ANALYSIS ON LEARNING STYLES IN ADAPTIVE MODELS FOR E-LEARNING MARINE STAFF

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ABSTRACT

The report analyzes the application of different learning styles according to Felder-Silverman in-built adaptive model in Learning Management Systems Moodle. Four parameters describing the learning process are identified – two continuous and two discrete ones. Two groups of statistical tests are applied over the data – one group for the discrete, and one group for the continuous parameters. Comparisons are made between the experimental and the control group on one hand, and between the advanced and the basic group on the other hand (divided in terms of level of knowledge). The statistical tests are realized in MATLAB and extensively use Bootstrap simulation. Results show that the basic group benefits from the proposed learning techniques, whereas more attention should be paid to providing stimuli to students from the advanced group to strive for higher and higher academic results.

Keywords: *adaptive, model, style, e-learning, statistical tests, Bootstrap*

1. INTRODUCTION

At this stage of development of information technology, management systems for training and curriculum (also called LMS - Learning Management Systems), and systems for e-learning in particular, are getting more and more popular in the area of maritime education. To cover a wider range of students (people receiving training) with their specific learning goals and capabilities, it is possible to use adaptive models. Learning styles can define the model of adaptability according to the characteristics of the student.

This paper describes a survey conducted among students from the N. Vaptsarov Naval Academy, Varna, Bulgaria. Participants are divided into two groups – experimental and control group. The experimental group comprises cadets majoring in mechanical engineering. The control group consists of civil students majoring in the same area. The analysis covers the results from the learning process in Informatics. The experimental group is additionally divided into advanced and basic group, depending on their level of knowledge and ability to comprehend the material. Different learning techniques are applied to the experimental subgroups, including different additional learning materials and different ways of presenting the material. Different scoring procedures are also applied. To analyze the results, four parameters (two continuous and two discrete) are identified and analyzed: duration of test, test scores, quality of education and lecturer evaluation. A series of statistical tests (one-tail and two-tail tests) using Bootstrap simulation are applied over the data in order to generate results regarding the effectiveness of the proposed learning technique.

In what follows, Section 2 gives the rationale of the experiment. Section 3 discusses the statistical tests to be applied to the discrete parameters, with appropriate reference to the tests to be applied to the continuous parameters. Section 4 presents the results from the statistical tests for each of the four parameters, for each of which there are two comparisons applied: 1) between experimental and control groups, 2) between advanced and basic groups. A detailed discussion of the test results is provided. Section 5 offers main conclusions from the test results.

2. DESCRIPTION OF THE EXPERIMENT

The Felder-Silverman model [Hawk et al., 2007] is employed as a basis for the study of learning styles in adaptive models. Several important aspects must be defined in that respect:

- What kind of student perceives information - sensory or intuitive;
- By what kind of external data analysts perceived best – visually or verbally;
- How do you process information – active or reflex;
- What is the way of understanding – gradual or complete.

Each style has the following characteristics [Graf et al., 2009; Viola et al., 2007]:

- sensing – practically oriented, works with facts and procedures;
- intuitive – oriented to concepts and theories, an innovator.
- visual - receives richest information on the basis of visual materials - images, diagrams and charts.
- verbal – remembers best read or heard information, prefers lectures and discussions.
- active – learns by doing something, experiments and summarizes the ideas of others.
- reflective - learns by analysing the object, prefers to work independently.
- sequential – perceive and understand the information if provided on small linked portions, straightforward and works by instructions.
- global – think globally, able to find the relationship between different categories.

When creating the model of e-learning and when conducting the experiments, the following restrictions apply:

- limited number of subjects included in the study;
- small volume curriculum - textbooks, exercises, tests, which prevents the creation of a large database;
- dynamic nature of the curriculum that does not allow the experiment to be carried out for several school years.

The experiment is carried out at the N. Vaptsarov Naval Academy, Varna, Bulgaria, in an e-learning *Moodle* environment, with an additional adaptable module. It comprises a total of 87 first year students attending classes in "Informatics", Module "Systems for table processing". The experimental group consists of 17 students (cadets), whereas the control group consists of 70 students (civil students), majoring in Ship Machines and Equipment. The criteria for adaptability in the function model are focused on the adaptability of the characteristics of the student: according to her knowledge and style of learning. The limited number of students in the study does not allow creating groups that could be characterized by all styles identified in the Felder-Silverman model.

