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Effectiveness Research of the New Learning Elements, Initiated by the Change to Competency-Based Education Model in Russia

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Abstract

Within the article the main principles for developing competency-based education, the principles for identifying competencies and the list of competencies that must be developed in a learner according to competency-based model, are analyzed. The new learning elements, initiated by the change to the competency-based education model in Russian Federation and by the new demands of Ministry of Education and Science of Russian Federation, have been included. The new learning elements have been analyzed for the compliance with the considered principles of developing competencies. The competencies, which are developed by each particular learning element, have been identified. The results of an experiment on developing competencies in two groups of students – taught with the use of new learning elements, and taught by traditional means, have been considered.

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Keywords: Competency-based education; competency; skills; knowledge; virtual stimulators

1. Introduction

Russia joined the Bologna Process in September 2003. Professional qualification "certified specialist" has been replaced by academic degrees "Bachelor" and "Master". The main distinction of new Educational Standards is the change from the knowledge-based education model to the competency-based education model, which implies transformation of knowledge into action (Navodnov et al., 2006; Navodnov, 2012).

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The problem of the change to the competency-based education model is being actively discussed in the English-speaking publications (Kerka, 1998; Deimann & Bastiaens, 2010; Soares, 2012; Patrick et al., 2013; Brown & Hurst, 2013; Weise, 2014), as well as in Russian-speaking publications beginning from 2001 (Bolotov et al., 2003; Shishov et al., 2005; Razuvaeva, 2012; Federov et al., 2012; Yagafarova, 2014). Many authors, although identifying the shortcomings and implementation problems, recognize the expediency of the change to the competency-based education model and accept its advantages over knowledge-based paradigm in the context of the changes, which have occurred over the past 2 decades in social, informational and technological fields of human activity.

Also, there are opponents of the competency-based approach (Bowden, 2002; Mulder et al., 2009). There are authors that indicate implementation problems of the competency-based education model in such fields as medicine (Leape et al., 2006; Wangler, 2009; Frank et al., 2010), linguistics and translation (PACTE group, 2000; PACTE group, 2008; Lafeber, 2012), pedagogy (Ilyazova, 2007; Yarulina et al., 2011), Music, Art and Culture (Kalinina, 2010; Peter, 2013; Mitina et al., 2014).

The publications also cover some particular aspects of competency-based education model in learning such field as information technologies as well as some aspects of information technologies implementation in developing competency-based education model (Adelsberger et al., 2008; Lystras, 2008; Hartley et al., 2010; Atif, 2010). However, in published works there are no results of the competency model effectiveness research in learning information technologies.

Also, the comparison of requirements for the educational programs, which are drawn up in accordance with the principles of competency-based model, with the hierarchy and structure of the competencies that must be developed in learners, cannot be observed in publications.

Thus, the purpose of this work is to identify the new types of learning elements, initiated by the change to the competency-based education model in Russia and to assess the competency-based model effectiveness for learning information technologies (on an example of students of the Ural State Forestry University).

2. Subjects and methods

The change of the base education model affects on changing teaching methods themselves, including learning materials and knowledge assessment system. Here are the main features of competency-based education, which are stimulating the emergence of the new learning elements:

1. Principles for developing competency-based education programs and organizing studying process, i.e. DCBEP&OSP principles. Within the article (Johnstone et al., 2014) 5 principles, on which the competency-based education should be developed, are examined:
    - 1.1. robust and valid competencies, that:
        - 1.1.1. should align with both industry and academic expectations;
        - 1.1.2. should reflect the skills and knowledge that students will need at the next stages of their development, whether it be further education or employment;
        - 1.1.3. should be iterative, evolving to incorporate marketplace demands, academic expectations, and student needs;
    - 1.2. students are able to learn at a variable pace and are supported in their learning:
        - 1.2.1. adapting regular terms to variable ones for the purpose of student progress;
        - 1.2.2. keeping students progressing at a reasonable rate;
        - 1.2.3. providing an orientation program;
        - 1.2.4. having a means to identify when a student is struggling and needs help;
        - 1.2.5. continually measuring how well each process and all learning resources offered are working;
        - 1.2.6. having readily accessible non-academic support services;
        - 1.2.7. agreeing on the metrics they will use to gauge the success of the CBE program;
    - 1.3. effective learning resources are available anytime and are reusable;
    - 1.4. the process for mapping competencies to courses, learning outcomes, and assessments is explicit;
    - 1.5. assessments are secure and reliable.
2. Principles for identifying and developing the competencies i.e. I&DC principles (Klein et al., 2005; Spector et al., 2006; Ciarniene et al., 2010). As the authors insist (Spector et al., 2006), each particular field of human

