Adaptive Drum Kit Learning System: Impact on Students' Learning Outcomes

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Abstract—**Computer technology is increasingly integrated into various teaching and educational processes. The role of various educational tools and artificial intelligence in the educational process is becoming more and more significant for overall educational success. In this paper, a review of the scientific literature on the application of computer technology for music education is given, with an emphasis on learning to play musical instruments. It has been observed that for many created systems, proper evaluation was not conducted to determine the created systems' effectiveness in achieving desired learning outcomes. An innovative part of this paper is a description of a new conceptual model of an adaptive system for self-paced learning to play musical instruments. A prototype of an adaptive drum kit learning system has been created based on the presented model. The main goal of this research was to determine the effectiveness of created prototype in achieving students' learning outcomes. In the evaluation process, the use of created prototype was compared to other self-paced learning methods to learn how to play the drum kit. The obtained data were analyzed by ANOVA method, along with other appropriate statistical methods. The results of the research showed that the use of an adaptive drum kit learning system has a positive impact on achieving learning outcomes. The participants who learned to play using the created prototype were more precise in playing, played more accurate rhythmic patterns, and were rated with higher marks by an independent expert compared to the control groups. Based on the obtained results, it can be concluded that there is a potential for the application of computer technology in the process of learning to play musical instruments.**

Index Terms—**Adaptive drum kit learning system, self-paced learning, drum kit playing, learning outcomes**

I. Introduction

Music plays an extremely important role in people's lives, especially young people. 2006 U.S. Gallup Poll conducted by NAMM (The National Association of Music Merchants) showed that 85% of Americans consider music to be an important part of their lives, 82% of Americans said they wanted to learn to play a musical instrument, and 67% of them still have a desire to start learning to play a musical instrument at some point [1]. A 2009 poll showed that most Americans strongly or mostly agree that there are benefits for children and teenagers from playing musical instruments: developing creativity (97%), overall intellectual development (94%), reducing stress, and providing relaxation (94%) [2].

Likewise, computer technology has become an integral part of our lives, both in the business context and in the context of education and entertainment. As for education, it is necessary to use digital technology in an efficient way as a tool that will additionally motivate students and contribute to faster and better achievement of learning outcomes [3, 4]. In the second part of this paper, a review of the scientific literature on the application of computer technology for music education is given, with an emphasis on learning to play musical instruments. Several different projects are presented. It has been observed that on many projects proper evaluation was not conducted to determine the created systems' effectiveness in achieving desired learning outcomes. Also, this part provides an overview of commercial products that use computer technology to help users to learn how to play musical instruments.

The third part presents a conceptual model of an adaptive system for self-paced learning to play musical instruments. Based on the presented conceptual model, a prototype of an adaptive drum kit learning system was created and is briefly described.

To determine the effectiveness of created prototype in achieving desired students' learning outcomes, an evaluation was conducted where created prototype was compared with other self-paced learning methods to learn how to play the drum kit. This evaluation is described in the fourth part of this paper. The collected data were analyzed by the ANOVA method, along with other appropriate statistical methods, depending on the obtained results. The results of this evaluation are presented and discussed in this part as well.

In the final part of this paper, the conclusion has been given, along with several limitations of the conducted evaluation.

II. Literature Review

Computer technology has been used for more than 30 years in music education [5]. There are three main areas of use: as an aiding tool to improve teachers' work with students, to increase motivation, and for individual practice.

Most computer programs are in the first (and partially in the second) category. They are used to teach the basics of music theory and to acquire some fundamental musical skills (writing music sheets, recognizing melodic and rhythmical patterns, hearing note intervals, etc.) [6–8]. Some computer programs promote teamwork and collaboration by creating virtual learning environments for acquiring basic musical knowledge and skills [9–11].

The most important area of use for this research are computer programs that assist students in their individual practice of playing musical instruments. These computer programs can usually capture students' playing through the specific interface (usually MIDI interface or recorded sound over a microphone) and give some kind of feedback that can

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help them in better self-evaluation (for example, show the playing accuracy of each note that should be played).

