US-China Education Review A 4 (2011) 439-463
Earlier title: US-China Education Review, ISSN 1548-6613

Science Learning With Information Technologies as a Tool for "Scientific Thinking" in Engineering Education

Eugeny Smirnov, Vitali Bogun
Yaroslavl State Pedagogical University, Yaroslavl, Russia

New methodologies in science (or mathematics) learning process and scientific thinking in the classroom activity of engineer students with ICT (information and communication technology), including graphic calculator are presented: visual modelling with ICT, action research with graphic calculator, insight in classroom and communications and reflection of integrative actions. How can we show our students the beauty of science (and mathematics) with ICT and the way scientists think and try to find the truth? Is it possible to create the motivation in science learning for students using ICT or graphic calculator? How can we organize the engineer training on such professional activity in classroom? In this paper, we tried to answer the questions using methodology of visual modelling and technology of resource lessons in high engineering school, including remote e-learning environment.

Keywords: visual modelling, ICT (information and communication technology) or graphic calculator, resource lessons, engineer education, motivation in science (mathematics) learning

Introduction

In education process for future engineer in science (including mathematics), we remark a lot of opportunities for the developing of "scientific thinking" and special engineering skills using ICT (information and communication technologies) which gives rise to new opportunities in increase of motivation and efficiency of problem-solving in science, as well as personal and mathematical training of the future engineer (Savenkov, 2000; Bogun & Smirnov, 2008; Motivation in Science Education, 2003; Voogt, Gorokhovatsky, & Almekinders, 2003).

One of perspective directions of computerization in a science and mathematical training of engineer is using of CMS (computer-aided mathematical systems) and graphic calculators in scientific research of students in learning of science and mathematics. CMS are universal mathematical packages of symbolical and numerical calculations (MathCad, Mathematica, Maple and so on) and have joined the category of working instruments for analytical calculations. Using of a graphic calculator in teaching of science and mathematics, being an operative instrument for solving complex computing problems as well as an instrument for recording and visualization of various stages in solving problems, raises interest to science and mathematics and makes the spectrum of cogitative operations. On the other hand, the future engineer should not treat the ICT only as the object of study of their functions, modes, options and communications in order to solve scientific and didactic problems, but a tool to control cognitive and communication activity of students in their future professional work.

Eugeny Smirnov, professor, Ph.D., Yaroslavl State Pedagogical University.
Vitali Bogun, assistant professor, Ph.D., Yaroslavl State Pedagogical University.

The ICT utilization gives a unique opportunity to increase the level of the personal development of a student: growth of computational and algorithmic culture, development of spatial reasoning and graphic culture and expansion of a cognitive circuit spectrum in thinking processes, i.e., perception, understanding, representation, etc.. Moreover, mastering of complex intellectual activity leads to acquiring and development of productive thinking of students on the base of scientific thinking and involving the scientific methodology in learning process.

The opportunity of communications, as well as using of information ideas in the process of exchange of didactic and scientific experience by students via Internet, for distance training and use of electronic working environments as well as training material, are of great importance of students more intense and influence the ways of the training contents presentation.

However, there is still some work to do. The experience of the projects mentioned show that most science teachers emphasize in their lessons the contents of science and pupils must learn concepts, formulas, laws and models without ICT or some. Education is in favor of acquiring declarative knowledge. Yet, there are a number of contradictions connected with the ICT used in scientific training and mathematical education of the future engineer, namely:

(1) Between the rate of development of information technologies and the state of teaching of science and mathematics in engineering universities and colleges;

(2) Between opportunities of use the CMS in teaching science and mathematics and inadequacy of scientific methodical development;

(3) Between the necessity of creating in students the skill of construction of algorithmic model, while solving a science, mathematical and real problem and significant volume of the calculations interfering with comprehension of a model structure;

(4) Between the necessities of formation computing skills of students and practical use by students of computer mathematical systems when they solve problems independently.

We understand that scientific thinking of students will have a background, if the essence of scientific recognition is opened and will have the special educational activity of students in the integration ICT in science oriented on competence-based education (Arnold, 2000; Smirnov, 1998; Salmina, 1988). We should pay attention to scientific activity, scientific interactions and cognitive acts similar to the scientists work. The good experience in technologies, the materials and infrastructure developed was considered as important for the development of patterns for repeating. We should create the innovative forms (didactical models and technologies) of organization of students' activities using ICT in science with high motivation. Therefore, we should consider with students the useful, beautiful and essential professional tasks in science learning using modeling and visualization of complex procedures.

In this paper, the authors will emphasize three aspects related to science learning with ICT and the professional development of engineer in integration process. First, we thought it is a good idea to emphasize the scientific methodology with ICT (Smirnov, Bogun, & Ostashkov, 2007; Smirnov, Shadrikov, Povarenkov, & Afanasyev, 2002). How can we show our students the beauty and use of science and the way a scientist thinks and tries to find the truth? Contents and subject matter will be important, but sometimes we should reach the essence of phenomena or process only using ICT. However, to introduce science for public understanding, we must emphasize the thinking process of scientists. It will help the students to get a better understanding of what science and practice is all about, and at the same time, it will motivate them to learn (more) about science with visualization of algorithmic procedures and adequate mathematical actions. Second, we liked to model the real phenomena and process (including mathematical, science and information models) in integration at different levels with forming the research habits and skills (with the use of ICT). Finally, we would like to form the engineering skills: problem-solving in choice situation, operating the evaluation, creating of models of real phenomena and process on the base of visualization and using ICT.

Goals

The problem of the research was to define conditions of the ICT integration into the process of becoming proficient in scientific and didactic problems of science and mathematical learning the visual modeling basis on of objects and processes by engineer students.

The purpose of the research was to create an integral system (including contents, forms, methods and conditions) of research by prospective engineer in solution of scientific and didactic problems of science education involving of the ICT and utilizing visual modeling of basis and processes, including remote e-learning environment.

Application of the CMS for solution of scientific and mathematical problems by students will promote growth of motivation in scientific research, as well as in professional development of the future engineer on condition that:

(1) The practice of visual modeling is included into educational activity during integration of science and information knowledge;

(2) Students construct models while solving scientific and mathematical problems with application of the CMS, which record mathematical optimum procedure mathematical and information actions;

(3) Students manifest creative activity while learning to use the CMS (a variation of data and analysis of results, formation of hypotheses and their testing and inter-conversion of the sign systems);

(4) Communicative opportunities for dialogue for groups of students during their educational activities are enlarged by means of information environments (media, Internet, conferences and so on).

Tasks (scientific, didactic, information, methodological and professional) are to:

(1) Study functional possibilities, analyze the basic CMS and graphic calculator and create the models for modes of work in the information environment;

(2) Reveal didactic conditions and develop a technique of visual modeling using the CMS (the graphic calculator) during the teaching of science and mathematics and solving of scientific problems;

(3) Develop a laboratory workshop aimed at solving science and mathematical problems using the CMS (the graphic calculator) and the methods of its conducting for students on resource lessons;

(4) Design interactive volume of information by groups of students on the basis of authoring software products and the results of the CMS (graphic calculator) research;

(5) Visualize the procedure of science and information actions on the basis of improvement of students' computing and logic culture.