activity shapes 4 factors:

- current practice;
- standards of performance;
- ethics and values;
- vision of the future.

These 4 factors, in turn, shape the requirements for knowledge and skills, which an employee should have to implement in a particular field of activity. Thus, the requirements are shaped as a structure consisting of the following elements (Spector et al., 2006):

2.1. domains (a grouping of related competencies) – a group of competencies, which an employee should have to implement in an activity, for example, the domain "Planning and Analysis";

2.2. competencies (consist of several specific performances) – abilities to perform specific tasks, that are necessary to possess a qualification in a particular field of knowledge, for example, the ability to identify target segment representatives features and ability to analyze external environment within the domain "Planning and Analysis";

2.3. performance statements, i.e. basic skills, that are necessary for a particular competence implementation, for example, a skill to make a quantitative assessment of the market share owned by competitors and a skill to estimate the inflation rate within the competence "ability to analyze external environment".

3. The list and hierarchy of the competencies to develop in a learner. In publications competencies hierarchy is identified differently. We have tried to compile comparatively complete classification, combining the competencies, that were considered by the following authors (Katz, 1974; Boon et al., 2001; Garavan et al., 2001; Rubin, 2005; Kumpikaite et al., 2009; Ciarniene et al., 2010; Yagafarova, 2014):

3.1. personal competencies:

3.1.1. creativity and creativeness;

3.1.2. activity;

3.1.3. critical thinking and criticism tolerance;

3.1.4. responsibility;

3.2. organizational competencies:

3.2.1. ability to discern others' potential;

3.2.2. ability to work in a team;

3.2.3. self-reliance;

3.2.4. communicability;

3.2.5. ability to show own opinion;

3.2.6. ability to reach an understanding in a team;

3.3. analytical skills (competencies):

3.3.1. ability to make a conscious choice;

3.3.2. systems thinking;

3.3.3. purposefulness, ability to analyze and to plan;

3.3.4. ability to solve problems;

3.4. technical skills (competencies):

3.4.1. professional knowledge;

3.4.2. professional experience;

3.4.3. practical experience;

3.5. competencies as a tool of regulation between education and market needs:

3.5.1. ability to apply knowledge in accordance with the requirements of production and market;

3.5.2. ability to formulate in what way the knowledge and trainings should be changed to align the competencies, derived by a learner, with the changing demands of the market;

3.5.3. ability to formulate the requirements, that an employer should set on the applicants in order to ensure that the future staff education level and qualification is the highest and consistent with the current demands of the market.

These have stimulated the emergence of the new learning elements - automated system of learning and knowledge control; lecturer's personal website (including means to interact with students and the tools of measuring how well the learning process goes on); virtual stimulators. We have considered all these elements in details.

2.1. Automated system of learning and knowledge control (ASLKC)

ASLKC is a complex, multi-component network system, which uses computing network capacity for the aim of learning and knowledge control (Popov, 2006; Popov, 2009).

ASLKC has been developed in the Ural State Forest Engineering University by members of Information Technologies Department, as evidenced by the two certificates of the Federal Institute of Industrial Property (Popov et al., Certificate № 2014611331; Popov et al., Certificate №2014611330).