Regarding scientific research in this area, several solutions have been developed over the years: computer programs for learning to play the violin, Violin Tutor [12] and i-Maestro [13], computer programs for learning to play the piano: pianoFORTE [14] and Piano Tutor [15], computer programs for playing wind instruments: developed during IMUTUS [16] and VEMUS [17] projects, and computer programs for playing drums: Digital Drum Tutor [18] and agent for creative development of drum kit playing [19].

What is missing in these studies is an adequate evaluation that would confirm the positive impact on learning outcomes. The Violin Tutor and the IMUTUS project conducted an evaluation on a total of 12 students [12, 20], Piano Tutor conducted an evaluation that was completed by 10 students [21], and Digital Drum Tutor conducted an evaluation on four students [18]. The evaluation was not carried out on other mentioned projects.

There are also certain commercial products in this area on the market. Considering that the piano is the most popular instrument among young people [22] and considering that it is easy to connect an electric piano to a computer via a MIDI interface, there are many computer programs with the purpose to teach students to play the piano [23].

When it comes to learning how to play a drum kit, the company Roland that's developing electric drums has created computer software called V-Drums Tutor DT-1 [24]. The same company later developed similar computer software called Melodics for learning to play the piano and drum kit [25]. The main feature of these programs is real-time feedback on playing accuracy.

Educational software in this domain also exists in the form of computer games. The computer game Rocksmith+ uses an electric and bass guitar as an input unit to play a video game [26], and video games such as Guitar Hero and Rock Band use special MIDI controllers as input units that resemble real instruments [27, 28].

New technologies are also slowly finding their place in the field of teaching musical instrument playing: instruMentor is an interactive robot that teaches users to play the flute [29], and the application of mixed and adapted reality is also being experimented [30, 31].

III. Conceptual Model and Implementation

The basic functionality of the created conceptual model of the adaptive drum kit learning system is the ability to dynamically generate lessons in real-time based on the success of playing the lesson, which consists of different rhythmic patterns. Depending on the precision of playing, new (and more difficult) rhythmic patterns are added to the lesson. In case the lesson becomes too difficult for the user, the newly added rhythmic patterns will be dropped until the user has mastered the easier rhythmic patterns. In this way, the lesson is adapted to the user's playing ability [32].

In addition, there is also an advanced possibility of detecting specific types of errors and generating lessons that serve to eliminate detected problems [33].

Previous research has shown that users would be interested in using such a system [34]. System and user interface design was created based on the data obtained from potential users [35]. Also, previous research has shown that the use of this system has a positive effect on user motivation [36]. The created conceptual model is shown in Fig. 1.

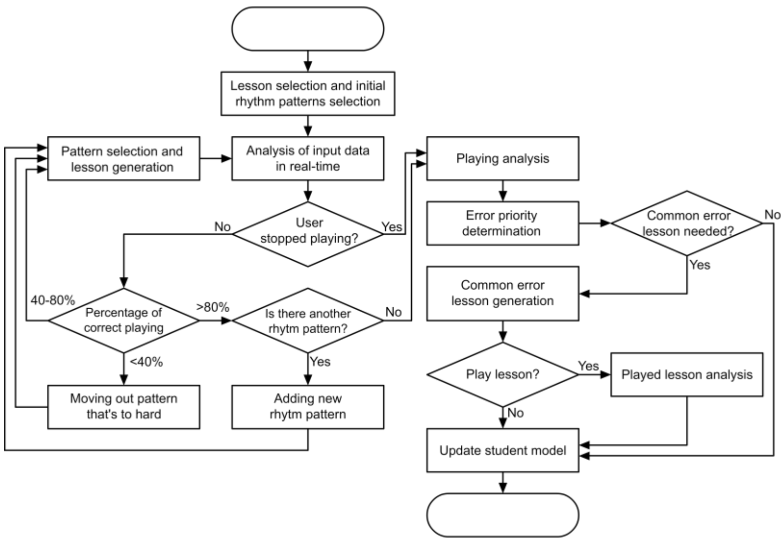

Fig. 1. Conceptual model: Adaptive drum kit learning system.

