THE SPECIFIC ASPECTS OF DESIGNING COMPUTER-BASED TUTORS FOR FUTURE ENGINEERS IN NUMERICAL METHODS STUDYING

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Introduction: the paper considers the topical problem of teaching students – future engineers – by computational methods of mathematics. The focus is on developing students' necessary professional competencies. Competencies are described in accordance with the Russian Federal State Educational Standard and the international standard by the European Association for Engineering Education SEFI. In order for students to thoroughly study the subject and have a strong professional competence, it is proposed to use a computer-based tutor. The aim of this research is to develop the special methodology of creating the computer-based tutors for teaching mathematical and engineering disciplines to students of technical specialties within the framework of a competence-oriented approach, to compare the effectiveness of classical teaching computational methods by using manual calculations, and training with the involvement of computer-based tutors. The advantages of computer-based tutors were proved in this paper.

Materials and Methods: the basis of the research was methods of system analysis and descriptive and analytical methods, primarily experimental. To identify advantages of the proposed approach the methods of empirical research were used (observation and comparison). To prove the efficiency, classical methods of measurement were used.

Results: based on the competence approach, a methodology of creating a computer tutor has been developed. It covers most the professional competencies that need to be studied. Also, students are guaranteed to receive the necessary competencies in the right sequence. The research showed that the use of specially designed software, such as Computer-based tutors, in the process of mathematical methods studying connected with the computational procedures allows us to achieve: on the one hand, deep digestion by students (as in using manual calculations), on the other hand to accelerate learning process and increase students motivation.

As a result of pedagogical experiment on the use the computer-based tutors the progress in studies has been recorded: the percentage of positive ratings increased from 65 to 88 %. Also, the motivation of students to study mathematics was increased by 12 percent on average.

Discussion and Conclusions: the methodology of creation and use of computer-based tutors has high practical significance and allows increasing the effectiveness of teaching mathematics within the competence approach for students of technical specialties. The use of the interactive computer-based tutors focused on mastering professional competencies, is effective for studying mathematical and engineering disciplines by students of technical universities. In particular, a positive effect has been achieved with the introduction of computer-based tutors in the educational process of Kazan National Research Technical University named after A. N. Tupolev-KAI, Kazan, Russia (the University is aimed at training engineers-designers for aerospace industry), Saarland Technical University, Saarbrucken, Germany (the University is focused on training IT engineers), and a number of other Russian and foreign technical universities.

Keywords: professional competencie; numerical method; computer-based tutor; manual calculation; computer-based training

ОСОБЕННОСТИ ПРОЕКТИРОВАНИЯ КОМПЬЮТЕРНЫХ ПРОГРАММ-ТЬЮТЕРОВ ДЛЯ ОБУЧЕНИЯ ЧИСЛЕННЫМ МЕТОДАМ МАТЕМАТИКИ БУДУЩИХ ИНЖЕНЕРОВ

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Введение: анализируется актуальная проблема обучения студентов – будущих инженеров вычислительным методам математики. Цель статьи – сравнение эффективности классических методик обучения вычислительным методам с использованием ручного счета обучения с привлечением программ-тьютеров и доказательство преимущества последнего.

Материалы и методы: основу исследования составили методы системного анализа, а также описательные и аналитические методы. Для выявления преимуществ предлагаемого в статье подхода использованы методы эмпирического исследования – наблюдения и сравнения, а для доказательства эффективности – классические методы измерения.

Результаты исследования: основываясь на компетентностном подходе, авторы разработали методику создания компьютерной программы-тьютера. Она охватывает большинство профессиональных компетенций, которые студенты должны получить в процессе обучения. Результаты педагогического эксперимента использования в учебном процессе компьютерных программ-тьютеров продемонстрировали повышение среднего балла успеваемости: количество студентов, успешно сдавших экзамен, увеличилась с 65 до 88 %. Также в среднем на 12 % возросла мотивация студентов к изучению математики.

Обсуждение и заключения: разработанная методика создания и использования компьютерных тьютеров имеет высокую практическую значимость и позволяет студентам технических специальностей повысить эффективность обучения математике в рамках компетентностного подхода. Применение интерактивных компьютерных тьютеров, ориентированных на овладение профессиональными компетенциями, эффективно при изучении математических и инженерных дисциплин для студентов технических высших учебных заведений. В частности, получен положительный эффект при внедрении компьютерных тьютеров в учебный процесс Казанского национального исследовательского технического университета им. А. Н. Туполева-КАИ (вуз направлен на подготовку инженеров-конструкторов авиационно-космической отрасли), Технического университета Саарланда (ориентирован на подготовку IT-инженеров) и ряда других российских и зарубежных технических вузов.

Ключевые слова: профессиональная компетенция; вычислительный метод; компьютерная программа-тьютер; вычисление вручную; компьютерное обучение

Introduction

Nowdays, in Russia, all educational programs of higher professional education are developed in accordance with the Bologna process, designed to bring together the education system in Europe, Russia and other participating countries [1]. Monitoring of practical knowledge and skills is carried out with competence building approach. The degree of mastering each competency is assessed according to the point-rating system [2].

In particular, in the study of mathematics and related engineering disciplines, the emphasis is on professional competencies, such as (for example FSES 09.03.04) PC-13: willingness to use the methods and study tools objects of professional activity GPC-1: control the basic concepts, principles, theories and facts related to computer science, etc.

In Europe, the list and content of the competencies for technical and engineering professions regulated by the European

Society for Engineering Education, known as "SEFI standard". If we compare Russian ones with SEFI Standards, so we can say SEFI Standards are very specific and allow unambiguous quantification of the level of each competence achievement. Therefore, the study and the transfer of such useful experience, as SEFI-standards in Russia are highly relevant [3].

The current problem importance of modern higher technical education, therefore, is to develop ways to increase the level of learning competencies across mathematical disciplines and at the same time minimizing the subjective evaluation component. So, the using computer based training software (special software, training, and simultaneously assessing the level of acquired skills) is a good answer to solve this problem.