Learning with ASLKC develops the skills of independent work and self study and shapes systematic knowledge through the science-based systematic control. It is an effective tool of education quality management for universities (Glushko, 2010). It gives the possibility of knowledge level assessment. Its systematic learning and control during all the learning process allows to motivate learners to a stirring cognitive and creative activity and healthy competition.

ASLKC includes the following components:

- administrator's automated workplace (system functionality modification, elimination of errors);
- lecturer's automated workplace (creating studying materials and new tests on a discipline, tests edition, creating lists of students, viewing test results);
- student's automated workplace (to learn and to be tested on a discipline).

Within the current version of ASLKC there are 4 types of questions provided:

1. Open answer - a student enters the answer from a keyboard. This type is close to traditional learning forms. It helps developing analytical skills, the skill of systems thinking. A student renders information, previously learned by heart. There are the following sorts of open answer:
   - 1.1. Coincidence – the right is the answer, which contains all the lexemes in the order, set by a lecturer. This sort is used for knowledge control in formalized subject areas.
   - 1.2. Lexemes selection - the right is the answer, which contains word forms of all the lexemes in any order. This sort is used for knowledge control of terms and definitions.
     - 1.2.1. Customized lexemes. The input of custom text is allowed in answer.
     - 1.2.2. Lexemes control. The input of such words as "this", "that", "or", "and", such symbols as "," and some others is allowed in answer.
   - 1.3. Synonymous - the right is the answer, which contains a word form of at least one of the lexemes.
     - 1.3.1. Customized synonymous. The input of custom text is allowed in answer.
     - 1.3.2. Synonymous control. The input of such words as "this", "that", "or", "and", such symbols as "," and some others is allowed in answer.
   - 1.4. Rate – the result depends on the rate of lexemes word forms, which are contained in the answer in any order.
     - 1.4.1. Customized rate. The input of custom text is allowed in answer.
     - 1.4.2. Rate control. The input of such words as "this", "that", and some others is allowed in answer.
2. Lexical choice – the choice of one or several right options among the proposed options, or matching of pair options. A learner must recognize the right option on the base of previously learned information. The presence of proposed options gives a prompt in a way. The answer requires careful analysis of the options and thoughtful reading of the question; it develops logical thinking and creativity, the ability to independently make a conscious choice. This type is used for knowledge control in poorly formalized subject areas. There are the following sorts of lexical choice type of answer:
   - 2.1. One right option – only one right option among all the options.
   - 2.2. Weighted options – several right options among all the options, which differ by completeness and/or adequacy.
   - 2.3. Multiple choices - several right options among all the options.
     - 2.3.1. Multiple coincidences – the right is the answer, which includes all the right options and does not

include any wrong options.

2.3.2. Multiple rates - the result depends on the quantity of the right and wrong options chosen.

2.4. Consequence – the right is the disposition of all options in the right order.

2.5. Matching – the right matching of pair options.

3. Graphical choice: a question in the form of a picture, the answer is determined by one or several points within zones of the right answer on the picture. This type develops visual memory, professional and personal experience. There are the following sorts of graphical choice type of answer:
   3.1. One right choice – the right is the choice of only one point or zone (the coordinates of which are determined within the question) on a picture.
   3.2. Multiple choices, coincidences - the right is the choice of all points or zones (the coordinates of which are determined within the question) on a picture.
   3.3. Multiple choices, rates – the result depends on the rate of the chosen points or zones on a picture, in total number of chosen points or zones. If a point, which lies out of zones of the right answer is chosen the result is reduced.
   3.4. Constructor – includes a lexical question and up to 8 graphical files fragments. The right is the pattern, composed of all the file fragments in the right order. This type is used for knowledge control in such subject areas as processing lines design, flowcharts, etc.
4. Grapholexical choice – the question includes text and a picture. This type of answer develops abstract thinking, the ability to analyze, the ability to choose the method for solution, ability to compare the facts, ability to implement the skills in practice.