Based on the created conceptual model, a prototype of an adaptive drum kit learning system was created. The system consists of the standard elements of an intelligent teaching system: domain model, user model, teaching model, and user interface [37]. The knowledge base created by an expert consists of 144 rhythmic patterns that are divided into nine categories. Within each category, the rhythmic patterns are also ordered by difficulty from easiest to hardest.

There are four types of lessons in the created system:

1) Video lessons—a lesson in the form of a video through

which the user receives various instructions.

2) Practice Lessons—a practice lesson on playing a particular rhythmic pattern along with a video lesson on how to play the rhythmical pattern.
3) Jam Session—a lesson of learning to play all rhythmic patterns within a particular category of patterns (dynamically generated lesson).
4) Review Session—learning lesson of all rhythmic patterns from all categories learned until the current moment (dynamically generated lesson).

Initially, the user needs to create his user profile, which will be used to save the user's progress. After that, a screen with a list of lessons (activities) appears. The lessons are arranged in the suggested order, but the user has the freedom to choose the order of the activities he wants to go through (Fig. 2).

Gamification elements are used on the lesson selection screen: checkmarks that indicate the completion of a certain lesson, stars that are indicators of success along with percentages that more precisely indicate the level of precision of playing a particular lesson. For example, in order for a rhythmic pattern to be declared learned, the user must play the rhythmic pattern 4 times in a row without making a mistake.

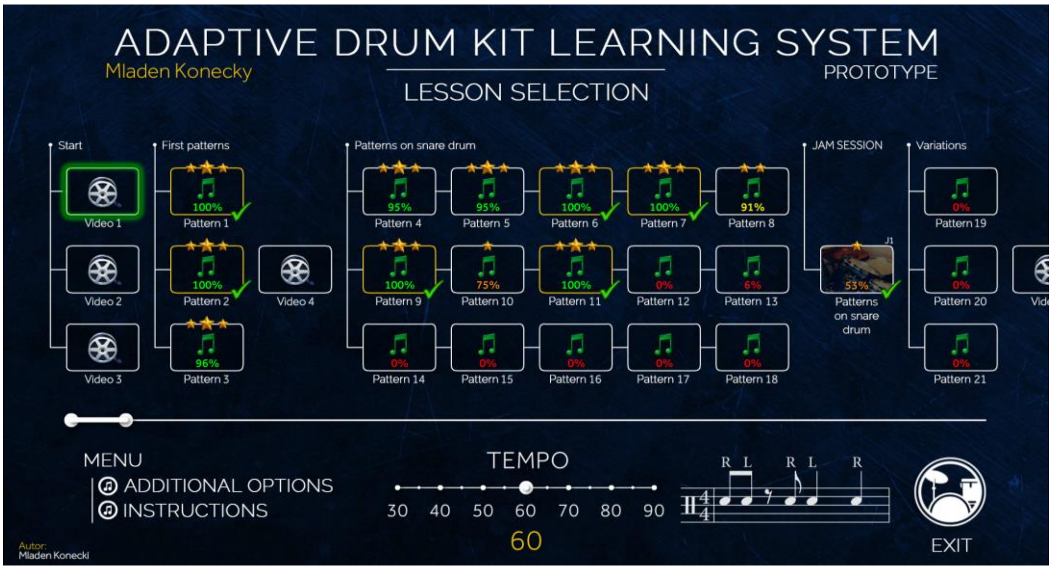

Fig. 2. Main screen for selecting a lesson (activity).

Jam session and review session lessons are generated in real-time based on the success of playing rhythmic patterns of a particular category or all patterns that the user has learned so far. If the user plays without many mistakes, then they will complete the activity faster than someone who makes more mistakes. Rhythmic patterns can be declared as learned (green color), in the process of learning (orange color), or not yet learned (red color). There is also feedback on the screen about this learning status of each rhythmic pattern. In this way, the user can identify problematic rhythmical patterns that he can (if he wishes) practice specifically. The jam session screen can be seen in Fig. 3.