The aim of this study is to develop the methodology and practical implementation of specialized computer programs, so-called "computer-based tutors". The tutors are aimed to students mastering the professional competencies specified in educational standards. Additionally, the paper explores the benefits provided by computer-based tutors in comparison with traditional methods of teaching mathematical disciplines.

Literature Review

Kazan National Research Technical University trains specialists in the field of aeronautical engineering. Numerical methods are an essential part of mathematics education in the Kazan National Research Technical University. In particular, the numerical methods are needed for students studying the design of aircraft engines [4; 5], fuselages [6; 7] optimization problems [8], for aircraft flight control tasks [9] etc. In opinion of many students the study of mathematics is the most difficult part of learning [10].

Now days, many university professors are disputing about whether the using computers is effective in numerical methods studying. Some of them insist that computer calculations can reduce time and improve calculations accuracy, while other believe that only classical computations (i.e. manual calculations) allow students to thoroughly understand the calculation algorithm. The last statement, however, largely depends on the teacher's personality and the level of understanding of his explanation for the students [11].

The years of the Optimization Methods and Decision Making Theory teaching in the Kazan National Research Technical University named after A. N. Tupolev-KAI enabled us to compare the different learning approaches [12–14]. It also helped to reveal the strongest points of each one.

The mastering specific knowledge, skills and abilities task gained additional impetus by introduction competence approach into educational process and demanded new solutions. To the fore the criterion of depth of assimilation of each competence. The main point for the practical blocks of mathematical disciplines is skills (operational and informational components), SEFI international standards to the levels of development level-1 *(Level 1 comprises the knowledge and skills which are necessary in order to underpin the general Engineering Science that is assumed to be essential for most engineering graduates. Items of basic knowledge will be linked together and simple illustrative examples will be used)* and level-2 *(Level 2 comprises specialist or advanced knowledge and skills which are considered essential for individual engineering disciplines. Synoptic elements will link together items of knowledge and the use of simple illustrative examples from real-life engineering)*.

As a result, so-called "computer-based tutor" has been defined as the most effective method of learning. It is a kind of algorithmic calculator that has a user-friendly interface executing step by step a studied algorithm and computational errors detection in parallel. The idea of intelligent computer programs, partially or completely replacing human teachers has been developing in Russia [15–17] and other countries [18–20] for a long time. However, in Europe, researchers made significant progress in their practical development and application in the educational process. For example, in German Research Center for Artificial Intelligence

(Saarbrücken, Germany), MathBridge system, a special intelligent environment has been created for developing e-learning mathematical courses, which enables to create interactive multi-level step-by-step exercises for fundamental mathematical disciplines [21; 22]. This system is successfully applied at the Technological University of Tampere (Tampere, Finland) [23], the University of Saarland (Saarbruecken, Germany) [24], Lyon University Claude Bernard 1 (Lyon, France) [25]. Also at the Claude Bernard University, the computer tutors with embedded objects GeoGebra are used for teaching the so-called "bridge-courses", which facilitate mastering higher mathematics for first-year students.

Materials and Methods

In order to find the best solutions for the implementation of educational practices within the competence approach, it is necessary to take into account not only the completeness and depth of the theoretical knowledge obtained, but also the practical aspects, that is, the skills for mastering the professional engineering competencies. That is the reason why the system analysis methods of modern domestic and foreign pedagogical practice have been used in this study.

The data of pedagogical experiments on the introduction of computer-based tutors into the training process for engineers collected under the international project TEMPUS-MetaMath (Tempus Project No. 543851-TEMPUS-1-2013-1-DE-TEMPUS-JPCR) have been analyzed. The author's computer-based tutor has been developed and introduced into the educational process. Based on empirical observations, its strengths and weaknesses have been revealed. As a result of the comparative analysis, it has been revealed that the developed approach provides the best conditions for mastering professional competencies in comparison with traditional methods. On the basis of the Rating system of measurements, a quantitative evaluation of the measure of this advantage has been obtained, which resulted in an increase in the percentage of successful students.

Results

Based on the competence approach, the methodology of creating a computer tutors has been developed. The target component of the methodology is to increase the effectiveness of the professional skills mastering for engineering students. Requirements of employers to the training quality of future engineers are the source for this methodology. The main content principle is the principle of practical training orientation. From a technological point of view, the methodology for creating a computer-based tutor is based on the following principles:

The computer-based tutor does not make calculations automatically and it does not replace a researcher. It does not work like "press the button and you will receive a result". Most points of computer studying opponents are just based on the assertion that the program "does everything instead of student". It is the disadvantage that computer-based tutor doesn't have. This feature provides cognitive and operational component of professional competence in Russian educational standards or competencies to level-1 standards SEFI.

The computer-based tutor has a multi-layer structure [26].

The first layer interacts with a student (let's call it the interactive layer). It implements a sequence of algorithm's operations and performs the simplest arithmetic operations requesting the key information from a student. The layer provides development of methodological, operational and informational components, and corresponds to level-2 standard SEFI. It is the lack of the simplest routine calculations in studying that inclines the manual calculations opponents to use computer-based tutors.

The second layer implements the basic calculations (let's call it the operational layer). It makes all calculations completely and it is used to control a student. The inner results of the operational layer are not available to a student. Despite the fact that the layer does not provide assimilation of competencies, it is very important as an objective verification the mastering degree of competencies. The application of com-
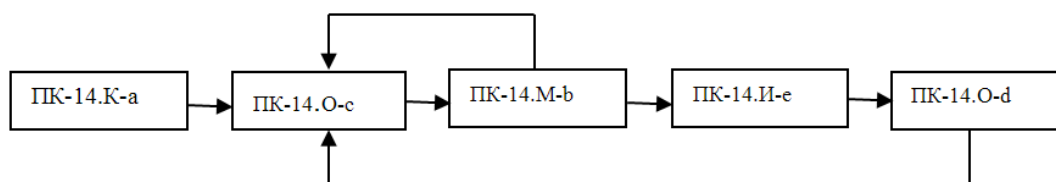
petence approach becomes meaningless without an objective assessment.

