Mathematical-statistical analysis of experimental work on the use of modeling programs for future engineers

Olimov Kahramon

1 Tashkent branch of Herzen Russian State Pedagogical University, Tashkent, Uzbekistan

Abstract. Through this article, you can get information about the methods implemented on the basis of training using programs for modeling the teaching process in the general professional subject “Technical applications on the basis of programming languages” and see the statistical analytical results of the effectiveness of the experimental tests conducted in order to determine the effectiveness of training using the programs. Keywords: Local, global, network variables, event driven programming, polymorphism in virtual hardware, internal virtual hardware, dynamic link libraries, OLEdf Active X, buffer memory.

1 Introduction

In order to determine the effectiveness of the results obtained in conducting experimental work, the results obtained in two parallel experimental and control groups from higher education institutions were compared with each other in the assessment of students’ professional knowledge and skills. In the control groups, the teaching process was carried out on the basis of traditional teaching, while in the experimental groups, the e-learning offered by us was conducted on the basis of distance learning using the resource [1]. The results of the control and experimental groups at the beginning and at the end of the experiment were systematically analyzed and compared to each other and summarized. The effectiveness of the use of electronic educational resources in the experimental group was proved on a theoretical basis and practically.

We have observed an increase in educational efficiency in teaching as a result of organizing the teaching process of the general professional subject “Technical applications based on programming languages” on the basis of electronic educational resources. For this purpose, for 2 years, we conducted research and monitoring work in control and experimental-testing groups at Bukhara Engineering-Technical Institute of Bukhara Region, Namangan Engineering-Technical Institute of Namangan Region, Fergana Polytechnic Institute and Jizzakh Polytechnic Institute of Jizzakh Region [2]. A total of 482 students participated in the experimental and control groups. Among them, 110 people (out of 52 in the experimental and control groups) in Bukhara Engineering-
The purpose of pedagogical experiments is to prove the correctness of the hypothesis put forward in scientific research work. This process can be conditionally divided into the following stages:

1. **The preparatory stage** - 2020-2021:
   - determining the main direction of research;
   - study of the theoretical and practical situation of the problem;
   - selection of higher education institutions, study of material-technical, scientific-methodical basis and pedagogical conditions for conducting experimental work in them;
   - preparation of materials necessary for experimental work;
   - conducting preliminary experimental work, etc.

2. **At the second stage - 2021-2022, the following was implemented:**
   - continue experimental work according to the plan;
   - conducting a survey of teachers and students of general professional disciplines of higher educational institutions;
   - preparation of teachers of general professional subjects working in higher educational institutions to conduct experimental work;
   - making changes to the content of experimental materials and the methodology for their implementation, if necessary;
   - quantitative and qualitative analysis of the results of experiments;
   - collection of scientific data, their generalization;
   - presentation of reports on the results of experimental work and their detailed discussion.

3. **The third stage of research - in 2022-2023:**
   - experimental work was continued;
   - A 72-hour training course on the development of "Technical applications on the basis of programming languages" in general professional subject using modeling programs was taught by teachers of general professional subjects of higher education institutions;
   - drawing scientific conclusions, scientific justification of the research results, their compatibility with the hypotheses and tasks, i.e. their suitability.

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**Fig. 1. Scheme of efficiency of use of e-learning resources**

![Efficiency graph](image)

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1. The preparatory stage
2. At the second stage - 2021-2022, the following was implemented:
3. The third stage of research - in 2022-2023:
opinions of the teachers of professional subjects who participated in the experimental work were studied, interviews and questionnaires were conducted in order to make sure that the quality and efficiency of the educational process increased;

statistical processing of all the materials collected during our research, to prove its reliability, and mass promotion of our methodical work in practice.

In order to conduct experimental work and ensure the objectivity of the results, two parallel groups were gradually designated as experimental and control group in each academic year. In the control groups, the educational process was carried out according to the current teaching methodology, while in the experimental groups, it was carried out on the basis of training using modeling programs of the educational process in the general professional subject "Technical applications on the basis of programming languages" offered by us.