Fig. 3. Jam session screen.

A special type of activity is the activity for correcting frequent playing mistakes. This activity is available to the user only if a certain type of error is made repeatedly. Then a special lesson is generated, and the purpose of that lesson is to correct a specific playing error.

IV. Evaluation of Learning Outcomes

To determine the effectiveness of the created adaptive system regarding learning outcomes, an evaluation was conducted in which the use of the created adaptive system was compared with alternative ways of self-paced learning of drum kit playing.

90 high school students who had no previous knowledge or experience of playing drum kit participated in the research. The students were divided into three groups:

1) The group that used the created adaptive system prototype (experimental group).
2) The group that used the alternative software Roland DT-1 V-Drums Tutor (control group no. 1).
3) The group that learned to play the drums using lessons in the form of video tutorials (control group no. 2).

To ensure the uniformity of the group participants, a pre-test was created in which students had to repeat 15 rhythmic patterns by tapping the rhythm by hand. Based on the results, 3 uniform groups of 30 students were created. All three groups used the same knowledge base: they were 144 learning rhythmic patterns that were divided into 9 categories.

The first group used a created adaptive drum kit learning system prototype where they had video lessons, feedback on playing accuracy in real-time, and dynamically generated lessons in real-time based on playing accuracy. The second group, a group that used DT-1 V-Drums Tutor had also video lessons (as video files) and feedback on playing accuracy in real-time through software. The knowledge base for this group was created as a MIDI files that they could load into the software. The third group used only video lessons and had no real-time feedback on playing accuracy, they only used the metronome as an additional helping tool. The knowledge base of rhythmical patterns is presented through video lessons to this group. This is the most common way to learn to play a drum kit for someone who is learning to play independently, without the tutor: watching instructional video lessons and practicing playing. Each student in each group learned to play a drum kit for 10 school hours by using a certain method.

After the learning process, all participants needed to play the final exercise (final test) that consisted of 64 chosen rhythmical patterns from the knowledge base. Patterns were chosen in such a way that all categories of rhythmical patterns were represented equally. The final test was the same for all students. Everyone played the same 64 rhythmic samples so that the playing precision of all research participants could be compared. The playing of the final test of all participants was also recorded in the form of an audio recording. Based on the success of playing the final test, conclusions were made about achieving the desired learning outcomes.

Three tests were conducted to determine if there is a statistically significant difference in the achieved learning outcomes between the three test groups:

1) measurement of playing precision (number of correctly played notes in final test),
2) measurement of learned rhythmic patterns (number of correctly played rhythmical patterns in final test), and
3) expert evaluation (rating ranging from 1 to 5).

Since the data for measuring learning outcomes were continuous numerical values, test groups were independent, the independent variable was categorical and the groups were equal in size, the data has been analyzed by the ANOVA method. To use this method, two conditions must be met: the normality of data distribution and the homogeneity of variances. The normality of data distribution was tested by Kolmogorov-Smirnov and Shapiro-Wilk tests and the homogeneity of variances was tested by Levene's test. If the normality of data distribution was not satisfied, then the Kruskal-Wallis H test was used and if the homogeneity of variances was not satisfied then the Welch test was used. For post-hoc data analysis, Kruskal-Wallis H, Games-Hawell, and Fisher LSD tests were used based on selected statistical tests. The process of selection of statistical methods for data analysis can be seen in Fig. 4.

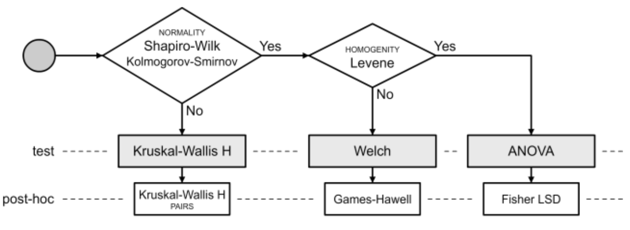

Fig. 4. Selection of statistical methods.