Scientific Methodologies

The results and products of psychology theories and conceptions will be input for a paper, in which we will emphasize the creative way in which the acquirement of scientific knowledge takes place. They are: competence-based education, visual modeling, scientific thinking, integration levels and motivation process. We will answer the question how to introduce the ICT in process of scientific thinking and professional skills forming into the learning process of students in engineering education. Action research with ICT will be introduced as a tool for future engineer to improve their profession.

Visual Modeling of Objects and Procedures With ICT

The pedagogical technology of visual-modeling learning of science and mathematics plays a fundamental role in the proposed didactic system of science and informatics integration of knowledge and actions (Smirnov et al., 2007; Shadrikov, 1996). This technology makes it possible to achieve stochastically guaranteed result of teaching of various qualitative levels of learned materials as well as integrity of representation of the basic science, information and mathematical structures.

Visual modeling methods of learning present:

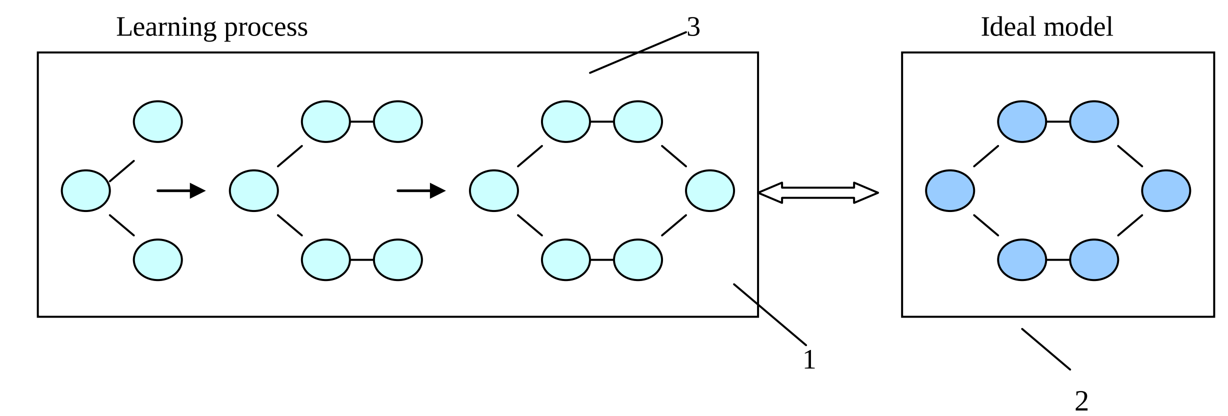
(1) “A priori” modeling the essential links of the object of perception;

(2) A process of forming an adequate category of ultimate purpose of the learners’ internal actions;

(3) During the process of immediate perception;

(4) All teachers’ managing actions, modeling of separate pieces of knowledge or an arranged set of knowledge for stabilizing the learners’ immediate perception.

The definition analysis is shown in Figure 1.



1—The procedure of arranged set of knowledge (the object of perception);

2—An ideal model of the object of perception according to the didactical aim;

3—The result of the student internal actions connected with immediate perception.

Figure 1. Visual modelling of mathematical object (procedure).

The process of perception of the given visual model presupposes all key qualities of the science, information or mathematical object. It is especially important when information is of great volume or contains a mix of mathematical (physical) and informatics knowledge or actions. It is necessary to keep in mind such actions when separate pieces of knowledge or an arranged set of knowledge are given. We can deal with proving theorems, solving problems, constructing the algorithm, modeling the real phenomena and learning some parts of scientific and mathematics analysis in its various logical correlations, with a single lesson presentation, a lecture, etc..

As it has already been mentioned, according to A. N. Leontyev (a Russian psychologist), when visual methods of learning and teaching are used, it is necessary to proceed from the psychological role which they (methods of learning or teaching) play in the perception of new material. He chose two functions of visual methods of learning or teaching: The first is aimed at extending the sensible experience; and the second is aimed at developing the essence of the processes or phenomena under study.

In connection with that, external teacher's actions are divided into bearing and structural actions depending on the orientation of the sensible or rational element of perception.

The external bearing actions can be as follows: writing down formulas, tables, displaying models, drawing up graphs, formulating theorems, programming or logical actions and using text-books or manuals. The structural external actions can be as follows: proving theorems, choosing the main theoretical notions and methods and realizing links among different subjects.

According to our concept, the use of visual methods in learning or teaching of science of a future engineer is treated as a special property of psychological images of science or mathematical objects, the essence of which is considered in an integral paradigm of perception of the basis of the following criteria:

(1) Diagnosable aim-finding of integrity of the science or mathematical object;

(2) Adequate perception (learner's comprehension of essence of the science or mathematical object in accordance with aims of learning or teaching);

(3) Stability of perceptive image and presentation under conditions of direct perception;

(4) Cognitive and creating activity on the basis of relaxed and successful learning.

We should follow he next structure of visual modeling as procedure the analysis of science, informatics or mathematical object as a part of scientific thinking (see Figure 2).

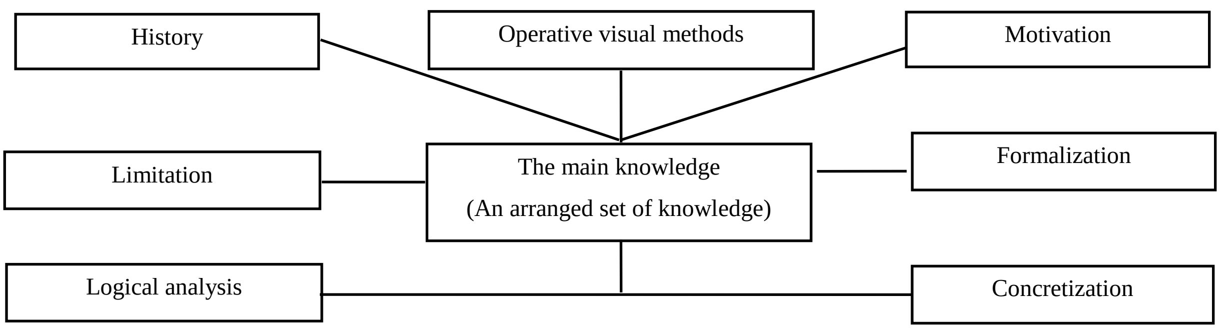


Figure 2. The structural analysis of the key knowledge.

Future engineer of the target group will develop lesson modules in joint activity to show how a start can be made with introducing scientific thinking in problem-solving with ICT. We will use new technologies, such as computers, in the learning environment of the students.

Uniform Environment of E-learning

Intensive development of ICT promotes their using within educational process at various levels, including high school. However, the basic criterion of ICT application within of educational activity is the organization of optimum schemes of integration ICT with various standard techniques of subject training and independent activity of pupils. The modern period in the development of ICT can be characterized by two essential tendencies. On the one hand, gradual transition from using ICT of local user directly on the realization of remote interaction between various users (pupils and teachers) within local or global networks is carried out. On the other hand, gradual transition from using of stationary ICT resources to the application of mobile ICT, treated as small resources of information (graphic calculators, a handheld computer, cellular telephones, smart phones, communicators, etc.) is observed. It is necessary to notice that now the given directions are considered as completely independent, not having essential points of functional crossing (Bogun, 2009).