To carry out the experiment it is assumed that division by knowledge may replace the division by characteristics. For that reason, the cadets are divided into two groups – basic and advanced. Each of them can adopt different features of the Felder-Silverman model. The criterion employed to divide the students is the score from their previous modules on the subject. It is assumed that students from the basic level experience difficulties when learning the discipline. The course provides them with training materials and exercises, which they need so that to acquire a basic level curriculum. In addition to that, students at the advanced level receive more complex tasks in order to stimulate their development and acquire particular skills and knowledge, so that to obtain higher scores in the final examination.

Separation by success assumes that students from both streams have the following features, according to the Felder-Silverman model:

- basic – active, sensing, visual, sequential;
- advanced – reflective, intuitive, verbal, global.

The learning content is divided into several categories, each of them directed to a particular learning style:

- lectures in PDF format – intuitive, verbal, global students;
- lectures in PPT format – sensing, visual, sequential students;
- flash animations – sensing visual students;
- online help – intuitive, verbal students.

To check the level of knowledge acquired, students are asked to answer a test. Different questions and styles of answering are included in order to address all styles of learning. Questions can be defined as text or illustrated by images. In the same time, they may be of the following types: description – describe an action; claim – to choose a statement; situation – describe the real situation. Technologically, the responses are divided into four types: multiple choice – choice of several specified actions; short answer – write the exact text or numeric response; relations – connect two statements; binary – true or false. Answers can be: path selection – pre-written way to perform an action; statement – a choice between assertions, and free response. The employed combinations of questions and answers are given in Table 1.

Table 1. Type of questions

type of questions		type of answers	
presentation of question	type of question	technology of answer	type of answer
text	description	multiple choice	path selection
text	statement	multiple choice	path selection
text	situation	multiple choice	path selection
visual	description	multiple choice	path selection
visual	situation	multiple choice	path selection
text	statement	multiple choice	statement selection
visual	statement	multiple choice	statement selection
visual	situation	multiple choice	statement selection
text	situation	multiple choice	statement selection
text	statement	multiple choice	statement selection
text	situation	multiple choice	statement selection
text	statement	short answer	statement selection
visual	statement	short answer	statement selection
text	statement	short answer	free response
visual	situation	short answer	free response
visual	statement	relations	statement selection
text	statement	relations	statement selection
text	statement	true / false	statement selection

Four parameters shall be subjected to further analysis in order to test the results of the learning experiment, all coming from the test that the participants filled in. The first two parameters are continuous, whereas the others are discrete parameters, and their possible discretes are given below:

1) *Duration of test*, measured in minutes;

2) *Test scores*, measured in points;

3) *Quality of education*, with five possible discretes: "Excellent", "Very good", "Good", "Satisfactory", "Bad".

4) *Lecturer evaluation*, with five possible discretes: "Excellent", "Very good", "Good", "Satisfactory", "Bad".

In the course of further analysis, statistical tests over discrete and over continuous features shall be employed. Description of the tests that would apply to discrete features shall be provided in Section 3. The work [Nikolova et al., 2013a] gives a detailed description of the tests that apply to continuous parameters. The work discusses three analytical tests over one-dimensional continuous features – Wilcoxon rank sum test, analytical Kolmogorov-Smirnov test, and analytical Kuiper test, and also offers an algorithm to find the p_{value} of Kuiper statistics using Bootstrap simulation. A discussion on Bootstrap statistical tests under the described setup is also provided in [Nikolova et al., 2013b; Nikolova et al., 2013c].

3. STATISTICAL TESTS

Two samples shall be compared, both one-dimensional and containing the values of a selected discrete feature. The elements of the two samples comply with different restrictions. Of course, those restrictions cannot be the same for both samples, because samples would be identical. In fact, the elements in the samples differ by a single factor, which allows comparing the influence of this factor over the samples.