The results of the control and experimental groups were systematically analyzed and compared to each other, and a conclusion was drawn. In necessary cases, opinions expressed by teachers directly participating in this process were thoroughly discussed. For this purpose, we conducted research and observation work in control and experimental groups for 2 years [6].

![Fig. 2. Scheme of the program for modeling the teaching process](image)

We performed mathematical and statistical processing to ensure the validity of the experimental results.

**Table 1.** Bukhara Engineering-Technological Institute, the results of the experimental tests conducted on student learning indicators in 2022-2023

<table>
<thead>
<tr>
<th></th>
<th>Experimental groups</th>
<th>Control groups</th>
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<tbody>
<tr>
<td></td>
<td>Number of students</td>
<td>Number of students</td>
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<tr>
<td></td>
<td>at the beginning</td>
<td>at the end</td>
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<tr>
<td></td>
<td>of the experiment</td>
<td>of the experiment</td>
</tr>
<tr>
<td>Excellent</td>
<td>8</td>
<td>14,5</td>
</tr>
<tr>
<td></td>
<td>17</td>
<td>30,9</td>
</tr>
<tr>
<td>Good</td>
<td>14</td>
<td>25,5</td>
</tr>
<tr>
<td></td>
<td>27</td>
<td>49,1</td>
</tr>
<tr>
<td>Satisfactory</td>
<td>27</td>
<td>49,1</td>
</tr>
<tr>
<td></td>
<td>9</td>
<td>16,4</td>
</tr>
<tr>
<td>Unsatisfactory</td>
<td>6</td>
<td>10,9</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>3,6</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>9,1</td>
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<tr>
<td></td>
<td>3</td>
<td>5,5</td>
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</tbody>
</table>
Table 2. Namangan Engineering-Technological Institute, the results of the experimental tests conducted on student learning indicators in 2022-2023

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Experimental groups</th>
<th>Control groups</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Excellent</td>
<td>13</td>
<td>16,3</td>
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<td></td>
<td>21</td>
<td>26,3</td>
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<td>Good</td>
<td>27</td>
<td>33,8</td>
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<tr>
<td></td>
<td>33</td>
<td>41,3</td>
</tr>
<tr>
<td>Satisfactory</td>
<td>33</td>
<td>41,3</td>
</tr>
<tr>
<td></td>
<td>23</td>
<td>28,8</td>
</tr>
<tr>
<td>Unsatisfactory</td>
<td>7</td>
<td>8,8</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>3,8</td>
</tr>
</tbody>
</table>

Table 3. Fergana Polytechnic Institute, the results of the experimental tests conducted on student learning indicators in 2022-2023

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Experimental groups</th>
<th>Control groups</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<tr>
<td>Excellent</td>
<td>9</td>
<td>17,3</td>
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<tr>
<td></td>
<td>14</td>
<td>26,9</td>
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<tr>
<td>Good</td>
<td>12</td>
<td>23,1</td>
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<tr>
<td></td>
<td>21</td>
<td>40,4</td>
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<td>Satisfactory</td>
<td>27</td>
<td>51,9</td>
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<tr>
<td></td>
<td>15</td>
<td>28,8</td>
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<tr>
<td>Unsatisfactory</td>
<td>4</td>
<td>7,7</td>
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<tr>
<td></td>
<td>2</td>
<td>3,8</td>
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</table>

Table 4. Jizzakh Polytechnic Institute, the results of the experimental tests conducted on student learning indicators in 2022-2023

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Experimental groups</th>
<th>Control groups</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Excellent</td>
<td>10</td>
<td>18,9</td>
</tr>
<tr>
<td></td>
<td>16</td>
<td>30,2</td>
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<tr>
<td>Good</td>
<td>14</td>
<td>26,4</td>
</tr>
<tr>
<td></td>
<td>23</td>
<td>43,4</td>
</tr>
<tr>
<td>Satisfactory</td>
<td>26</td>
<td>49,1</td>
</tr>
<tr>
<td></td>
<td>13</td>
<td>24,5</td>
</tr>
<tr>
<td>Unsatisfactory</td>
<td>3</td>
<td>5,7</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>1,9</td>
</tr>
</tbody>
</table>
Based on the author's methodology, the high level of teaching the subject "Technical applications on the basis of programming languages" using modeling programs was confirmed by the results of experimental work - it can be seen that excellent grades increased from 10.1% to 30.8% in the period from 2022 to 2023.