The organization of REP (remote educational process) within local and global networks was carried out to active using of interaction between pupils and teachers in various operating modes ("Prometej", "WebTutor", Moodle, etc.). They often used an on-line mode with direct display of contents, as a rule, in a browser, with necessity of constant connection to a network, or an off-line mode with possibility of necessary materials downloading in the local computer with the purpose of further studying without necessity of connection to a network. Two various interconnected environments for work of users depending on their accessory to pupils or teachers were realized (Ibragimov, 2007; Anisimov, 2009). It is obvious that there are certain distinctions in the organization of work with REP for the given basic categories of participants of educational process.

On the basis of characteristics research of modern REP, it is possible to formulate of essential lacks modern REP, used in Russia:

(1) Absence within REP some realizations of uniform database on teachers and students, considering names of high schools, faculties, specialties, groups and subject matters. It is necessary to underline that the given problem is actual owing to possibilities, on the one hand, teachers work in several high schools simultaneously; on the other hand, train them in various high schools, besides on different specialties within one high school as a whole;

(2) Absence of uniform methodical complex on similar subjects in homogeneous high schools as from the point of view of structure, and the maintenance of methodical and didactic materials. The given problem directly follows from the first problem as absence of a uniform relational database on teachers, students and subject matters directly reflecting the absence of a uniform methodical complex in Russia;

(3) Absence in REP some dynamic resources for realization of educational settlement projects including interconnected works. From the given point of view, modern REP is at all adapted for application in educational process of various settlement projects. Unfortunately, available for today, REP allows realizing of independent students work only on four components. The first is acquaintance of pupils with the lecture contents presented in the form of the electronic textbook; the second is testing of students (use both directly total tasks is supposed, and generating of demos) by in advance teacher completely making by manually of questions and corresponding variants of answers to each of them (there are no automated processes, both generation of various values initial given and logic chains in tasks in general); the third is dialogue within of forums or guest books (as a rule, within considered subject matter as a whole); and also the fourth is possibility of export-import files of documents by the user. Now, designing activity is reduced to creation of presentations and similar documents, which there are no computing and logic projects as those also are inadmissible. It is necessary to notice that, as a whole, there are information possibilities of realization not only computing or logic operations within educational projects on science, but also application of various logic chains and operations to the realization of educational projects on humanities.

At the most modern REP, there is a monitoring of educational students activity only within total control on a subject matter as a whole. It is obvious that the received estimation only indirectly reflects the true level of knowledge and skills of pupils. Absence of the intermediate control on each of sections within subject matter is caused, as it was marked earlier, the absence of possibility on performance of projects and intermediate testing on each of subject sections;

(4) Absence of intuitively clear and high-grade system of navigation within REP finds the negative reflexion in realization of the unfriendly users' interface. The given circumstance is caused by necessity of using a considerable quantity of the program modules which are responsible for various functionality in REP, including beyond educational process, from the point of view of the realization on direct activity of pupils within educational disciplines.

Now, V. V. Bogun has carried out technological working out of information system of REP monitoring of students in high schools which is directed on the decision of absence problem in modern REP of dynamic resources for realization of educational settlement projects. Innovations are presented on the basis of the using of dynamic Internet site that some algorithms of problem-decision generated at the program level with the automated processes of initial data generation, processing and monitoring of intermediate and total results. In particular, the corresponding applied software, which is based on using of Web-server Apache for realization of virtual server in a combination to technology of dynamic Internet sites creation on the basis of programming language PHP (Hypertext Preprocessor) and control systems by relational databases MySQL (Base Data Managing) for realization of necessary inquiries, is developed. REP with strengthening adaptive interactions, constructed on the basis of developed information system of monitoring REP of students, is characterized by following features:

(1) The uniform database on teachers and students within region or the state on the basis of automated account of basic signs (the name of high schools, faculties, specialties, groups and subject matters) was realized, and the uniform database under educational projects and studies entering into their structure for necessary subject matters was realized. Applying to teaching mathematics was shown directly reflecting the presence of a uniform methodical complex on subject matters in homogeneous high schools;

(2) The dynamic system of educational projects from the point of view on necessary of didactic and methodical components of pupils' design activity includes the description of the considered course within subject matters. The list of names and the description of corresponding projects of each course and the list of names, the description, theoretical aspect, demos and settlement tasks on corresponding works within of each educational project were realized. Automated generation of independent variants of demos (values of the initial given, intermediate and total results) for the teacher and the student with possibility of demos viewing both representatives and administrations only for one of the parties was used. Generation of tasks (variants of values of the initial data) was made for students unitary, the teacher should get access to work of students only in a viewing mode and students should get access to the work with possibility of viewing on correctly specified values, viewing and editing of intermediate before values intermediate and total results. It is necessary to notice that realization of demos and settlement tasks for students' activities is carried out according to decision algorithm of corresponding problems developed at programming level of activity;

(3) The dynamic system of pupils testing of subject matters, the project or activity with completely automated processes of values generating of initial data, correct both obviously erroneous results and checks of answers' correctness on test tasks is realized. Possibility of demos generating of corresponding tests, realization of high-grade monitoring of students educational activity of necessary subject matters from the point of view as disciplines as a whole and taking into account results of settlement projects performance and activity thinking completely automated mechanisms of data processing was, thus, used;

(4) Dialogue between students and the teacher in the form of a forum within learning activity was realized that essentially raises clearness of discussed problem borders in forums. It is necessary to notice that the given

process means all-around automation presence. Intuitively clear the user's interface and navigation of REP owing to use of various kinds of dynamic menus essentially facilitating an access to the necessary information (the hierarchical menu with tree use, the menu with use hypertexts, etc.) was applied.

It is necessary to notice that it is possible to be used as didactic material certain sections of linear algebra (a matrix, system of linear algebraic equations and analytical geometry), mathematical analysis (limits and continuity, calculus and differential equations), combinatory, probability theory and mathematical statistics.

Aims and Indicators for Success

To reach goals related to our goals as formulated in the preceding paragraph, we must:

(1) In relation with scientific methodology

(a) Analyze the (international) experiences on how to attract future engineer to science with ICT;

(b) Investigate whether and how the ideas of students on science and the scientific world change during the project;

(c) Describe learning activities (including ICT) in relation with creative and scientific thinking (paradigm shift);

(d) Design activities that can take place within the regular curriculum and/or during short-time thematic projects;

(e) Pilot the develop lesson modules as resource lessons with ICT in engineering education in Russia (see Figure 3).

(2) In relation with action research

(a) Introduce the methodology of action research with ICT;

(b) Support future engineer during the process of action research with ICT;

(c) Create and analyze the methodology of resource lessons with ICT and rewrite the modules;

(d) Develop a manual to show future engineer how to implement and use action research with ICT in their professional practice;

(e) Develop a manual to show future engineer how to implement the kind of activities we designed during the project;

(f) Create the base of professional oriented tasks using ICT in different levels and forms.