ASLKC allows logging responses and generating performance tables containing the topics, the intermediate results on each topic and the final grade on a 100-point scale.

ASLKC has 3 modes:

- Examination – control test with the grade on a 100-point scale.
- Learning – the learning materials are available, and can be shown on demand or after a wrong answer.
- Prompt – the right answer is available and for the aim of rapid elimination of gaps in knowledge can be shown after a wrong answer.

ASLKC has the tool, which allows accumulating statistics on learners' tests results on a discipline as a whole, as well as on a particular topic or a question.

The statistic on a discipline as a whole shows how many learners passed the exam and the average grade obtained in a group. These results give possibilities to assess the complex knowledge level of learners on a discipline. The results on a particular topic are used as indicators for the aim of educational program correction. The results on a particular question are used to examine whether the question formulation is correct, and whether answer options are consistent, unambiguous and adequate to the question.

2.2. Lecturer's personal website

The Federal Law "On Education in the Russian Federation", entered into force in 2013, defines the new content of higher education, new models and technologies of the educational process in universities. Obviously, these requirements are impossible to meet without the use of information technologies in educational activities at all levels of education (Chasovskykh, 2015), and the only form to meet these requirements is a website.

The subject area of a lecturer modern site includes components (Chasovskykh, 2015; Chasovskykh, Kokh, 2015):

1. Learner – first name; last name; form of learning; education; form of payment; group; date of admission.
2. Discipline – name; learning hours; term paper; examinations; grade; the program of the discipline.
3. Literature on the discipline – book name; type of book; author(s); edition; year.
4. Master's researches – research program; master's educational program; field of research.
5. Scientific fields for students – name, description.
6. Graduate departments researches – name of research; registration number; period of execution; obtained results; performers; intellectual product.
7. Intellectual property – document type; property type; registration number; rights holders; authors; registration

date.

8. Students practice – student's name; practice name; reference to the practice; place of practice; date - the beginning; date - the end; date - the defense; grade.
9. Publications – type; status; name of publication; authors; edition; year.
10. Timetable – form of learning; term; timetable.
11. Examination topics – topic (or task) of examination; type of examination; learner; discipline.
12. Term papers topics – topic of term paper; type of term paper; learner; discipline.
13. Studying process – learner; discipline; term; lectures; term papers; term papers grades; examinations; examinations grades; practical classes; grades; independent works; hours.
14. Final qualifying work – learner; topic; approval date; end date; preliminary defense date; preliminary defense grade; preliminary defense record number; conclusion of scientific adviser; conclusion on plagiarism; text of the work; final defense date; final defense grade; final defense record number.
15. Consultations: online forms for questions and answers.

In accordance with the Order of the Ministry of Education and Science of the Russian Federation №785, a university website must also include a subsection "Education", which must contain the following required elements:

- curriculum;
- educational program description;
- disciplines programs and annotations;
- methodical and other documents, including lectures, methodical manual on laboratory and practical works and classes, guidelines on term papers and projects, tasks for independent work, controlling and measuring materials and lists of recommended literature.

Thus, all these items should also be seen as learning elements of competency-based model, and should be included in a lecturer's website.

2.3. Virtual stimulators

Some skills, such as decisions making, super large databases management and others cannot be developed by the traditional means of learning within a university. These skills can be developed only under the conditions of practical activity (Voronov & Chasovskykh, 2012). The use of real situations for learning in a real enterprise is often unacceptable for universities as the consequences of a wrong decision may turn out to be irreparable for the enterprise and can even force the enterprise to go out of business. Thus, the most acceptable means for developing competencies is a package of computer virtual simulators, which are able to imitate practical situations that involve student into practical activity and do not lead to fatal consequences in case of a mistake (Voronov & Chasovskykh, 2011; Chasovskykh & Voronov, 2013).

The complex learning system, which includes virtual simulators, can be represented as a scheme (Fig. 1).