Assume there are two one-dimensional samples of a discrete feature with *r* number of discretes, called Sample 1 and Sample 2. Assume also that Population 1 contains the values of the discrete parameter in the population of all data points that comply with the restriction for Sample 1. In the same fashion, assume that Population 2 contains the values of the discrete parameter in the population of all data points that comply with the restriction for Sample 2.

There is a total of (2+4*r*) tests in such a setup, divided into (*r*+1) groups: one group to compare the discrete distributions, and a group per each discrete.

3.1. First group

This first group presents tests that search for difference in the discrete distribution of Population 1 and Population 2. The null hypothesis is that the distributions of the Populations are equal, and the alternative hypothesis is that the distributions of the Populations are different. This group contains two statistical tests – Bootstrap ANOVA contingency table test [Efron, Tibshirani, 1993] and analytical ANOVA contingency table test [Hanke, Reitsch, 1991].

3.2. The (i+1) group, where i changes from 1 to r

The tests in these groups search for differences in the probabilities for occurrence of the *i*-th discrete in both Populations. If Sample 1 and Sample 2 have zero frequencies for occurrence of the *i*-th discrete, then this group of tests is not conducted. The null hypothesis is that the two Populations have equal probabilities for occurrence of the *i*-th discrete. This group contains four statistical tests – two-tail and one-tail Bootstrap test for equality of proportions [Efron, Tibshirani, 1993], two-tail and one-tail analytical hyper geometric test for equality of proportions [Groebner et al., 2011]. The value of p_{value} for the latter pair is derived by integration of the hyper geometric distribution using the function *higecdf* of MATLAB [Mathworks, 2013]. For the two-tail tests, the alternative hypothesis is that the probability for occurrence of the *i*-th discrete under Population 1 is different from the one in Population 2. For the one-tail tests, the alternative hypothesis depends on the calculated frequencies for occurrence of the *i*-th discrete for both samples. If Sample 1 has higher frequency for occurrence of the *i*-th discrete than Sample 2, then the alternative hypothesis states that the probability for occurrence of the *i*-th discrete for Population 1 is higher than the one for Population 2. If Sample 1 has lower frequency for occurrence of the *i*-th discrete than Sample 2, then the alternative hypothesis states that the probability for occurrence of the *i*-th discrete for Population 1 is lower than the one for Population 2. In some rare cases, when Sample 1 and Sample 2 have equal frequencies for occurrence of the *i*-th discrete, then the one-tail tests are not performed.

4. EXPERIMENTS

The statistical tests, discussed in the previous section shall be applied over the data from the study. All tests and analyses are performed at a significance level α =0.05.

4.1. Duration of test – comparison of experimental and control groups

The results from the statistical tests are given in Table 2. None of the tests shows statistically significant difference in the characteristics of position; however the experimental group has significantly shorter duration of test compared to the control group (mean of 53 min vs. 63 min; median of 52 min vs. 63 min). All tests show statistical significance of the characteristics of dispersion ($p_{value} \leq 0.0166$). The practical significance of the differences is in the much higher variance in the experimental group (standard deviation two times higher: 28 min vs. 14 min; IQR (interquartile range) is more than three times higher: 59 min vs. 17 min). The Bootstrap tests show statistically significant difference in the distributions ($p_{value} \leq 0.0166$), where the distribution of the experimental group is shifted right and is much wider.

Table 2. Numerical characteristics of experimental and control group regarding duration of test

	Sample 1	Sample 2
# of observations	17	55
Mean	52.96	63.1
Median	51.9	63
STD	28.33	13.72
IQR	59.29	17.34

4.2. Duration of test – comparison of advanced and basic groups

The results from the statistical tests are given in Table 3. None of the tests shows statistically significant difference in the characteristics of position and the advanced group has practically the same mean, but has significantly lower median compared to the basic group (mean of 52 min vs. 53 min; median of 52 min vs. 60 min). None of the tests shows statistically significant difference in the characteristics of dispersion. The practical significance of the differences is small, which is justified by the direction of difference in the standard deviation and IQR (standard deviation of the advanced group 29 min vs. 30 min in the basic group; IQR of 60 min in the advanced group vs. 54 min in the basic group). None of the tests shows statistically significant difference in the distributions.