The operational layer of the computer-based tutor performs all calculations in one stage and it keeps the key calculation results and each step operations in a special storage facility for follow-up control of student's actions.
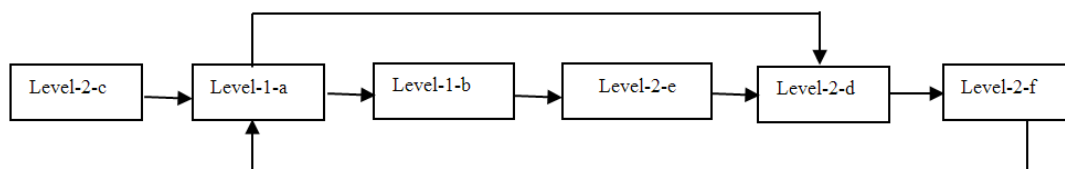
The interactive tutor's layer works by step-by-step manner according to algorithm's stages. At every step a student answer (input data) is checked wherein standard response is retrieved from internal storage. Going to the next step is possible only if the current step is learnt successfully. This feature provides operational and information component of professional competence in Russian educational standards or competence level-2 SEFI standards.

The computer-based tutor has a friendly interface to monitor progress solution, input data and implementing operations. Also, the interface provides information about mistakes that have been made. This function is necessary to assess the competencies mastering level and as an informational component of professional competence.

The evaluation component of the methodology consists in the ability of the computer tutor to independently adequate estimation of the received skills of students on the basis of point and rating system.

The methodology covers most the professional competencies that need to be studied. Also, students are guaranteed to receive the necessary competencies in the right sequence.

Thus, competence-based scheme of operation of a particular computer tutor to study computational potential method can be represented in the following way:

For Russian Competence system:

For SEFI standard competences:

The functioning of a computer based tutors in the process of mastering professional competencies.

As example, let's consider a computer-based tutor for UV-method. It is used for solving the Classic Transportation Problem (CTP) [27].

According to the educational program (curriculum) of discipline, the following competences must be mastered in the process of studying this unit:

РС(ПК-14): to justify design decisions, to carry out the formulation and execution of experiments to test their correctness and effectiveness.

The contents of the components:

1. Cognitive (C):

a) build mathematical models for typical application tasks.

2. Methodical (M):

b) apply effectively the techniques of finding solutions to research problems.

3. Operational (O):

c) apply the classification to determine the optimal methods of solution;

d) use effectively a ready-made software packages to solve applied problems.

4. Informational (I):

e) apply existing methods of solution for problems of different classes.

SEFI European competences for this section of the course are:

Level-1:

a) apply the functions to a practical problem;

b) represent a system of linear equations in matrix form.

Level-2

c) recognise a linear programming problem in words and formulate it mathematically;

d) understand the concept of duality and be able to formulate the dual to a given problem;

e) convert a linear programming problem into a simplex table;

f) use the dual problem to solve a minimisation problem.

The sequence of the training program units is dictated by the sequence of the development of appropriate competencies. "The Classical transportation problem" competences should be mastered in the following sequence:

For Russian system of competences
• PC-14.C-a (ПК-14.К-a)
• PC-14.O-c (ПК-14.О-c)
• PC-14.M-b (ПК-14.M-b)
• PC-14.I-e (ПК-14.И-e)
• PC-14.O-e (ПК-14.О-d)

For SEFI competences
1) Level-2-c
2) Level-1-a
3) Level-1-b
4) Level-2-e
5) Level-2-d
6) Level-2-f

It is important to keep this sequence in the design of the computer based tutors to prevent any lag or skipping necessary competences, however, avoiding the premature flow of the material, when mastered level doesn't allow the student to proceed to the next stage.

Let's consider how these competences are learnt while using a computer based tutor. This tutor teaches numerical iterative method, so the sequence of competences learning can (and in this case should) contain cycles that do not contradict the principle of sequence mastering.

The algorithm for the UV-method includes both calculating steps (scope of delivery calculation and so on) and positioning tasks to define which cell is to modify or which cells must be chosen for solving task. Also, the algorithm has graphical steps such as defining the nodes and arcs of loops. Therefore, the computer-based tutor is able to demonstrate the advantages of suggested approach.

Let's consider the steps of computer-based tutor to understand how the tutor works

Step 1. Data Input. (The interactive layer is functioning).

The applying competences :

For Russian Competence system:
• ПК-14.К-a

For SEFI standard competences:
• Level-2-c
• Level-1-a
• Level-1-b

An example of tutor functioning:

To begin the program the executable file "КТЗ.exe" must be run. Then the tutor requires to assign the dimension of CTP (Fig. 1).
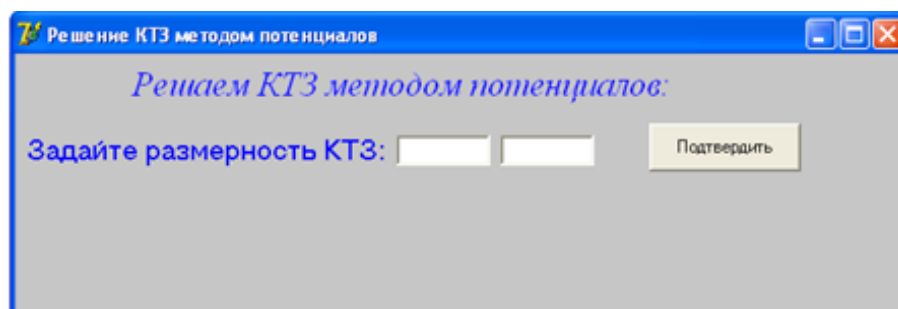

F i g. 1. Input of CTP's dimension
Р и с. 1. Окно задания размерности КТЗ

According to the input dimension, the tutor requires to input the transportation tableau with amount of shipping for each cell (Fig. 2, 3).