Methods of Research

Integration of knowledge assumes possession of the following professional skills:

(1) Skill to solve a problem (formation of a question, finding of scientific information for solution, analysis of a problem situation and setting up of a hypothesis);

(2) Capability for science, mathematical and information modeling (definition of the data, conditions and borders of search of the solution, translation of a problem into the language of mathematics, construction of the adequate mathematical device and integration of the solution);

(3) Skill to apply the ICT;

(4) Skill of scientific and logical thinking;

(5) Communication skills.

Developing the genesis of learning element with ICT as a pedagogical problem (object for mastering by another subject in learning process with ICT) requires the calculation not only mental experience, person characteristics and conditions of activities, but also system analysis of analogical substructure of future subject of mastering in new pedagogical conditions.

Figure 3 shows the structure and factors contents which influence on projecting of science objects (process and phenomena) with ICT as a pedagogical problem (Smirnov et al., 2002; Shadrikov, 1996; Smirnov, 1998).

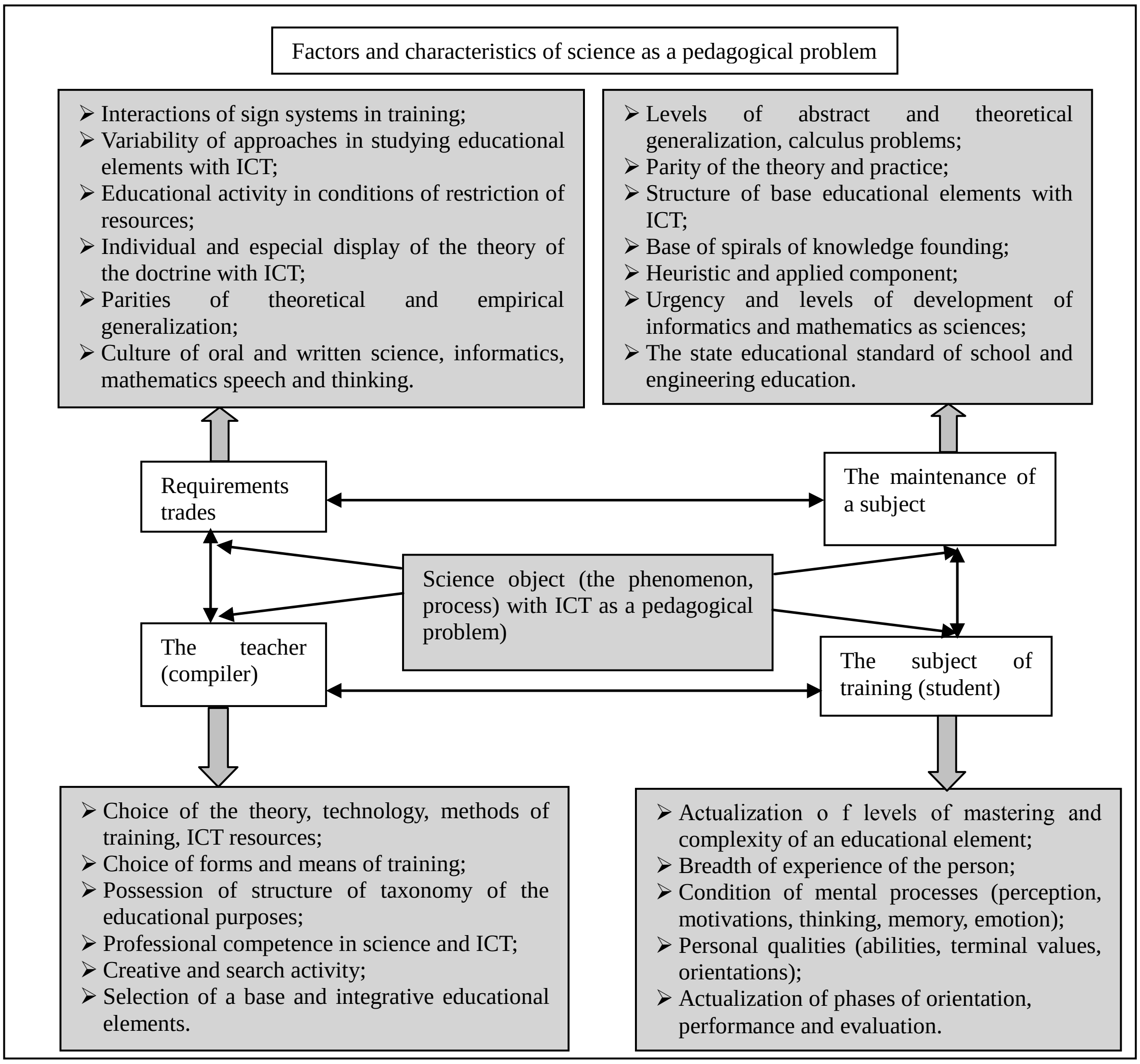


Figure 3. Factors and characteristics of science as a pedagogical problem.

Integration ICT With Science Learning

It is required to teach students to project and investigate mathematical models utilizing the ICT in such components in which their application are necessary and justified (complex computing algorithms, visualization and recording of various stages of science, mathematical or information actions, construction of complex graphic objects, etc.). Thus, the construction of the integrative information model which optimizes the use of an information resource (functions, commands, modes, algorithms, etc.) is a very important problem (Bogun, 2008; Voogt et al., 2003). Figure 4 presents the integrative model of ICT with science learning.