Table 3. Numerical characteristics of advanced and basic group regarding duration of test

	Sample 1	Sample 2
# of observations	9	8
Mean	52.21	53.81
Median	51.9	60.44
STD	28.86	29.67
IQR	60.02	53.65

4.3. Test scores – comparison of experimental and control groups

The results from the statistical tests are given in Table 4. All tests show statistically significant difference in the characteristics of position ($p_{value} \leq 1.115e\text{-}9$). The experimental group has significantly better scores than the control group (mean in the experimental group of 41 points vs. 33 points in the control group; median in the experimental group of 41.5 points vs. 34 points in the control group). All tests show statistically significant difference in the characteristics of dispersion ($p_{value} \leq 0.0055$). The practical significance of the differences is in the much lower variance in the experimental group (standard deviation two times lower: 2.7 points vs. 6 points; IQR is about three times lower: 3.4 points vs. 10.3 points). All tests show statistically significant difference in the distributions ($p_{value} \leq 3.291e\text{-}5$), where the distribution in the experimental group is shifted right and is much tighter.

Table 4. Numerical characteristics of experimental and control groups regarding test scores

	Sample 1	Sample 2
# of observations	17	56
Mean	40.67	33.27
Median	41.5	34.33
STD	2.685	5.955
IQR	3.443	10.34

4.4. Test scores – comparison of advanced and basic groups

The results from the statistical tests are given in Table 5. The Bootstrap tests show statistically borderline significance of the difference in the characteristics of position, where the advanced group has practically slightly better scores than the basic group (mean in the advanced group of 42 points vs. 40 points in the basic group; median in the experimental group of 42 points vs. 40 points in the basic group). None of the tests shows statistical significant difference in the characteristics of dispersion, and the slightly lower values in the advanced group are of little practical importance (standard deviation in the advanced group of 2.1 points vs. 2.9 points in the basic group; IQR in the advanced group of 2.5 points vs. 3.6 points in the basic group).

Table 5. Numerical characteristics of advanced and basic groups regarding test scores

	Sample 1	Sample 2
# of observations	9	8
Mean	41.69	39.53
Median	42.33	39.59
STD	2.137	2.904
IQR	2.5	3.645

4.5. Quality of education – comparison of experimental and control groups

The results from the statistical tests are given in Table 6. None of the tests shows statistically significant difference in the frequency of any of the discretes regarding quality of education. There is slight improvement of opinion in the experimental group, because: a) in the experimental group there is no satisfactory and bad opinion, whereas in the control group 6% have such opinion; b) in the experimental group, there are participants with excellent opinion that are 5% more than in the control group (59% vs. 54%). None of the tests shows statistically significant difference in the discrete distributions.

Table 6. Numerical characteristics of experimental and control groups regarding quality of education

	Sample 1	Sample 2
# of observations	17	68
Percentage of the discrete 'Excellent' in the Sample	58.82%	54.41%
Percentage of the discrete 'Very good' in the Sample	23.53%	30.88%
Percentage of the discrete 'Good' in the Sample	17.65%	8.82%
Percentage of the discrete 'Satisfactory' in the Sample	0.00%	4.41%
Percentage of the discrete 'Bad' in the Sample	0.00%	1.47%

4.6. Quality of education – comparison of advanced and basic groups

The results from the statistical tests are given in Table 7. None of the tests shows statistically significant difference in the frequency of occurrence of any of the five discretes of quality of education. In any case, there is practically significant improvement of opinion regarding quality in the advanced group: a) in the advanced group there are only 11% good estimates for the quality of education, vs. 25% for the basic group; b) in the advanced group, the participants with excellent opinion are about 17% more than those in the basic group (67% vs. 50%). None of the tests shows statistically significant difference in the discrete distributions.