F i g. 2. A blank window for input
Р и с. 2. Пустое окно ввода данных о перевозках

F i g. 3. The data have been input
Р и с. 3. Данные о перевозках введены

Solution verification starts when data are input. According to the UV-method the transportation problem has solution only if the condition of balance is satisfied. In other words, there is an equality between output and consumption. A student has to check the balance in advance. If output and consumption are not balanced, so a student has to do some additional operations before solving the problem. The tutor checks the balance. If input data are not balanced then the error message appears (Fig. 4).

So, it is impossible to continue solving the problem. The student has to change the data so they will be balanced. Then he inputs new data again.

If the data are preprocessed in the right way, then the computer-based tutor will admit the student to the next steps (Fig. 5).
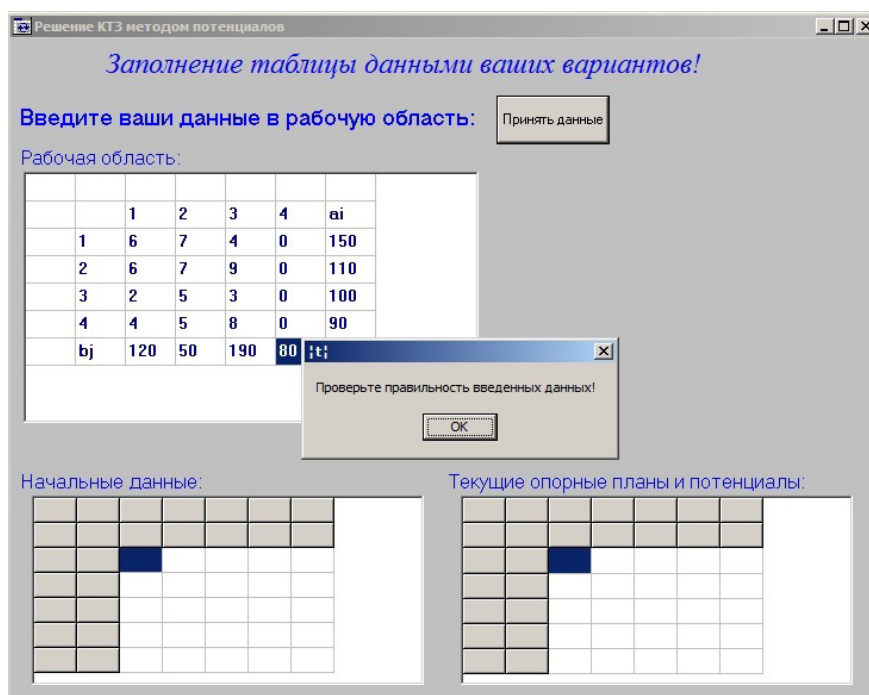
ТЕОРИЯ И МЕТОДИКА ОБУЧЕНИЯ И ВОСПИТАНИЯ

F i g. 4. The data have not been balanced
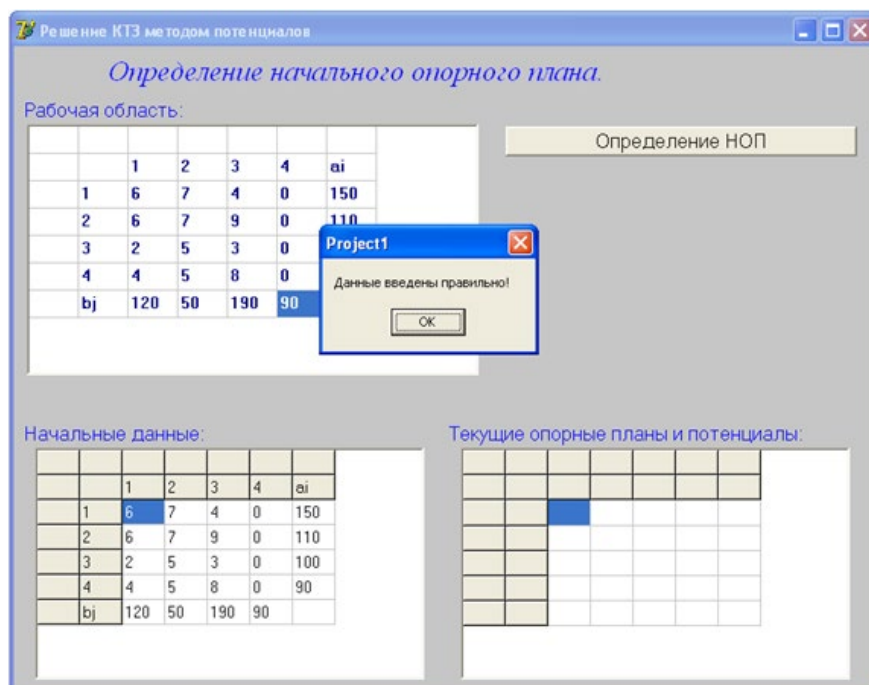Р и с. 4. Данные не сбалансированы

F i g. 5. The input data are correct
Р и с. 5. Данные введены правильно

The advantages provided on the step 1 are the following.

• Dealing with a computer program is far more comfortable for young people today than making calculations manually [28]. The students have feelings that performing a task with the help of computer is easier. It motivates students and attract interest.

• The computer-based tutor excludes automatically the possibility of using incorrect data in calculations. While you are calculating manually the mistake would be detected only in few steps later. It is impossible to continue calculations without correcting the error of the current step. This condition exempts students from unnecessary work in the future, and at the same time it draws attention to the mistake.