V. Results and Discussion

In the first test, playing precision was measured by measuring the number of correctly played notes on the final test. The final test consisted of a total of 628 notes. Based on the collected data, a statistical descriptive analysis was performed, and the obtained data is shown in Table I.

TABLE I: Descriptive Statistics—Playing Precision

group	N	Average	SD	Minimum	Maximum
(1)	30	557.733	49.134	455	626
(2)	30	491.733	76.530	362	608
(3)	30	444.267	58.949	368	578

The data shows that the average value is the highest in the experimental group (Group 1). Interestingly, the first control group (Group 2) also performed better than the second control group (Group 3). The standard deviation is the smallest in the experimental group, which suggests greater consistency of results compared to the control groups, especially group 2. A big difference can also be seen in the minimum value (lowest result in the group): the experimental group has much better results compared to the control group. A much smaller difference can be seen in the maximum value (best result in the group), but the experimental group has the highest value.

TABLE II: Distribution Normality—Playing Precision

	Kolmogorov-Smirnov			Shapiro-Wilk		
Group	Stat.	df	Sig.	Stat.	df	Sig.
(1)	0.138	30	0.152	0.934	30	0.063
(2)	0.112	30	0.200	0.942	30	0.101
(3)	0.119	30	0.200	0.939	30	0.085

The data in Table II show that in both tests (Kolmogorov-Smirnov and Shapiro-Wilk) for all three groups, the significance is greater than 0.05. Therefore, it can be concluded that all three groups have an approximately normal distribution.

TABLE III: Variance Homogeneity—Playing Precision

Levene statistic	df1	df2	Sig.
3.915	2	87	0.024

Given that the significance of Levene's test is less than 0.05, it can be concluded that the groups do not meet the assumption of homogeneity (shown in Table III). In this case, Welch's test was used to determine if there was a statistically significant difference in the results.

TABLE IV: Welch's Test—Playing Precision

	Statistic	df1	df2	Sig.
Welch	33.182	2	56.354	0.000

Based on the analysis results (shown in Table IV), it can be concluded that there is a statistically significant difference in the results between the groups, as the significance is less than 0.05. To determine between which groups there is a difference, a post-hoc Games-Howell test was performed, which is used in case of inhomogeneity of variance.

Given that the significance between the experimental group and both control groups is below 0.05 (shown in Table V), it can be concluded that there is a statistically significant difference in playing accuracy between the experimental group and both control groups. What is also interesting is that the results show that there is a statistically significant difference between the control groups in favor of group 2.

Based on this, we can conclude that participants achieved better learning outcomes using interactive computer software compared to using only multimedia materials.

TABLE V: GAMES-HOWELL'S TEST—PLAYING PRECISION

	(I) Group	(J) Group	Mean Difference	SD	Sig.
Games-Howell	(1)	(2)	66.000	16.604	0.001
		(3)	113.467	14.011	0.000
	(2)	(1)	−66.000	16.604	0.001
		(3)	47.467	17.637	0.025
	(3)	(1)	−113.467	14.011	0.000
		(2)	−47.467	17.637	0.025

In the second test, learning outcomes were measured by the number of learned rhythmic patterns by measuring correctly played rhythmic patterns on the final test, which consisted of 64 rhythmic patterns.

All groups of rhythmic patterns that were learned during the process of learning were equally represented in the final test and all participants had the same final test, they had to play the same 64 rhythmical patterns. Obtained data is shown in Table VI.

TABLE VI: DESCRIPTIVE STATISTICS—LEARNED PATTERNS

Group	N	Average	SD	Minimum	Maximum
(1)	30	38.733	13.323	13	61
(2)	30	30.233	12.993	10	52
(3)	30	23.000	9.476	10	42

The data show that, as in the measurement of correctly played notes, the experimental group achieved the best result compared to both control groups. The standard deviation is relatively equal in all three groups, although it is slightly lower in the third group compared to the first two groups. Regarding the minimum and maximum values, the minimum value of the experimental group is slightly better compared to both control groups. A bigger difference can be seen in the maximum value. The experimental group has much better results compared to both control groups. Also, the difference in the maximum value is significant between the two control groups in favor of group 2.