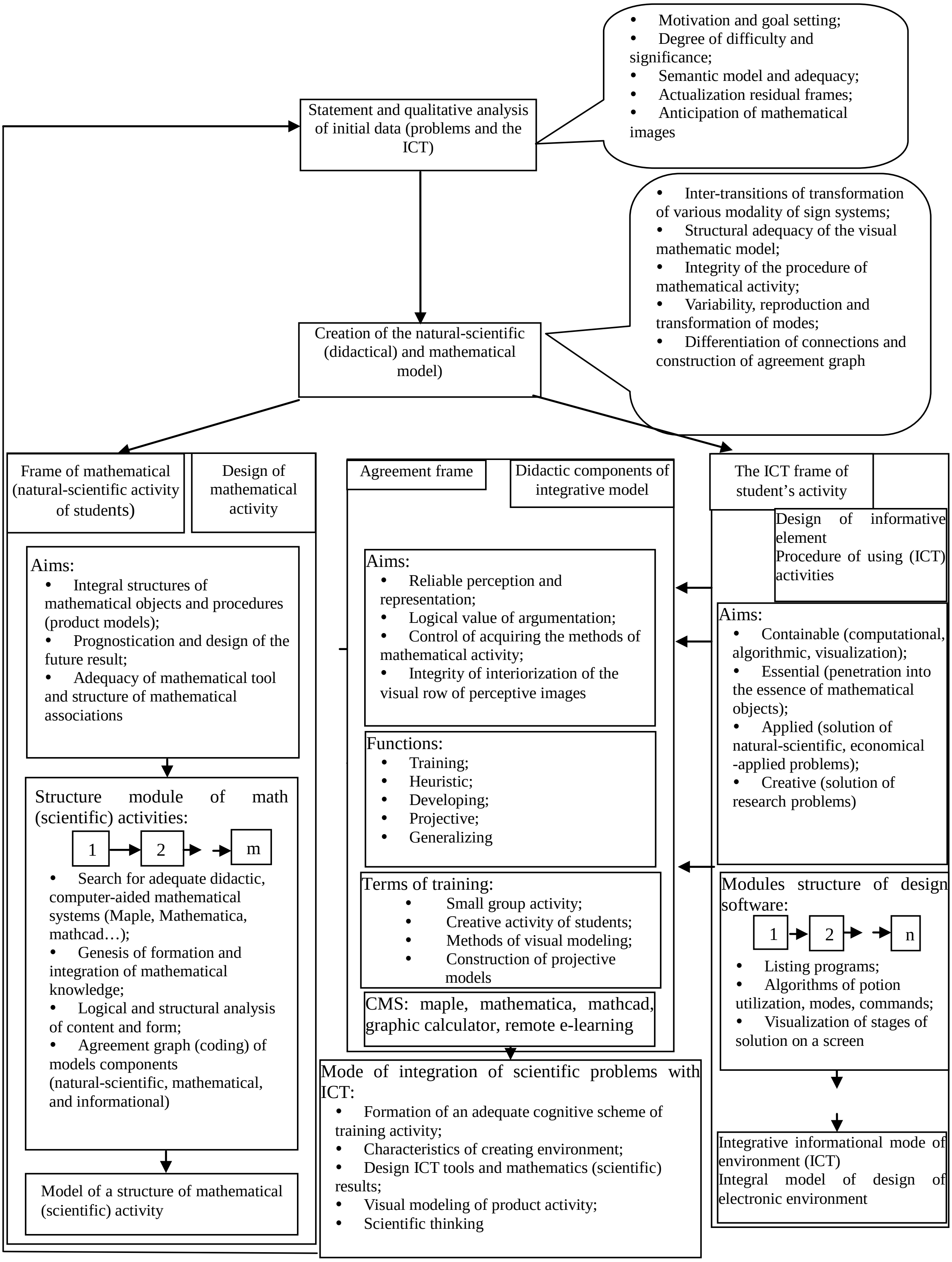


Figure 4. Integrative model of mathematics (science) and ICT activities.

Remote Training in Uniform Environment of E-learning

The organization of educational process using students' monitoring system of REP was carried out on following algorithm (see Figure 5):

(1) The formulation by teacher of necessary methodical and didactic components of educational process using of design activity, including the description of considered course of subject matters, the list of names and the description of corresponding projects of each course, the list of names, the description and theoretical aspect on corresponding activity of each educational project with the subsequent reflexion of specified components within of students monitoring system of REP;

(2) Working out of settlement algorithms necessary and corresponding programming modules for realization of each problem-decision of educational project with the subsequent reflexion of specified components of students monitoring system of REP;

(3) Generating by the teacher and students of demos independent variants of considered activity with possibility of demos viewing both representatives and administrations only for one of the parties. On the basis of values, generating of initial data using of random numbers and generating initial code of programming module of problem-decision should be receipted of automatically calculated values of intermediate and total results;

(4) Generating by each student the corresponding variant of activity with possibility of viewing (not editing) by the teacher of intermediate and total results values and possibility for students of correctly specified values viewing, editing and viewing of current values and intermediate and total results on the basis of values generating of the initial data using of random numbers. There are used proceeding from formulated conditions the generated initial code of programming module of problem-decision;

(5) Realization of monitoring of students design activities from the point of view as teacher, and students. The main purpose of process analysis is the performance of students' project work and formation of further strategy of current design activity realization;

(6) Realization of dialogues between students and the teacher in the form of a forum of each project activity that essentially raises clearness of discussed problem borders in forums, for the purpose of problem allocation of areas and their further decisions.

On the base of development network and Internet technologies in educational process, there is an almost completely unresolved problem of ICT mobilization for the purpose of small resources of information using. Practically at all stages of educational process realization (classroom activity without dependence from possibility of their carrying out in a display class, in house conditions, library and in the open air, etc.), the requirement for integration of subject and information knowledge is obvious. The given problem reflects the essence of ICT development designated above the second direction for today, consisting in necessity of ICT transition from the level of local user to the mobile level of an information technology realization.

Now, practically within small resources of information, there is no possibility for monitoring of students, educational activities, not to mention of design activity realization. To track all available achievements on ICT mobilization for today, it is possible to allocate only one class of small resources of information as graphic calculators which are rational for using in educational process with restriction of a scope of reception and visualization decisions of necessary educational problems. Possibility of graphic calculators using in educational process speaks a primary orientation of given mobile devices from the point of view of hardware and program maintenance. However, primary possibilities on using in educational process of other classes of representatives of small resources of information (cellular telephones, smart phones, communicators, a handheld computer, etc.) are simply absent as those (Deacons, 2002). The matter is that the given mobile devices have initially been focused on especially applied problems, a little connected with educational process that is for realization of telecommunication, access to the network, the Internet as user and use of additional user functions, for example, application of the device as the camera, a player, an alarm clock, etc..