Step 2. The defining an initial Basic Feasible Solution (BFS). The operational and the interactive layers are functioning. The applying competences:

For Russian Competence system:
• ПК-14.О-c
• ПК-14.М-b

For SEFI standard competences:
• Level-2-e
• Level-2-d

An example of tutor functioning:

The operational layer makes calculations the values of amount of shipping in the transportation tableau with the Least-Cost Method [29]. The following internal structures are created to store the results:

• interim results for each stage of the Least-Cost Method;

• the accessory table of each cell to the basis;

• the distributional table with calculated amount of shipping.

The interactive layer suggests determining step by step the elements of the initial BFS with the Least-Cost Method. Each stage is divided into separate operations. On each step, the validity of each operation is controlled by comparing stored data with student input data.

• The **Stage 1** of defining an initial BFS is the shipping amount calculation for the pair of supplier-customer with the lowest transportation cost.

Operation 1. To define minimum transportation cost. In case the answer is correct, the cell of the distributional table with this value is rubricated (Fig. 6; 7). If the answer is incorrect, the interactive layer provides a message, and it is required to carry out the current operation again.

F i g. 6. The value entry of the minimum cost
Р и с. 6. Ввод значения минимальной стоимости с проверкой

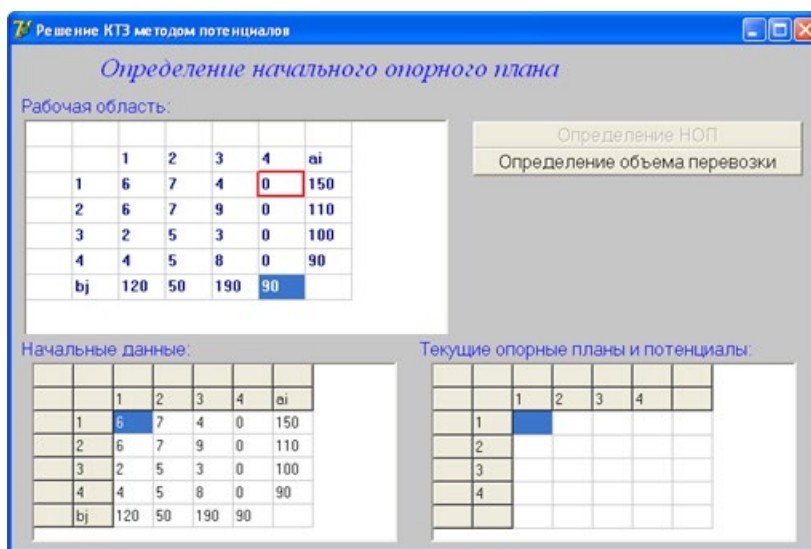ТЕОРИЯ И МЕТОДИКА ОБУЧЕНИЯ И ВОСПИТАНИЯ

F i g. 7. The cell for amount of shipping assignment
Р и с. 7. Клетка для назначения объема перевозки

Operation 2. Determination of the amount of shipping for the cell with the minimum cost. If the value entry is correct, so the interactive layer displays a message about the right decision. It stores the calculated volume from the inner table of the operational layer to the dynamic distribution table which is viewed at the right bottom of the window (Fig. 8). In the main distributional table the data is updated in accordance with the intermediate calculations results of the operational layer (Fig. 9).
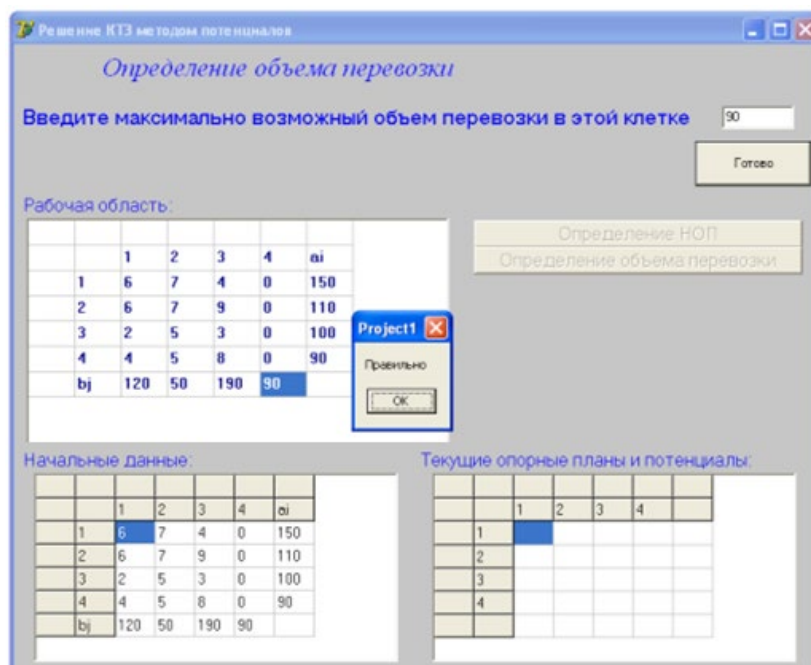

F i g. 8. Entry the maximum shipping amount
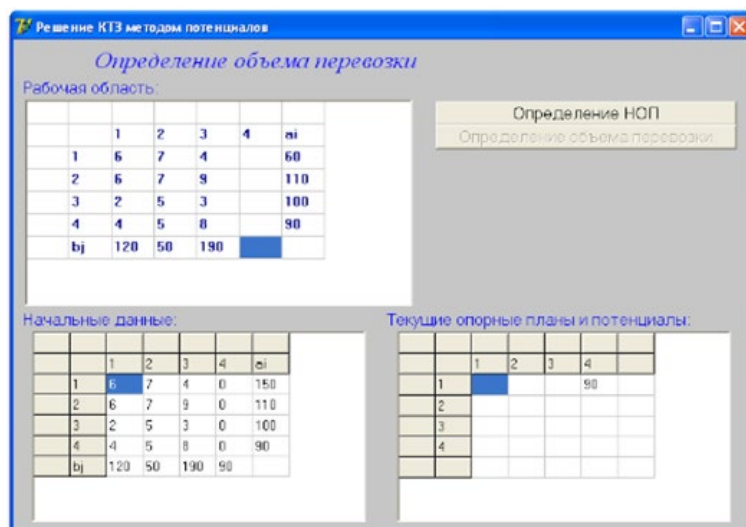Р и с. 8. Ввод максимально возможного объема
перевозки с проверкой

