous counter.

All simulations in this application are entirely controlled by mouse. Changing the parameters is done with the help of combo boxes and the predefined values they contain. In this way the

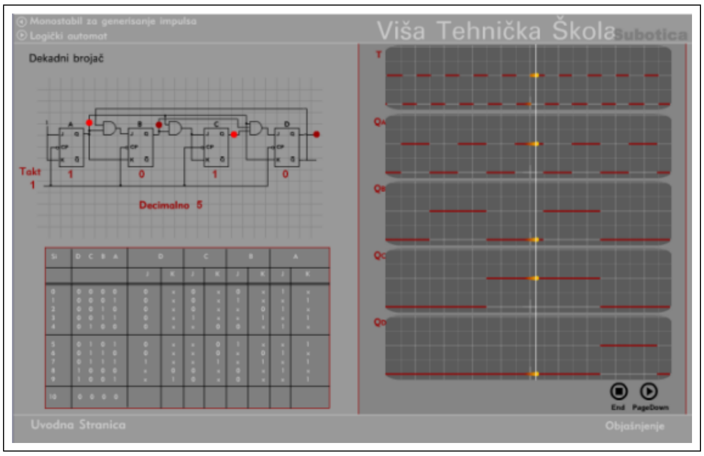

Figure 2: Representation of the exercise “Decade counter”

application is protected from irregular data. It is important to mention the following advantages of these simulations:

- it is not necessary to really ‘create’ an electric circuit in order to see how it works,
- changing the components in the system only takes a few clicks in the checkbox,
- it is possible to show the state of important values in continuity, as done by an oscilloscope.

The following few paragraphs present some ActionScript (version 2) programming code, which shows how one can input data from the combo box, calculate the output voltage, and draw the form of voltage signal like it is done on a real oscilloscope. The combo box is presented as an object on the main animation scene. The next figure shows a combo box, which is used for input of predefined resistor values:

Figure 3: Input option via combo box

The following code was attached to the combo box:

```
_root.shema.r11 = r1.getSelectedItem().label;
_root.shema.r1 = r1.getSelectedItem().data;
```

Figure 4: Source code for combo box’s onClipEvent event

When the user selects a value from the "r" combo box’s list, the code is executed . The first line of the code assigns the currently selected item’s label (currently it is a "50k" string) to the ’r1’ variable. The ’r1’ variable is the label in the scheme (see Figure 5, dashed line rectangle, right from the R resistor). So changes in the values in the combo box are displayed also on the scheme. The second line of the code assigns the value (numerical value: 50000) associated with the item currently selected ("50k" string) to the "r" variable. The scheme has its own action script code, which uses the "r" variable for calculating the new output value of the voltage. Because this code changes several global variables, other movie clips on the scene which also use those variables are affected with it. In this way, for example the changes in the resistor value

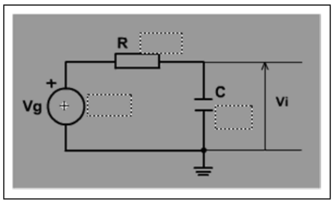

Figure 5: Scheme of the RC low–pass filter

```
_root.bode.lin1._y = 105;
_root.bode.lin1._x = 40*Math.LOG10E*Math.log ((1/r) * (1/c));
_root.bode.w0._y = 100;
_root.bode.w0._x = 40*Math.LOG10E*Math.log(_root.shema.vg);
tacX = 40*Math.LOG10E*Math.log(_root.shema.vg);
tacX1 = 40*Math.LOG10E*Math.log ((1/r) * (1/c));
razlika = (tacX1 - tacX);
if (razlika > 0) slabljenje = Math.exp(razlika/40);
else     slabljenje = 1;
if (_root.shema.vg == 1000)      f = 400;
if (_root.shema.vg == 10000)     f = 40;
s = 90/slabljenje;
w = (Math.PI/2)-(f/(4*Math.PI)*Math.atan(1/(2*Math.PI*f*r*c)));
y1 = 100-_root.sinus(s,f,-w,i);
struja = 100 - _root.sinus(90,f,0,i);
i = i+2;
if (i >= 400) i = 0;
```