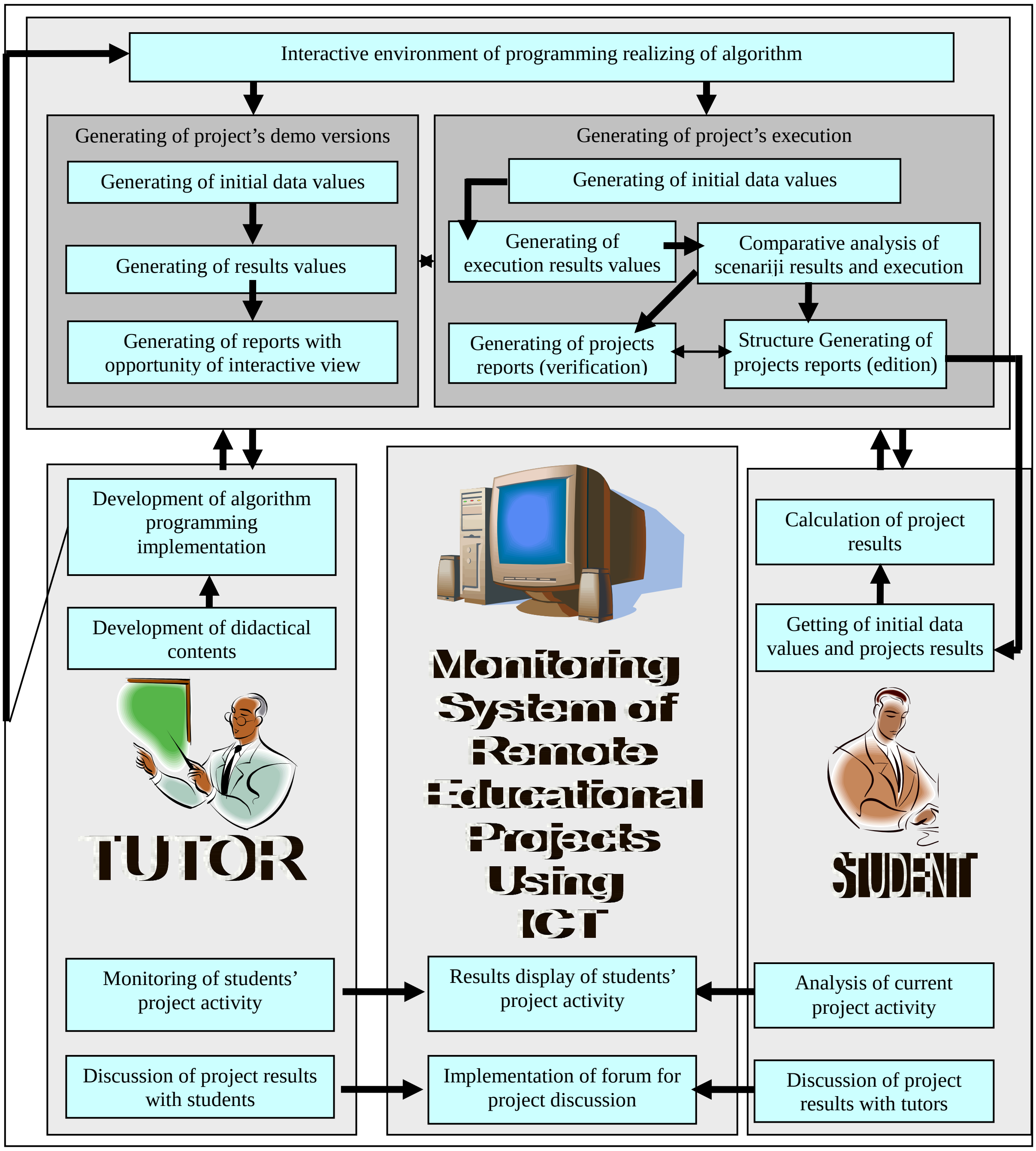


Figure 5. The scheme of implementation of REP monitoring.

At the same level with the essential lacks generated above modern REP, applied in high schools of the Russia, it is possible to allocate real problem areas which arise at realization of educational process with the use of small means of information:

(1) Practically, a total absence of the concept and techniques using of small resources of information in educational process that directly reflects small volumes of studies support of similar mobile devices;

(2) Primary absence of the software for small resources of information, directed on using of given devices in educational process in all its displays. It is unacceptable in itself as on the studies spent without attraction of display class, mobile devices are the unique alternative of personal computers replacement on realization of computing projects and problems;

(3) Absence of direct application of small resources of information within of REP that is strange enough circumstance as the majority of modern mobile phones, smart phones and communicators give possibility of access to a network the Internet under HTTP (Hyper Text Transfer Protocol) report and some other reports with application of technology GPRS (General Packet Radio Service).

Now, the authors actively developed and approved the concept using small resources of information in teaching mathematics (Bogun, 2008; 2006). As a didactic material, the methodical complex of graphic calculator CASIO ALGEBRA FX 2.0 PLUS using was developed. Thus, various graphic calculators of Texas instrument corporations and CASIO as one of the representative of small resources of information in the course of teacher training can be applied. Research includes the description of necessary methodical and didactic making various studies (a laboratory practical work, a practical training and an open classroom) and the design problems focused on active using of educational activity realization.

The basic lack of graphic calculators as well as all representatives of small resources class of information is the total absence of interaction with Internet environment as directly or through local networks. Thus, there is no necessary software for work in Internet network (browser), therefore, to unite graphic calculators in the uniform environment of remote training from the point of view of pupils, accessing to educational projects for the purpose of subsequent monitoring of educational activity of students by the teacher is impossible. Unique possibility of graphic calculators using in educational process is presence of powerful built in mathematical software realized on the level of computer mathematical systems and directed on realization and visualization of mathematical calculations connected with research of difficult phenomena and processes.

The technique of graphic calculator using offered by the authors in the course of teacher training is characterized by following aspects (see Figure 6):

(1) Revealing and statement of the didactic problem consisting in necessity of using of graphic calculator at certain stages of problem-decision connected with application of visualization, algorithmization, difficult computing procedures and variability of initial data values;

(2) Allocation from didactic problem designated above, mathematical, science and applied problems and problems deducing on realization of difficult computing and logic operations, connected with visualization and also variability of initial data values;

(3) Realization of conceptual, mathematical and information modeling for the decision of problems;

(4) Working out of an algorithm of problem-decision on the basis of received mathematical and information models and its realization on programming level within of graphic environment calculator;

(5) Using of applied software developed on graphic calculator of realization of task-decision for the purpose of hypothesis formulation. After checking it on the basis of carrying out of a comparative analysis of intermediate and total results in the course of a variation of initial data values, it is expedient to organize in this

case some processed of training in small groups of pupils that allows for revealing of various personal psychological features of students.

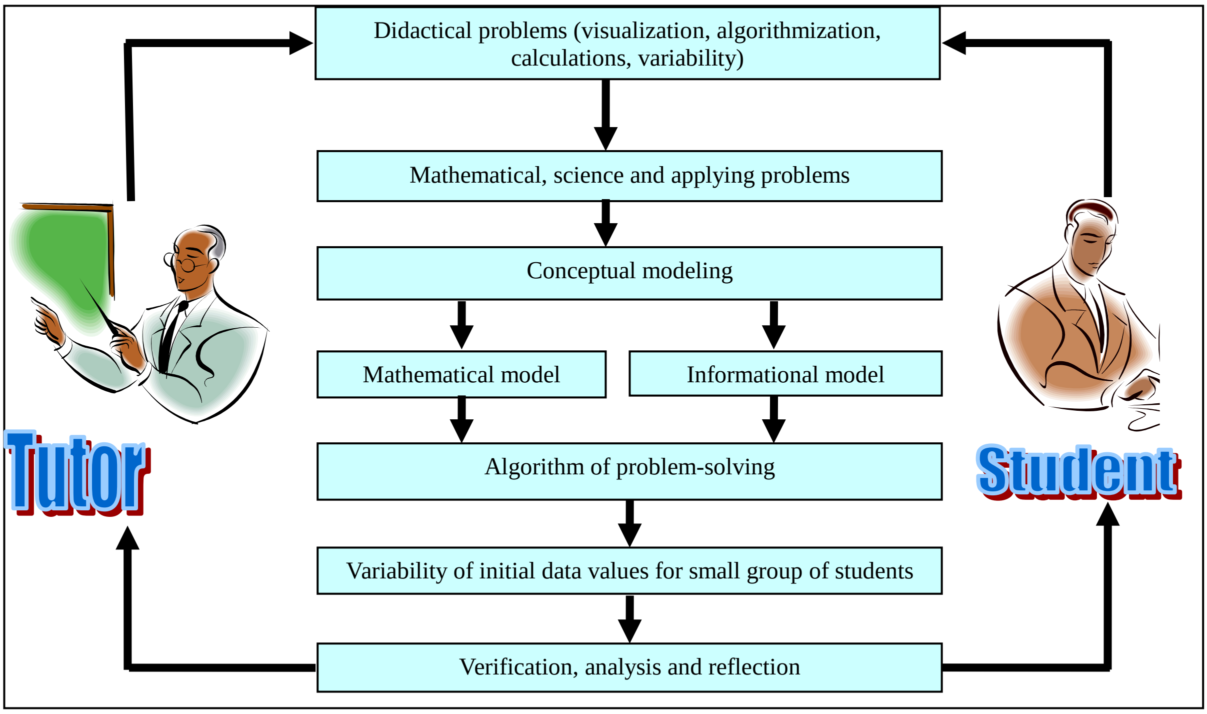


Figure 6. The scheme of graphic calculator using in science learning.