Table 7. Numerical characteristics of advanced and basic groups regarding quality of education

	Sample 1	Sample 2
# of observations	9	8
Percentage of the discrete 'Excellent' in the Sample	66.67%	50.00%
Percentage of the discrete 'Very good' in the Sample	22.22%	25.00%
Percentage of the discrete 'Good' in the Sample	11.11%	25.00%

4.7. Lecturer evaluation – comparison of experimental and control groups

The results from the statistical tests are given in Table 8. None of the tests shows statistically significant difference in the frequency of occurrence of any of the five discretes of the lecturer evaluation. However, in the experimental group there is slight improvement of the lecturer evaluation, because: a) in the experimental group there are no participants with good or bad opinion, whereas in the control group respectively 10% and 6% of participants have that opinion; b) in the experimental group, the participants with good opinion are about 16% more than those in the control group (29% vs. 13%). None of the tests shows statistically significance in the discrete distributions.

Table 8. Numerical characteristics of experimental and control groups regarding lecturer evaluation

	Sample 1	Sample 2
# of observations	17	68
Percentage of the discrete 'Excellent' in the Sample	64.71%	64.71%
Percentage of the discrete 'Very good' in the Sample	29.41%	13.24%
Percentage of the discrete 'Good' in the Sample	0.00%	10.29%
Percentage of the discrete 'Satisfactory' in the Sample	5.88%	5.88%
Percentage of the discrete 'Bad' in the Sample	0.00%	5.88%

4.8. Lecturer evaluation – comparison of advanced and basic groups

The results from the statistical tests are given in Table 9. None of the tests shows statistically significant difference in the frequency of occurrence of any discrete regarding lecturer evaluation. In any case, in the advanced group there is practical improvement of the opinion regarding lecturer evaluation, because: a) in the advanced group there is no satisfactory opinion for the lecturer, whereas in the basic group, 12.5% have such an opinion; b) in the advanced group, the people with excellent opinion are around 28% more than those in the basic group (78% vs. 50%). None of the tests shows statistically significant difference in the discrete distributions.

Table 9. Numerical characteristics of advanced and basic groups regarding lecturer evaluation

	Sample 1	Sample 2
# of observations	9	8
Percentage of the discrete 'Excellent' in the Sample	77.78%	50.00%
Percentage of the discrete 'Very good' in the Sample	22.22%	37.50%
Percentage of the discrete 'Satisfactory' in the Sample	0.00%	12.50%

5. CONCLUSIONS

All statistical tests performed in this study are realized using original software in MATLAB R2013a environment. The program functions are available free of charge upon request from the authors.

The following conclusions can be made from the statistical results:

- there is statistically insignificant difference in the duration of exam between the experimental and control groups;
- there is no statistically significant difference in duration of test between the advanced and the basic group;
- there is statistically significant difference in the test scores between the experimental and control group, with better scores in the experimental group;
- there is statistically borderline significance of the better test scores in the advanced group, but with no difference in terms of dispersion;
- the assessment of the quality of education in the experimental and the control group are almost the same , with slight improvement of the opinion in the experimental group;
- the assessment of the quality of education in the advanced and the basic group are statistically almost the same, with practically significant improvement of opinion in the advanced group;
- there is no statistically significant difference in the lecturer assessment in the experimental and control groups, with only slight improvement of the opinion in the experimental group;
- there is no statistically significant difference in the lecturer assessment in the advanced and basic groups, with practical improvement of the opinion in the advanced group;

Based on that, there are several conclusions to be made regarding this study:

- the use of learning materials and test questions, targeted at different learning styles, improves the utilization of the information provided;
- the separation into groups depending on exam results has positive impact on students. More particularly, the statistical results show that the basic group has improved in performance thanks to the proposed learning techniques and it has high chances of becoming competitive to the advanced group in time;
- the overall satisfaction of students from the learning process has increased, which is a strong justification to continue applying the proposed approach;
- more attention has to be paid to the members of the advanced group; the results show that for all students the major motivation is to pass the exam, so once this is guaranteed students have no ambitions of achieving higher academic results; therefore stronger stimuli should be provided to the advanced students, such as providing more complex tasks, financial support of excellent students, inclusion in specialized academic programs for learning and mobility, etc.;
- the lack of usage of the e-learning communication modules by the students does not allow studying the communication aspects of the Felder-Silverman model.
- it is mandatory to expand this research over larger and varying student groups in order to justify the positive effects of the proposed learning technique;

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