Within Fig. 1 the following notation conventions have been imposed:

$x_1 \ldots x_n$ – input values of parameters, associated with a student's actions during interaction with a virtual simulator.

$\mu_{1i}(x_1) \ldots \mu_{mj}(x_n)$ – membership functions of input parameters values $x_1 \ldots x_n$ to input fuzzy sets $1_i \ldots m_j$.

$\mu_{1i}(x^*_1) \ldots \mu_{mj}(x^*_n)$ – membership grade of input parameters values $x_1 \ldots x_n$ to input fuzzy sets $1_i \ldots m_j$.

$\mu_1(y_1) \ldots \mu_r(y_r)$ – membership functions of output parameters $y_1 \ldots y_r$.

$\mu_{res1}(y_1) \ldots \mu_{res\,r}(y_r)$ – resultant membership functions of the model output parameters $y_1 \ldots y_r$.

Fuzzification – calculation of membership grade to input fuzzy.

Inference – calculation of resultant membership functions of output parameters.

Defuzzification – calculation of output parameters values on the basis of resultant membership functions.

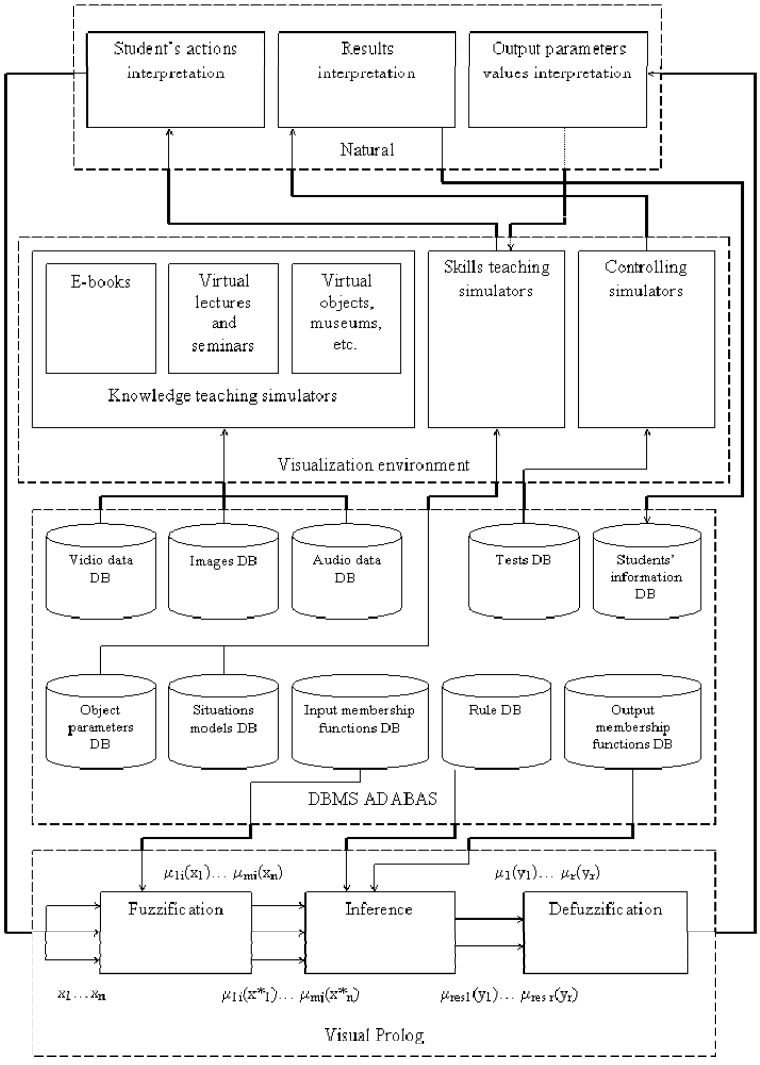

Fig. 1. Complex learning system of virtual simulators

3. Results and discussion

Within Table 1, there is the list of the new learning elements and their components and hierarchy numbers of the principles they correspond to and the competencies they develop in a learner.