![Graph showing performance results](image)

**Fig. 3.** 2022 to 2023 Performance Results Scheme

In this case, students were evaluated on the basis of appropriate criteria in the course of the test conducted on the example of the subject "Technical applications on the basis of programming languages".

**2 Criteria for evaluating the use of student modeling programs in the process of test-verification work on the subject "Technical applications on the basis of programming languages"**

**HIGH** -
- Data input and output to the computer.
- Management of equipment for data collection.
- Using local, global and network variables.
- Event driven programming.
- Structures for removing codes.
- Polymorphism in virtual machines.
- Create internal virtual machines.
- Dynamic Link Libraries.
- Working with streams.
- Knowledge and experience with technologies such as OLE and Active X controls and buffering is required.

**INTERMEDIATE** -
- a lower level, except for the specified criteria.
- There are two types of loops in LabVIEW.
- Shift registers.
- Option structure.
- Arrays.
- Clusters.
- LabVIEW visualization tools.
- Working with additional components.
- Must have knowledge, skills and experience in database linking and reporting applications.

**LOW** -
- Introduction to the LabVIEW environment.
- Creation of virtual hardware.
- Connecting elements.
- Program firmware.
- Download and save virtual hardware.
- Visual model of Delphi.
- Working with components.
- Availability of knowledge, skills and experience in creating work applications.

**LOW** -
- Lack of familiarity with the LabVIEW environment.
- Not knowing how to connect fundamental concepts and elements in the LabVIEW environment.
- Lack of
Based on these indicators, an experiment was conducted on the results of a test to determine the effectiveness of teaching students the subject "Technical applications based on programming languages" using modeling programs based on the author's methodology, and their average assimilation in the control group was analyzed using the $\chi^2$ mathematics statistics method according to Student and Pearson.

The brief essence of the problem is as follows: Let two prime sets be given. One is the mean scores of the students in the experimental group and the other is the mean scores of the students in the control group. The scores are assumed to have a normal distribution. This assumption is reasonable because the conditions for approximation to the normal distribution are simple and they are satisfied.

Based on the above tables, we choose hypothesis $H_1$, which shows the effectiveness of students' learning in the experimental group and in the control group, and the hypothesis $H_0$, which contradicts it.

We can determine the mastery rates and the number of students in the experimental group and the control group by means of $x_i$, and $y_i$ respectively.

$$x_i -$$ values corresponding to the experimental group. $i = 1, 3$

$$y_i -$$ values corresponding to the control group.

$$x = \frac{\sum x_i n_i}{n} = \frac{\sum y_i m_i}{m}$$

Here: $n_i$, $m_i$ - the number of students in relation to the corresponding grades.

The average value that evaluates the effectiveness of the educational process is the ratio of the average arithmetic values of the experimental and control groups, that is, the efficiency coefficient was obtained as follows:

$$\eta = \frac{x}{y}$$

Mean square deviation values:

$$S_x = \frac{\sum n_i \cdot (x_i - \bar{x})^2}{n}$$

$$S_y = \frac{\sum m_i \cdot (y_i - \bar{y})^2}{m}$$

Standard deviation values:

$$S_x = S_y$$

$$S_x = S_y$$

Confidence intervals for unknown population means:

$$[\bar{x} - t \cdot S_x, \bar{x} + t \cdot S_x]$$

$$[\bar{y} - t \cdot S_y, \bar{y} + t \cdot S_y]$$
We present the analysis of the results of the experimental work based on the above data using Student's statistics. The hypothesis about the equality of mean values is rejected. This is determined by the fact that the sampling value of the statistic is greater than the critical point: $t = 1.96$. The value of the efficiency coefficient $\alpha_x \in [3,12;3,30]$ and $\alpha_y \in [3,25;3,44]$. Here:

- $t = 1.96$: normalized deviation confidence probability
- $H_0$: $a_x = a_y$
- $H_1$: $a_x \neq a_y$

$$T_{m-n} = \frac{|y - x|}{\sqrt{\frac{S_x}{n} + \frac{S_y}{m}}}$$

We compare with the beginning of the experiment:

- Experimental group: $x_{\text{m}} = 240$, $n = 242$
- Control group: $y_{\text{m}} = 8,34$

The sample value of the statistic is greater than the critical point: $t = 1.96$. Hence, the average acquisition rates in the experimental group are higher than the average acquisition rates in the control group. We can say with 95% reliability that the average acquisition rates in the experimental group obtained a higher score of 1.15 (15%) at the end of the experiment compared to the control group.

$$\eta_m = \frac{x_0}{\bar{x}_6} = 1,26$$
$$\eta_y = \frac{y_0}{\bar{y}_6} = 1,05$$
$$S_x^2 = 0,43$$
$$S_y^2 = 0,55$$
$$S_x = \sqrt{S_x^2} = 0,65$$
$$S_y = \sqrt{S_y^2} = 0,74$$

$$C_x = 1,04\%; C_y = 1,34\%$$

$$\alpha_x \in [3,99;4,16] \quad \alpha_y \in [3,45;3,63]$$

The values of indicators for determining average values:

- Arithmetic average values
- Standard errors
- Mean squared errors
- Efficiency coefficient

Present the analysis of the results of the experimental work at the end of the experiment compared to the control group.

Present the analysis of the results of the experimental work at the end of the experiment compared to the control group.

Based on these formulas, we will perform calculations and provide their analysis below.

The value of the efficiency coefficient $\alpha_x \in [3,12;3,30]$ and $\alpha_y \in [3,25;3,44]$. Here:

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The value of the efficiency coefficient $\alpha_x \in [3,12;3,30]$ and $\alpha_y \in [3,25;3,44]$. Here:
\[ \eta_n = \frac{\overline{y}_0}{\overline{y}_n} = 1.05 \quad \text{and} \quad T_n = 1.38 \]

\[ T_n = 1.38 < 1.96 \quad \text{hypothesis is accepted.} \]

Table 5. Numerical data calculated based on the above formulas are presented in table [10].

<table>
<thead>
<tr>
<th>№</th>
<th>Indicators</th>
<th>Experimental group</th>
<th>Control group</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Arithmetic mean (x,y)</td>
<td>3.21</td>
<td>4.07</td>
</tr>
<tr>
<td>2</td>
<td>Efficiency index (\eta)</td>
<td>1.26</td>
<td>1.05</td>
</tr>
<tr>
<td>3</td>
<td>Average value confidence interval (a_x, a_y)</td>
<td>[3.12; 3.30]</td>
<td>[3.99; 4.16]</td>
</tr>
<tr>
<td>4</td>
<td>Standard error of the mean (S_{\bar{x}}, S_{\bar{y}})</td>
<td>0.71</td>
<td>0.65</td>
</tr>
<tr>
<td>5</td>
<td>Detection indicator (C_{\bar{x}}, C_{\bar{y}})</td>
<td>1.04</td>
<td>1.82</td>
</tr>
<tr>
<td>6</td>
<td>Student’s statistics (T)</td>
<td>8.34</td>
<td>1.38</td>
</tr>
</tbody>
</table>

Hypothesis \(H_1\) is accepted. Hypothesis \(H_0\) is accepted.

3 Conclusions

The results of the experimental work showed that it is important to develop students' skills to work independently with learning material, to search, find and apply knowledge independently through a printed textbook, e-textbook and e-learning guide, web platform, YouTube channel and modelling software. The number of students who received "excellent" and "good" grades increased in higher education institutions and the number of students who received "unsatisfactory" and "satisfactory" grades decreased compared to the control groups.

References

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