Figure 6: Source code attached to the RC low–pass filter schema

affects the movie clip which represents the oscilloscope function, and the new form of the output signal is displayed. Drawing the form of voltage signal on the oscilloscope is done by moving a special movie clip on the coordinates which are determined in the code above. In the movie clip which presents the current output value one yellow circle changes to a smaller and orange colored circle. This animation of the movie clip with 4 picture out of 10 is presented in Figure 7. When drawing the output signal this movie clip is moving on the screen, and with its own

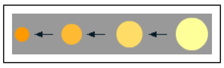

Figure 7: Movie clip of the oscilloscope drawing beam

animation the effect preented on the Figure 8 is achieved. Figure 9 shows one of a series of seven interactive simulations that are part of the e-curriculum which had been developed for the Microcontrollers course. The simulations present the i8051 microcontroller's timer/counter hardware, the setting and use of interrupts, and the application of the special forms of the ADD and MOV instructions.

Figure 10 presents one of the four interactive simulations created specifically for the Microcontrollers course. The simulations refer to the practical use of the i8051 microcontroller.

4 Experiments and Analysis

For the purpose of this study the following research questions were specified: what is the impact of interactivity of the animations on learning? The null hypothesis is defined as follows:

Interactive animations have no significant positive impacts on studying "Microcontroller" and "Analog and Digital Electronics" courses.

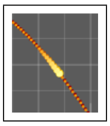

Figure 8: Appearance of the drawing beam in the oscilloscope movie clip

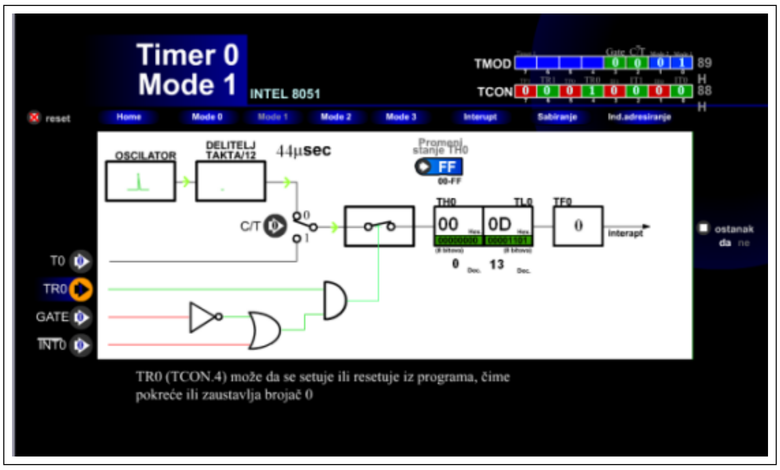

Figure 9: Representation of the exercise "Timer0 in mode 1"

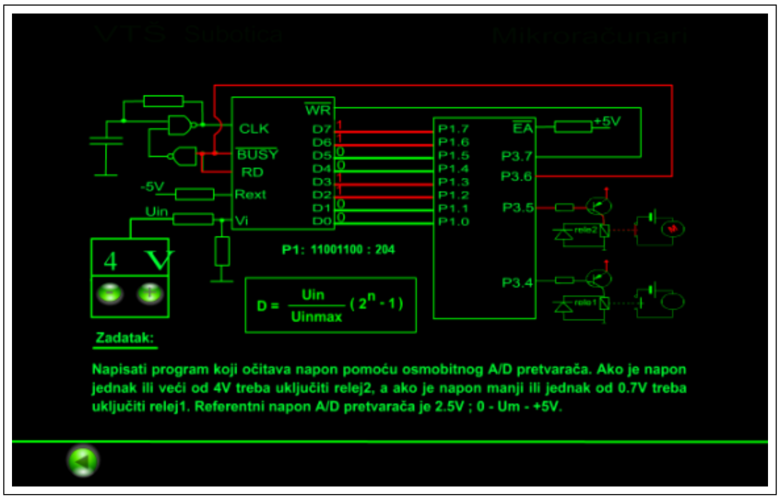

Figure 10: Representation of the exercise "Microcontroller with A/D"

In order to obtain answers to the research questions, the authors compared the final exam score standard deviation at "Analog and Digital Electronics" and "Microcontrollers" courses independently, where the animations were used as supplementary tools for learning and practicing after class.