F i g. 9. Updating the interactive layer's tables
Р и с. 9. Обновление таблиц интерактивного слоя

If the student's value entry is incorrect, the operation is repeated. The steps of the Least-Cost Method are repeated until the initial BFS is built. Totally, student must implement the (m + n1) steps of the same type (Fig. 10).
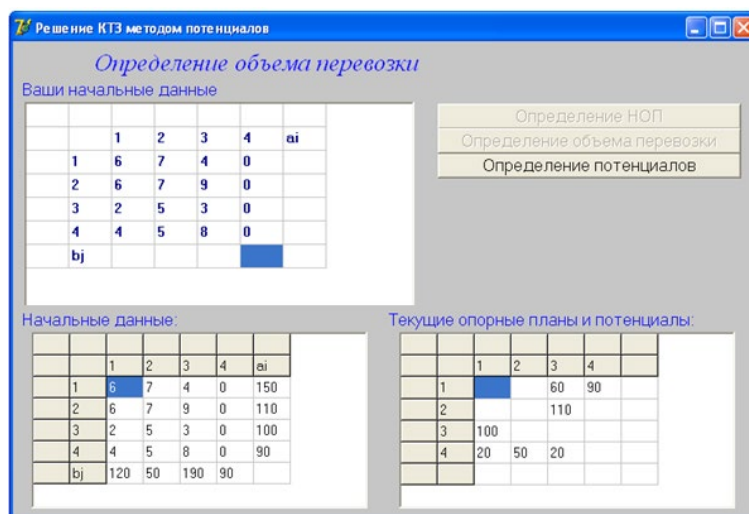

F i g. 10. The initial BFS has been built
Р и с. 10. Опорный план построен

The advantages provided in Step 2 are the following:

• The student reiterates homogeneous computational procedures that help to drill the using the method skills into the students. However, there is no risk of computational error accumulation, which is very typical for manual calculations.

• The computer-based tutor does not allow the student to deviate from the algorithm, and it monitors the correct input at each operation. It allows practicing the ability of the method using for second-nature.

• The results of decisions are rendered in real time that gives a comprehensive picture of the calculations.

Step 3. The dual variables calculation. (The operational and interactive layers are functioning). The applying competences:

For Russian Competence system:
• ПК-14.И-е
• ПК-14.О-d

For SEFI standard competences:
• Level-2-d
• Level-2-f

An example of tutor functioning:

The operational layer calculates the dual variables [30] of lines U and columns V of the transportation table. It is based on the table of element signs belonging to the set of the BFS. The table has been obtained in the previous step. As well, the operational layer uses the input data, i.e. the cost of transportation between the points of production and consumption. Based on the calculated values of the dual variables, the operational layer produces elementary calculations to determine the opportunity cost Δ_{ij}. Then, it calculates the integrated logical criterion of optimality. As a result, two dynamic data vectors, one matrix and one logical value are generated:

• U, the vector of dual variables for rows;
• V, the vector of dual variables for columns;
• Δ, the matrix of opportunity cost;
• the logical criterion of optimality.

The interactive layer provides a student with the information in tables which is necessary for the calculations. To make correct calculations of dual variables, the student has to be able to use the data obtained on the previous step, and the input data (Fig. 11). The student must fill in the column u_i and the row v_j with the corresponding values of dual variables. Besides computer-based tutor does not hint what data should be used for calculations and how it should be used. After filling in the corresponding cells of the transportation tableau by the obtained values, the data validation is performed by comparing the data from the internal vectors U and V of the operational layer (Fig. 12).

F i g. 11. The prepared data for calculating dual variables
Р и с. 11. Подготовленные данные для расчетов потенциалов

If data filling is totally correct, the student will be able to go to the next step. Otherwise, the step has to be repeated.

The advantages provided in Step 3 are the following:

• The student has only the necessary data for calculation. All redundant data remain hidden by the computer-based tutor. On the other hand, the calculation process at this step is quite intricate, and it requires

a clear understanding the sequence of using available data. Such selective approach allows the student to focus only on the important aspects of the making calculations, and avoid errors, and at the same time to feel features independently.

F i g. 12. The entry values are ready to test
Р и с. 12. Введенные значения готовы для проверки

• Control of calculation correctness does not allow going to the next step without mastering this one.

Step 4. Making decision if the received BFS is optimal. (The interactive layer is functioning).

For Russian Competence system:
• ПК-14.О-с
• ПК-14.М-b
For SEFI standard competences:
• Level-1-a
An example of tutor functioning:

The decision of optimality is based on information about the signs of the opportunity cost matrix Δ elements. The student is provided with the calculated the opportunity cost matrix Δ elements. A required answer to the only question is if plan in this case is optimal. The correctness of the choice is determined by comparison the response with the existing logical criteria of optimum of the operational layer (Fig. 13).

It is a logical step. The wrong answer does not entail a return to the beginning of calculations, but the total error count increases.

Step 5. Determining the loop to improve the basis. (The operational and the interactive layer are functioning). Step is positional and it does not require any calculations. The applying competences:

For Russian Competence system:
• ПК-14.О-с
• ПК-14.М-b
For SEFI standard competences:
• Level-1-a
An example of tutor functioning:

Based on the values of opportunity cost matrix elements and the distributional table with the current basis, the operational layer determines the coordinates of the table cells within the loop. Using parity indication, the operating layer determines a mark for each selected cells. As a result, the following arrays are created:

• The array which is the sequence of loop cell coordinates;
• The array with loop cell marks.