Table 1. The list of the new learning elements and corresponding principles and competencies

Components	Learning element	DCBEP&OSP principles	I&DC principles	Competencies
Open answer (all types)	ASLKC	1.1.2; 1.2.1; 1.2.3; 1.2.6; 1.3	2.3.	3.1.2; 3.2.3; 3.3.2; 3.3.3; 3.4.1
Lexical choice (types - one right option;	ASLKC	1.1.2; 1.2.1; 1.2.3;	2.3.	3.1.1; 3.1.3;

weighted options; multiple choice)		1.2.6; 1.3		3.3.1; 3.3.2; 3.4.1
Lexical choice (types – consequence; matching)	ASLKC	1.1.2; 1.2.1; 1.2.3; 1.2.6; 1.3	2.3.	3.1.2; 3.2.3; 3.3.1; 3.3.2; 3.3.3; 3.4.1
Graphical choice (types - one right choice; multiple choices coincidences; multiple choices, rate)	ASLKC	1.1.1; 1.1.2; 1.2.1; 1.2.3; 1.2.6; 1.3	2.3.	3.1.1; 3.3.3; 3.4.1; 3.4.2
Graphical choice (type - constructor)	ASLKC	1.1.1; 1.1.3; 1.2.1; 1.2.3; 1.2.6; 1.3	2.2	3.1.2; 3.1.4; 3.3.2; 3.3.3; 3.4.2, 3.4.3; 3.5.1
Grapholexical choice	ASLKC	1.1.1; 1.1.2; 1.1.3; 1.2.1; 1.2.3; 1.2.6; 1.3	2.2, 2.3	3.1.2; 3.1.3; 3.3.3; 3.3.4; 3.4.3; 3.5.1
Lecture (including electronic and video versions)	Lecturer's personal website	1.1.3; 1.2.1; 1.2.2; 1.2.6; 1.3	-	3.4.1
Independent works	Lecturer's personal website	1.1.2; 1.2.1; 1.2.2; 1.2.4; 1.2.6; 1.3	2.2; 2.3	3.1.1; 3.1.2; 3.2.5; 3.4.1
Practical tasks	Lecturer's personal website	1.1.2; 1.1.3; 1.2.2; 1.2.4	2.2	3.1.2; 3.2.2; 3.3.4; 3.4.2; 3.4.3; 3.5.1
Final qualifying work	Lecturer's personal website	1.1.2; 1.1.3; 1.2.2; 1.2.4	2.2; 2.3	3.1.2; 3.3.4; 3.4.2; 3.4.3; 3.5.1
Consultations	Lecturer's personal website	1.1.3; 1.2.1; 1.2.3; 1.2.4; 1.2.5; 1.2.6; 1.3; 1.4	-	3.1.2; 3.2.5; 3.2.6; 3.3.4
-	Virtual stimulators	1.1.1; 1.1.2; 1.1.3; 1.2.1; 1.2.2; 1.2.3; 1.2.4; 1.2.5; 1.2.6; 1.2.7; 1.3; 1.4; 1.5	2.1	3.1.2; 3.1.4; 3.2.2; 3.2.3; 3.3.1; 3.3.2; 3.3.3; 3.3.4; 3.4.1; 3.4.2; 3.4.3; 3.5.1

In order to assess the efficiency of the new learning elements, which had been developed on the base of the considered principles and requirements, two groups of students in the field of "Applied Computer Science" were selected. In the beginning of a semester the students of group_1 and group_2 were tested on the basic disciplines, they had studied at schools. The tests results are shown within Fig. 2.