4.1 Participants and Data Collecting Method

The data acquisition was done at Subotica Tech - College of Applied Sciences over a three-year period. It involved the second year students from two undergraduate programs the Electrotechnical Engineering major (EE) where these two courses were obligatory and the Computer Science major (CS) where these courses were optional. The number of participants for the first course (Analog and Digital Electronics) over the period of 3 years is 441 students, 56 female (12.7%) and 385 male (87.3%) students. The second course's participants (Microcontrollers) were the same students from EE major, and from the CS major there were some old students and some new ones (those who did not select the first course). The composition of this group was: 464 participants, 58 females (12.5%) and 406 males (87.5%) See Table 1. Most participants, 98.5%, were between 18 and 20 years old; the remaining percentage is represented by a few students whose age were between 20 and 30. In these 3 years at the beginning of the semesters (the first course was in the fall and the second in the spring semester), the students were divided in two equal-sized groups, the control and the experimental group. The group members were chosen randomly, and only one condition had to be satisfied for the experimental group members: to have possibility of accessing the web application and the simulations from home. If this condition was not satisfied, that student automatically becomes the member of control group.

After forming the groups accessing the web application was enabled only for the experimental group. There was no additional motivation for the students. All participants visited face to face (f2f) classes of these two courses, which were taught by the same lecturer presenting identical material. This further strengthens the consistency of comparisons.

The web application collected the following data from the users:

1. How many time did he/she logged on to the system to use the e-content,

2. How many time did he/she spent using the particular simulation.

Students who logged on only few times and spent less time that the authors foresaw are assumed to be not using the system in an adequate mode, and they are not taken as members of the experimental group, so they were transferred to the control group (for details see Table 1). Ineligibility meant that the number of loggings is less than half of the available exercises, and the time spent in the system is less than 2 minutes per exercise

The authors took as null hypothesis that the two groups would have the same mark average at both courses. The alternative hypothesis claims that the control group will achieve better result at both courses. The data was analyzed with one-sided, t-test, assuming that the variances of the two samples are different. Because one course was in the fall semester and the second one in the spring semester, the analysis was done twice a year at the end of the semesters and independently for both courses.

Courses	2007 school year		2008 school year		2009 school year	
	Experiment. group	Control group	Experiment. group	Control group	Experiment. group	Control group
Analog&Digital Electronics	61	83	72	80	69	76
Microelectronics	75	86	74	81	73	75

Table 1 –The number of participants in the groups

4.2 Student Survey

At the end of each semester and before the final exam, the control group members were asked to fill out a questionnaire with 5 questions. From the answers (marks from 1 to 5 and comments) the authors received feedback about generally how students were satisfied with simulation, how did it help or not in the learning process and what would they like to see done in a different way. These data were collected in order to perform further improvement of the teaching materials in the way that would lead to a widely accepted e-curriculum.

5 Results and Discussion

The t-test applied to our two sample groups (main and control group) allows us to compare the means of the final exam marks of both groups. The following table presents these values.

	2007 Microcontrollers course					
	n	SS	Mean	MeanE-MeanC	df	t_{obs}
Experimental group	75	121.9467	7.973	0.438	159	2.16
Controll group	86	139.3953	7.534			

	2008 Microcontrollers course					
	n	SS	Mean	MeanE-MeanC	df	t_{obs}
Experimental group	71	105.098	7.887	0.420	144	2.06
Controll group	75	110.666	7.466			

	2009 Microcontrollers course					
	n	SS	Mean	MeanE-MeanC	df	t_{obs}
Experimental group	73	99.780	8.054	0.375	146	1.93
Controll group	75	104.32	7.680			

	2007 Analog and Digital Electronics course					
	n	SS	Mean	MeanE-MeanC	df	t_{obs}
Experimental group	61	57.147	8.540	0.457	142	2.48
Controll group	83	124.409	8.084			