F i g. 13. The interactive form of optimality validation
Р и с. 13. Интерактивная форма проверки оптимальности

The interactive layer provides the student with the necessary data tables and offers to mark out the cells of the loop with the mouse. The cells allocated by the student are encircled in red (Fig. 14). Allocation of cells can be performed in any order. The allocated cells are compared with the array of cells' coordinates of the loop of the operational layer. In the case of correct indication of positions, the found loop is drawn on the working form and the loop's nodes are automatically marked on the base of the mark array of the operational layer. Then the student goes to the next step (Fig. 15).

F i g. 14. The positional loop's cell identification
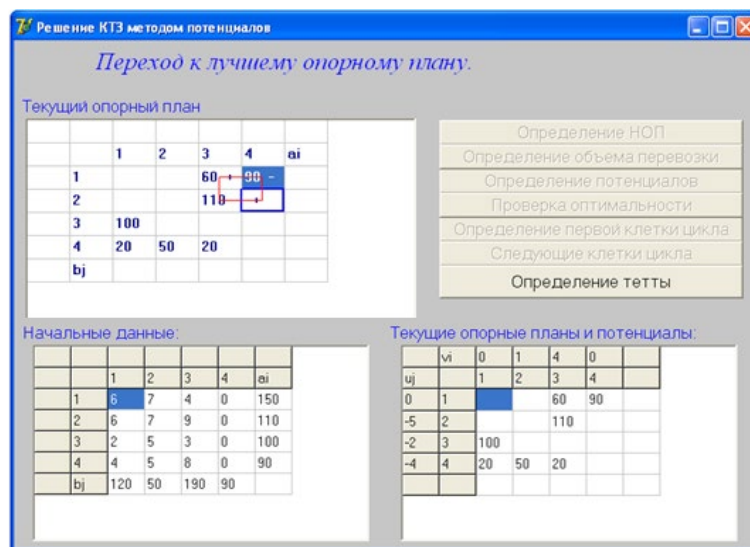Р и с. 14. Позиционное определение клеток цикла

F i g. 15. Visualizing the selected loop with notes
Р и с. 15. Визуализация выделенного цикла с пометками

Otherwise you must specify the position again.

The advantages provided in Step 5 are the following:

• The step does not require calculations, but presenting it as a separate stage of the algorithm as a whole, the computer-based tutor focuses the student on the importance of this step.

• The visualization of the determining positions of cell cycle process allows the student to present the loop as a whole. Incorrect indication of the position can be determined by the visual level, without recourse to the verification procedure.

• Checking the correct positioning does not allow going to the next step without mastering this. Incorrect definition of the cell cycle can lead potentially to false-optimal results.

Step 6. Improving the initial BFS. (Operational layer and Interactive layer are functioning). The applying competences:

For Russian Competence system:

• ПК-14.И-е
• ПК-14.О-d

For SEFI standard competences:

• Level-2-d
• Level-2-f

An example of tutor functioning:

The operational layer calculates the correction the elements (value) of loop cell traffic volumes and adjusts the loop. As a result, the following data are generated:

• The correction value;
• An improved BFS after the correction.

The interactive layer provides the student with a window to enter the calculated value of the offset. If the value has been calculated correctly the interactive layer adjusts the current basis on the active form (Fig. 16).

When there is successful completion of this step it will return to Step 2.

The advantages provided in Step 6 are the following:

• The correctness calculation control does not allow going to the next step without mastering this one.

• The step algorithm reiteration and simultaneous inability to perform further error calculations allow students to learn the algorithm thoroughly and only in its correct implementation.

Step 7. Displaying the results of material mastering. (The interactive layer is functioning). This step represents a tool of quantitative assessment of mastering level competencies and it is necessary for the adequate estimation of the received skills of students on the basis of point and rating system. The calculation can be performed for Russian and European system of competencies.

ТЕОРИЯ И МЕТОДИКА ОБУЧЕНИЯ И ВОСПИТАНИЯ
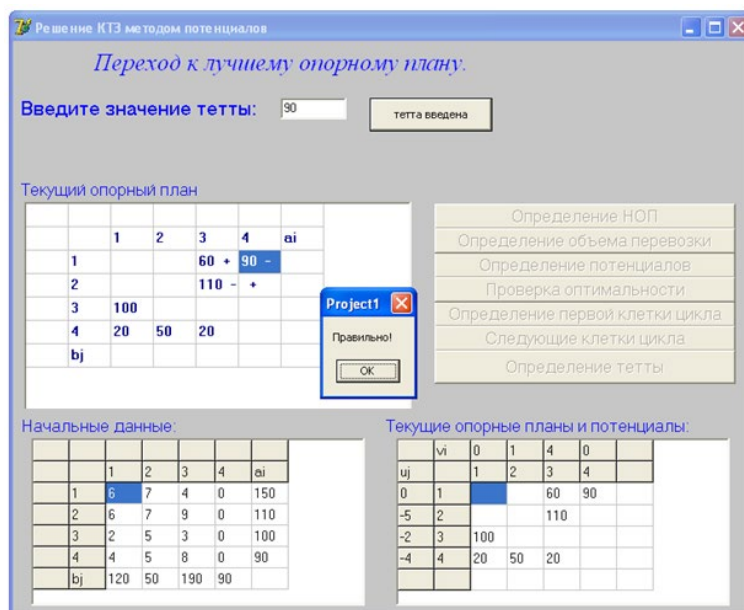
F i g. 16. Inputting the correction value with checking
Р и с. 16. Ввод величины коррекции с проверкой