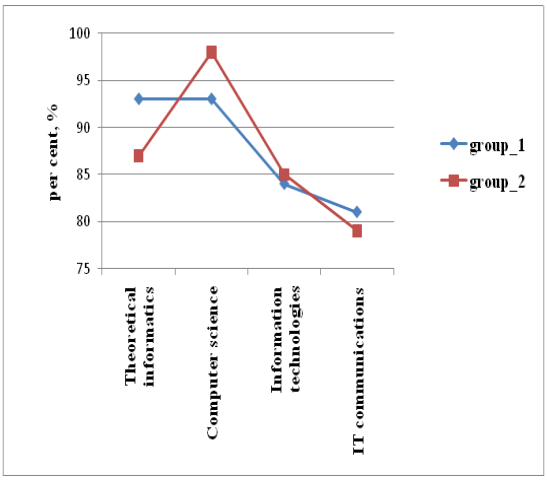

Fig. 2. Average per cent of right answers on the basic disciplines

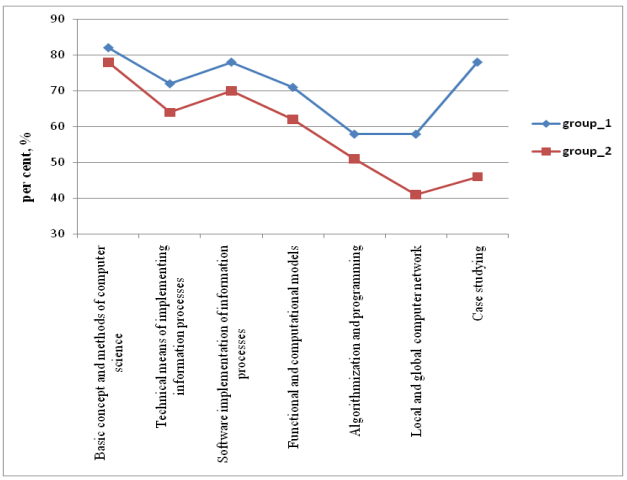

Fig. 3. Average per cent of right answers on the learnt disciplines

As the graphs show (Fig. 2), the level of knowledge on the basic disciplines in two groups is approximately the same. Due to the experiment, we decided to teach students of group_2 by means of traditional learning elements, and to use the new learning elements in teaching students of group_1. At the end of the semester the final tests on the disciplines, they had learnt, was passed with the results, shown within Fig. 3.

As the graphs show (Fig. 3), the students of group_1 achieved higher average per cent of right answers on all the learnt disciplines. Thus, using of the new learning elements as well as their accessibility to learners at any time - an additional means for achieving high pedagogical results.

4. Conclusion

None of the new learning elements meet all modern principles and requirements of competency-based model (as shown in Table 1). The learning element, which develops the largest number of competencies and meets the largest number of competency-based education principles, is virtual stimulator. Thereby, we can consider it as the most perspective learning element. Though, we should take into account that labour intensity of developing virtual stimulators is still high nowadays, and it does not allow universities in Russian Federation to redirect all the studying process and teach only with the use of virtual stimulators.

Even all the new learning elements together do not meet all the principles and requirements of competency-base education model. In our opinion, nowadays there are no learning elements, which are able to develop such competencies as:

- ability to discern others' potential;
- communicability;
- ability to formulate in what way the knowledge and trainings should be changed to align the competencies, derived by a learner, with the changing demands of the market;
- ability to formulate the requirements, that an employer should set on the applicants in order to ensure that the future staff education level and qualification is the highest and consistent with the current demands of the market.

Thus, further researches in this field should be focused on investigating the learning elements, capable of developing these competencies.

Implementation of the new learning elements allows improving academic performance of learners and promotes their active learning work, which is confirmed by the results of the experiment. The time, which is taken for developing learning elements, can be compensated by their reusability and by the time released due to independent work of students with the learning elements developed.

On the whole the implementation of the new learning elements for learning information technologies is more efficient in comparison with the traditional elements, and it has been confirmed by the results of the experiment.

The analysis of students' results allows teachers to focus on each student and on a group as a whole, which is especially important for implementation of competency-based model, based on the development of personal, organizational, and professional competencies, technical skills in accordance with the principles of plurality and diversity of knowledge.

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