An example of developed laboratory work using graphic calculator as integration tools of mathematical and information knowledge is offered at performance of numerical algorithms whose essence consists in construction and visualization of iterative processes converging to required decision.

The technique of laboratory works using communications principle in small groups was carried out on following stages:

(1) The actualization of knowledge and the control of theoretical aspects and practical skills on using of graphic calculator;

(2) The formulation of the name, the purpose and the plan of laboratory work carried out;

(3) The consideration of mathematical problem-decision as an indicative example;

(4) The distribution of students on small groups (on three or four persons) for the purpose of the various variants analysis of initial data;

(5) Evident modeling and the decision of an offered mathematical problem with application of three numerical methods on the basis of mathematical and information knowledge integration with the use of graphic calculator;

(6) The reflection and carrying out of comparative analysis of received results for the purpose of conclusions formulation and checking out of hypotheses;

(7) The registration of laboratory work with subsequent representation to the teacher;

(8) The presentation of results;

(9) Individual interviews or verifying testing.

Diagnostic Procedure for Defining of Students Motivation and Calculation of Positive Shifts

Cognitive interest determines the activization of:

(1) Achievement motives

(a) Presence of adequate result in practical activities;

(b) Construction of mathematical and science model of process or the phenomenon;

(c) Ability to consolidation (in thinking of the pupil and activity) the initial data for the decision of a problem;

(d) Realization of a choice in methods and procedures of tasks decision;

(e) Appearance of pupils insight in action research;

(2) Social motives are defined by the dialogue and interaction in small group

(a) A choice of a social role;

(b) Social tests and search positive (internal and external) results of dialogue;

(c) Expansion and development of activity in a direction of self-realization of the person;

(3) Motives in action research of pupils

(a) Actualization of pupils insight;

(b) Integration of thinking efforts of pupil;

(c) Visual modeling in knowledge and process.

Table 1 shows the diagnostic procedure of students' motivation defining.

So we base on detailed structure of a student's interests components, which consist from three areas of characteristics: A—motivation of results achievement, R—motivation of self-realization and E—motivation of thinking efforts. Based on this position, we defined the interests of students (I) as vector (oriented) psychological category:

$$\vec{I} = \vec{A} + \vec{R} + \vec{E}$$

All of these characteristics should be actualized by special pedagogical instruments, actions and resources according to educational aims using ICT (see Figure 7).

The Model and the Evaluation of a "Resource Lesson With ICT"

The authors tried to use methodological ideas of problem-solving, visual modeling, work in small groups, humanizing of science and mathematics education with ICT:

(1) Setting of the productive science problem with mathematics and informatics decision (actualization of science, informatics and mathematics knowledge of the last years on the basis of integration; participation in discussion and statement of educational tasks; construction of science, informatics and mathematical model of process or the phenomenon; and the ability to consolidation (in thinking of the pupil and activity) the initial data for the decision of the problem);

(2) Educational activity of pupils at high level of complexity (quasi-research activity of pupils aimed at analysis of results and search of new patterns of relationships; experiment using numerical methods and computing procedures, diagnostics of information dynamics of parameters, monitoring and correctional interaction of obtained results, integrative knowledge and prospect of development, skills of visual modeling and estimation of real processes);

(3) Efficiency of using resources (material, materialized and ideal) for activization of cognitive processes

and social interaction (presence of adequate results in practical activities; joint analysis, information interchange and presentation of results; visual modeling in educational activity; and reflection and internal plan of pupils action);

(4) The organization of work in small groups (distribution and the choice of social roles, planning, forecasting, acceptance of decisions, selection of the data and modeling, registration of results; social tests and search positive (internal and external) results of dialogue; expansion and development of activity in the direction of self-realization of the person).

Table 1

Diagnostic Procedure of Students' Motivation Defining

Kind	Characteristic	Criteria	Technique of measurement	Measuring instruments
1. Motivations of achievement of results and an estimation of a level of claims	Define the stability of motives of aspiration to success and escape the failures on the basis of expansion of knowledge and interests. Estimates a degree of difficulty of the purposes which the person puts before itself.	Presence of adequate result in practical (experimental) activity, —construction of mathematical model of physical process or the phenomenon; —ability to consolidation (in thinking and activity of pupils) the initial data for the decision of a problem (physical or mathematical); —realization of a choice in methods and procedures of tasks decision; —insight in action research.	The test consists of lines of the statements concerning the separate sides of character, and also opinions and feelings concerning some vital situations. In the second test on the end of process of problem-decision, the question naira directed on studying of internal both external motives and estimating a level of person's claims is offered to the pupils. It is spent twice (the beginning—the end).	Updating of a test-questionnaire of Mehrabian (in Magomed-Efimova's edition), Gerbacheskii's questionnaire (St. Petersburg, 1990).
2. Motivation of self-realization of the person	Social motives are static zed by dialogue and interaction in small group.	—a choice of a social role; —social tests and search positive (internal and external) results of dialogue; —expansion and development of activity in a direction of self-realization of the person.	The version of socio-metric Moreno's method is used. The principle of an estimation is put in a basis by each pupil's degree of sympathies-antipathies to each of the schoolmates by means of a polar numerical scale —socio-metric. It is spent twice.	Sociometric tests are at studying system of interpersonal mutual relation of pupils (Zavertkina, & Shvetsona, 2001).
3. Motivations of integration of thinking efforts	Enrichment of interests, emotional tone, intensity in development of resource and thinking activity in interaction of physics and mathematics.	—mental activity of the pupils in action research on the base of integration of physics and mathematics; —increase of interests to learning physics and mathematics; —insight and nonlinear thinking.	The examinee independently estimates the condition on a seven-mark scale (interests, an emotional tone, a pressure, comfortable psychological activity). It can be spent in group and it is designed for repeated inspection. It is spent twice.	The modified technique the DIGNITY (Doskin, & Lavrent'eva) by a principle of polar structures of C. Osgud.