An example of the operation of the machine. Once an optimal plan (Fig. 17) is obtained as a result of multiply sequences of repeating the steps 2-6, the interactive layer shows overall statistics on the errors made in the calculations (Fig. 18).
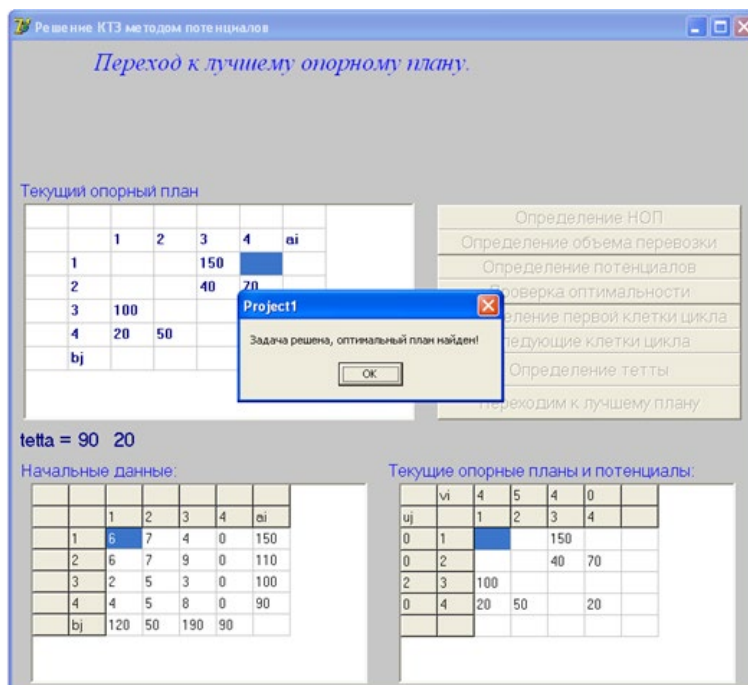

F i g. 17. The message about calculation completion
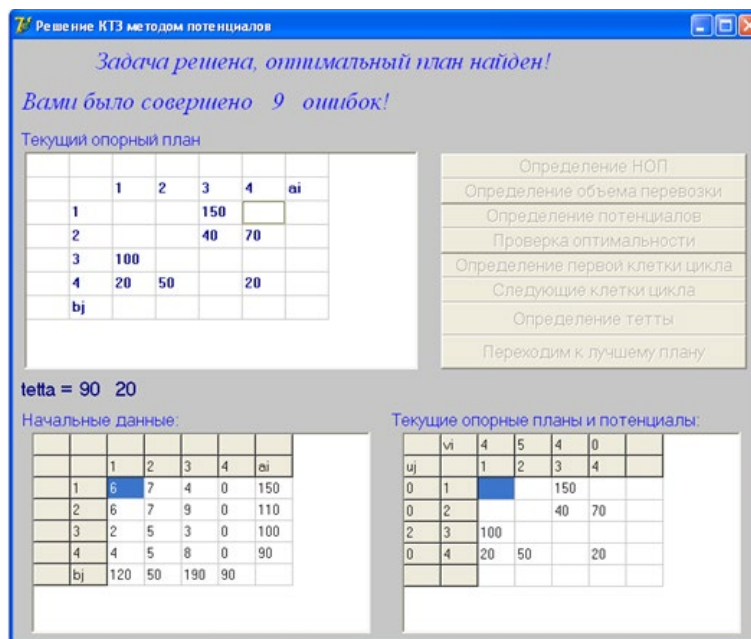Р и с. 17. Сообщение о завершении вычислений

F i g. 18. Information about the errors
Р и с. 18. Информация о допущенных ошибках

The pedagogical experiment on the introduction of a computer tutor into the educational process was implemented at Applied Mathematics and Informatics Department of Kazan National Research Technical University named after A. N. Tupolev-KAI for 3rd year students studying on the Bachelor program "Applied Mathematics and Informatics", "Informatics and Computers", and "Software engineering". The results were evaluated according to two criteria:

• Improving the quality of training (on the point and rating system)

• Increase the students motivation to study mathematics (based on a special questionnaire by Lyon University Claude Bernard 1).

As a result of using the computer-based tutors in the training in computational optimization methods and in Making Decision Theory methods of technical universities students, the progress in studies has been recorded: the percentage of positive ratings increased from 65 to 88 %. The interest of students in mathematics increased by 12 percent on average. These results are explained by the following benefits of the computer-based tutors over the classical method of manual calculations:

1. Automatic exclusion errors in intermediate calculations.

2. The multiple repetitions of routine computational procedures without the threat of the accumulation of errors.

3. The high-quality visualization of solutions.

4. The automatic analysis of the solutions (counting errors, identifying the most serious errors, the most frequent errors, etc.).

Discussion and Conclusions

The method of computer-based tutors creation and use is intended for application in the educational process of technical universities when teaching students mathematical and engineering disciplines.

The use of computer equipment allows increasing the effectiveness of teaching mathematics within the competence approach by:

1) a full accounting all required competencies in the construction of the software blocks of the tutor;

2) a strict keeping the sequence of competencies mastering and program units with tasks for students;

3) objective quantitative assessment of the competencies mastering level.

The results of this research can be applied to create both auditory and remote computer mathematical courses on the basis of specialized e-learning systems (Math-Bridge is the implementation on the base of Saarland Technical University), multifunctional e-learning systems (MOODLE is the implementation on the base of University Claude Bernard Lyon 1), or as independent e-learning units implemented in high-level programming languages. The last version of the implementation is used in the educational process at Applied Mathematics and Informatics Department of Kazan National Research Technical University named after A. N. Tupolev-KAI for 3rd- year students studying on the Bachelor program "Applied Mathematics and Informatics", "Informatics and Computers" and "Software engineering".

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Svetlana V. Novikova – scientific supervisor of the project.

Sergey A. Sosnovsky – developed the training trajectory and evaluated the results of the program-tutor introduction in the educational process.

Rouzilya R. Yakhina – made a significant contribution to the translation of the text into English.

Natalia L. Valitova – participated in the development and technical support of the computer-based tutor.

Elmira Sh. Kremleva – actively participated in the implementation of the computer-based tutor in the learning process.

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