TABLE VII: DISTRIBUTION NORMALITY—LEARNED PATTERNS

	Kolmogorov-Smirnov			Shapiro-Wilk		
Group	Stat.	df	Sig.	Stat.	df	Sig.
(1)	0.141	30	0.134	0.950	30	0.163
(2)	0.106	30	0.200	0.945	30	0.128
(3)	0.137	30	0.160	0.945	30	0.122

Based on the obtained data presented in Table VII, given that the significance of all groups in both tests is greater than 0.05, it can be concluded that the assumption of normality of the distributions is satisfied.

TABLE VIII: VARIANCE HOMOGENEITY—LEARNED PATTERNS

Levene statistic	df1	df2	Sig.
3.039	2	87	0.053

Although close to the limit value, Levelen's test shows that the homogeneity of variance is satisfied (shown in Table VIII). Considering these results, one-factor analysis of variance was performed, and the following results were obtained (shown in Table IX).

TABLE IX: ANOVA—LEARNED PATTERNS

	Sum of Squares	df	Mean Squares	F	Sig.
Between	3721.089	2	1860.544	12.799	0.000
Within	12647.233	87	145.370		
Total	16368.322	89			

Based on the obtained results, it can be concluded that there is a statistically significant difference between the groups because the significance level is below 0.05. To determine between which groups exactly there is a difference, Fisher's LSD test was performed. The Games-Howell test was also performed regarding the limit value of homogeneity of variances. The obtained results are shown in Table X.

Although closer to the limit value, the results of the Games-Howell test are consistent with Fisher's LSD test. The significance levels for all comparison groups are below 0.05, which means that there is a statistically significant difference in the number of learned rhythmic patterns of the experimental group compared to both control groups. Likewise, it was again shown that there is a statistically significant difference between the two control groups in favor of group 2.

TABLE X: FISHER'S LSD AND GAMES-HOWELL'S TEST—PLAYING PRECISION

	(I) Group	(J) Group	Mean Difference	SD	Sig.
Fisher LSD	(1)	(2)	8.500	3.113	0.008
		(3)	15.733	3.113	0.000
	(2)	(1)	−8.500	3.113	0.008
		(3)	7.233	3.113	0.022
	(3)	(1)	−15.733	3.113	0.000
		(2)	−7.233	3.113	0.022
Games-Howell	(1)	(2)	8.500	3.398	0.040
		(3)	15.733	2.985	0.000
	(2)	(1)	−8.500	3.398	0.040
		(3)	7.233	2.936	0.044
	(3)	(1)	−15.733	2.985	0.000
		(2)	−7.233	2.936	0.044

In the third test that was conducted as part of this research, an independent expert evaluated the user's final test playing by listening to audio recordings of the user's final tests. The expert did not know to which group each audio recording of the final test belonged. The expert had to listen to each audio recording and rate the performance with a mark ranging from 1 to 5. For a more precise evaluation, he could also determine the first decimal number of a mark. The expert also received the score (sheet music) of the final test to know what the examinees should have played. The obtained results are shown in Table XI.

TABLE XI: DESCRIPTIVE STATISTICS—EXPERT EVALUATION

Group	N	Average	SD	Minimum	Maximum
(1)	30	4.113	0.588	3.0	5.0
(2)	30	3.703	0.843	2.0	4.8
(3)	30	3.623	0.787	2.4	4.9

The obtained results are consistent with previous results, but this time the difference is much smaller than in previous analyses. The experimental group has the highest average value, but the following tests will show whether it is a significant difference. The standard deviation is slightly smaller in the experimental group compared to the control groups. Regarding the minimum value, the experimental group has a slightly higher value than the other groups. As for the maximum values, there is no significant difference between groups.