	2008 Analog and Digital Electronics course					
	n	SS	Mean	MeanE-MeanC	df	t_{obs}
Experimental group	72	110.611	8.139	0.451	150	2.18
Controll group	80	135.187	7.687			

	2009 Analog and Digital Electronics course					
	n	SS	Mean	MeanE-MeanC	df	t_{obs}
Experimental group	69	104.289	8.232	0.403	143	1.97
Controll group	76	110.776	7.829			

Table 2 – Students' score distribution

Where the notations in the table are:

- n - number of participants,
- SS - sum of squared deviates,
- MeanE/MeanC - mean for of experimental/controll group,
- df - degrees of freedom,
- t_{obs}- observed values of t-distribution.

6 Conclusions and Future Works

The authors compared the observed value of t with the t from the table of critical values that pertain to $df > 140$, and the results are shown in Table 3:

Courses	Significance of the Difference between the Variances of the Two Samples	
M2007	$t_{95\%} < t_{obs} < t_{99\%}$	1.98<2.16<2.61
M2008	$t_{95\%} < t_{obs} < t_{99\%}$	1.98<2.06<2.61
M2009	$t_{obs} < t_{95\%}$	1.93<1.98
AD2007	$t_{95\%} < t_{obs} < t_{99\%}$	1.98<2.48<2.61
AD2008	$t_{95\%} < t_{obs} < t_{99\%}$	1.98<2.18<2.61
AD2009	$t_{obs} < t_{99\%}$	1.97<1.98

Table 3 – Significance differences between two groups

From the presented data, the following conclusions can be drawn:

- In 4 cases out of 6 we can reject the null hypothesis, and we can say with probability of 95%, that those experimental groups achieved better results on exam than the control groups.
- In two cases there are no reasons to reject the null hypothesis.

The results show evidence that interactive simulation contents can be very effective tools in the learning process. It can deliver information in a very attractive way, which also can be advantageous in assembling curricula for the students who have different skill levels and learning styles. Besides that, it can help learners to understand scientific topics, with presenting important conceptual relationships. It is also important that simulations enable students to become acquainted with the shown system and make changes in the parameters with no additional costs or risks.

But only well-designed animations may help to ease and shorten the learning process, and only with them, through play and experimentation can the learning process become more interesting [17] [18]. The students' answers from the questionnaires show that not every simulation is accepted in the same manner. For example, the third e-content (Figure 10) was given lower grades/worse comments than the other two. The reasons for this could be the themes which were presented with the simulation, because it does not contain spectacular and experimenting options. The design/the look of the animation also received worse marks from the students. Some future researches should also investigate how effective the interactive animations are when the users have different learning styles

Various researches focusing on the effectiveness of learning with the help of visualization point out that in order for the animation to be well accepted, by the [19] [20] [21] the following have to be kept in mind :

- positive effects in learning can only be achieved in topics that are dynamic in character,
- an exaggerated multitude of colors in the animation will have the exact opposite effect,
- it is important for the application to contain an optimal amount of information.

Due to the lack of a standard in creating successful visual applications [22], experiences gained from well-accepted electronic materials may serve as guidelines for defining a methodology, which, if applied in the design of animations and simulations, will lead to greater effect and efficiency in the learning process [23].

However, results also show that there is a tendency of decreasing the difference between those learners who had used the animation and those who had not. Is this because there is an increasing number of such and similar e-curricula available to students, and this kind of attractive multimedia presentations are no longer motivate students as they used to before; or was is simply the case of students of the control group getting hold of the animations and using them in their learning process. Unfortunately, the questionnaire filled in by the students at the end of the semester failed to provide definitive answers to this question. The questionnaires show that students were on the whole satisfied with the applications.

A number of studies indicate that the user's performance is much better if the teaching methods are matched to the user's learning style [24]. Designing the animation's interface and contents to match the students' preferred learning style could lead to a more effective learning process. For example, according to the Felder–Silverman [25] learning style model, the animations containing a lot of visual elements, such as pictures, diagrams, flow charts etc. are preferred for the visual learning profile, while written and auditory explanations are effective with the verbal type of student. And to mention another example: students with an active profile prefer the simulation (interactive animation) which allows experimenting with the system parameters.

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