TABLE XII: DISTRIBUTION NORMALITY—EXPERT EVALUATION

	Kolmogorov-Smirnov			Shapiro-Wilk		
Group	Stat.	df	Sig.	Stat.	df	Sig.
(1)	0.145	30	0.111	0.941	30	0.095
(2)	0.122	30	0.200	0.926	30	0.038
(3)	0.117	30	0.200	0.939	30	0.084

Based on the Kolmogorov-Smirnov test (shown in Table XII), it can be concluded that the distributions meet the condition of normality. According to the Shapiro-Wilk test, the distribution of Group 2 does not satisfy this property. Considering that this is the case for only one group in one of the tests and considering that certain sources state that one-factor analysis of variance is robust enough for such situations [38], the analysis is continued with the assumption that normality is satisfied.

TABLE XIII: VARIANCE HOMOGENEITY—EXPERT EVALUATION

Levene statistic	df1	df2	Sig.
2.128	2	87	0.125

Based on Levele's test (shown in Table XIII), it can be concluded that the homogeneity of the variances is satisfied and thus the conditions for conducting a one-factor analysis of variances are met.

TABLE XIV: ANOVA—EXPERT EVALUATION

	Sum of Squares	df	Mean Squares	F	Sig.
Between	4.146	2	2.073	3.713	0.028
Within	48.578	87	0.558		
Total	52.724	89			

Given the significance, which is less than 0.05, it can be concluded that there is a statistically significant difference between the examined groups in the obtained results (shown in Table XIV). To determine exactly between which test groups that difference is significant, Fisher's LSD test was performed.

TABLE XV: FISHER'S LSD—EXPERT EVALUATION

	(I) Group	(J) Group	Mean Difference	SD	Sig.
Fisher LSD	(1)	(2)	0.410	0.193	0.036
		(3)	0.490	0.193	0.013
	(2)	(1)	-0.410	0.193	0.036
		(3)	0.080	0.193	0.679
	(3)	(1)	-0.490	0.193	0.013
		(2)	-0.080	0.193	0.679

According to Fisher's LSD test (shown in Table XV), a statistically significant difference was found between the experimental group and both control groups. Regarding the difference between the control groups, the results show that there is no statistically significant difference in the result. Based on the obtained data, it can be concluded that the experimental group was rated on average with a statistically significantly higher mark compared to both control groups.

VI. CONCLUSION

Based on the conducted tests, it can be concluded that students who learned to play the drums using an adaptive drum kit learning system achieved better learning outcomes compared to students who used alternative educational software and students who used only multimedia content. At the final test, their playing precision was better, they played a greater number of rhythmic samples correctly, and an independent expert rated their playing with a higher average score. Based on this, it can be concluded that a computer system that provides customized direct feedback on playing performance can have a positive effect on student learning outcomes.

It is also worth noting that in two out of three tests it was shown that learning using alternative software DT-1 V-Drums Tutor for learning to play drum kit was more efficient than using only multimedia content. A common feature for the experimental group and the first control group is direct feedback on the correct notes played when learning to play the drum kit. Based on these data, it can be concluded that this direct feedback is very important and can have a positive impact on achieving learning outcomes.

This research certainly has several limitations. The research compared three methods of self-paced learning to play drum kit. In the future, it would be good to compare these methods with learning methods in music schools where a mentor is involved in the learning process.

Another limitation is that the drumming technique itself was not evaluated in any way, which is an important factor when learning outcomes are considered.

Also, the research was conducted on beginners who had no prior knowledge or experience in playing drum kit. It would be interesting to see what the results would be if the participants already had certain prior knowledge or experience. This kind of system could be useful for learning to play certain musical compositions and could probably speed up the process of learning to play a specific composition because the musician could immediately notice playing errors and more easily focus on the problematic parts of the composition.

At the time of the pandemic, music schools had great challenges to achieve the desired learning outcomes remotely. This kind of system could be a very good aiding tool in the process of learning to play musical instruments at a distance. Interactive systems such as created software could also be good motivators for students to start learning to play a musical instrument.

Based on obtained data, it can be concluded that computer technology has the potential to be successfully used in the process of learning to play musical instruments.

CONFLICT OF INTEREST

The author declares no conflict of interest.

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