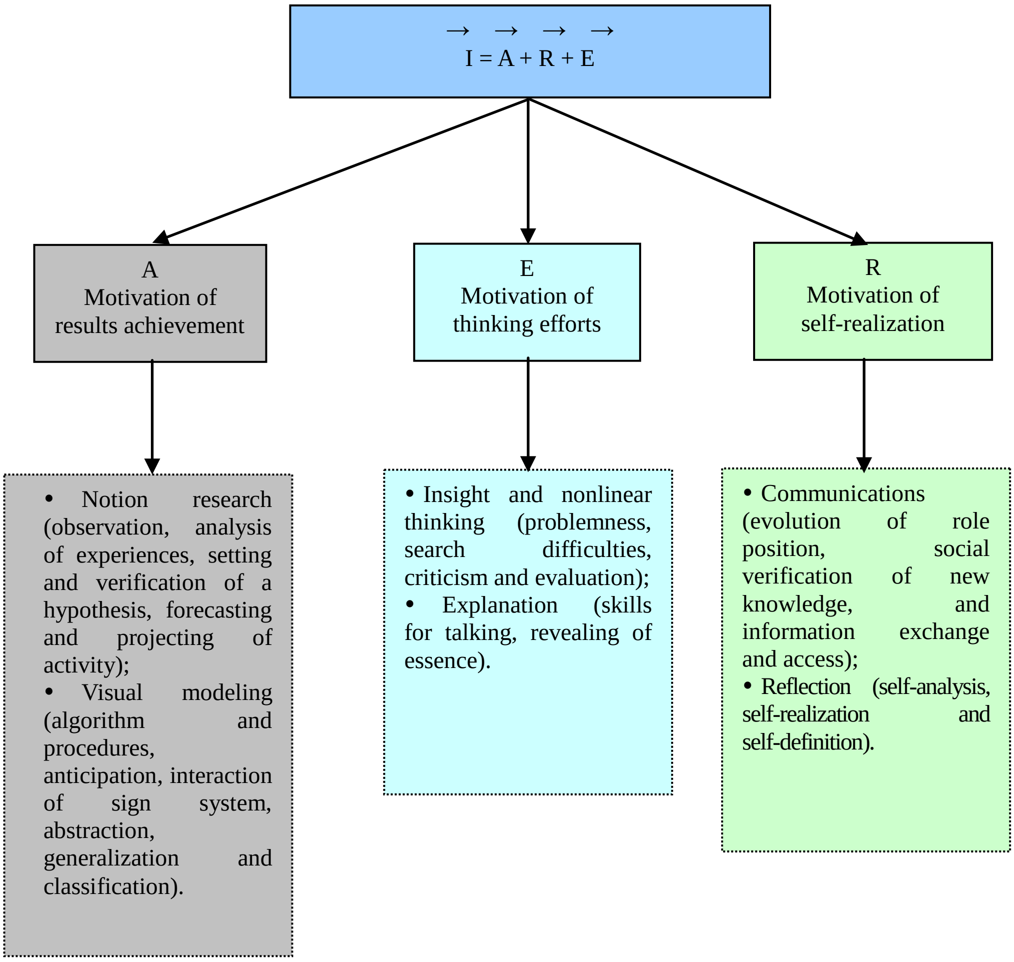


Figure 7. Characteristics of components of students' interests.

As the result of such approach on organization of learning process for students in engineering universities, the authors introduced the notion of "resource lesson with ICT" as the form of teachers and students activities for two subjects in one lesson on ICT, so we define the "resource" as a necessary volume of the educational information in science (mathematics) sufficient for successful development of pupils' proficiency in mathematics (science) according to educational aims, integration of subjects based on the ICT and following characteristics:

(1) Equal volume and complexity of subjects material (science, informatics and mathematics knowledge);

(2) Setting of subjects aims (scientific, informatics and mathematical);

(3) Setting of science and real problem using of ICT and mathematical resource (algorithms, countable, logical, sign-symbolical, modeling and so on);

(4) Computing and science experiment;

(5) Social activities of pupils and work in small groups;

(6) Preliminary procedure of actualization of science, informatics and mathematics knowledge;

(7) Teachers manage the learning process of students together.

The educational aims of "resource lessons" are the investigation of two to three engineering tasks with ICT, in integration of science, informatics and mathematics using visual modeling technology across the series of models (conceptual, science, informatics and mathematical). The frequency of resource lessons in semester is five to six lessons using the competence-based education, scientific thinking and works in small group of students. The dynamics of procedure using the "resource lessons" is shown in Figure 8.

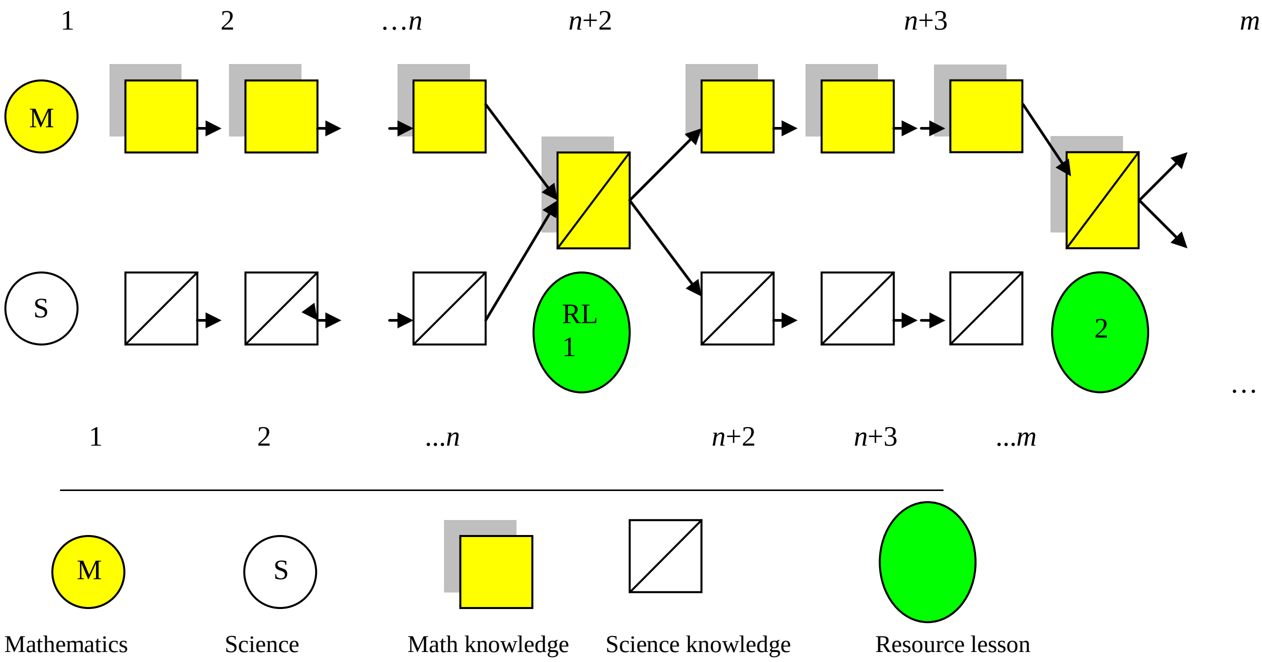


Figure 8. Dynamics of resource interactions.

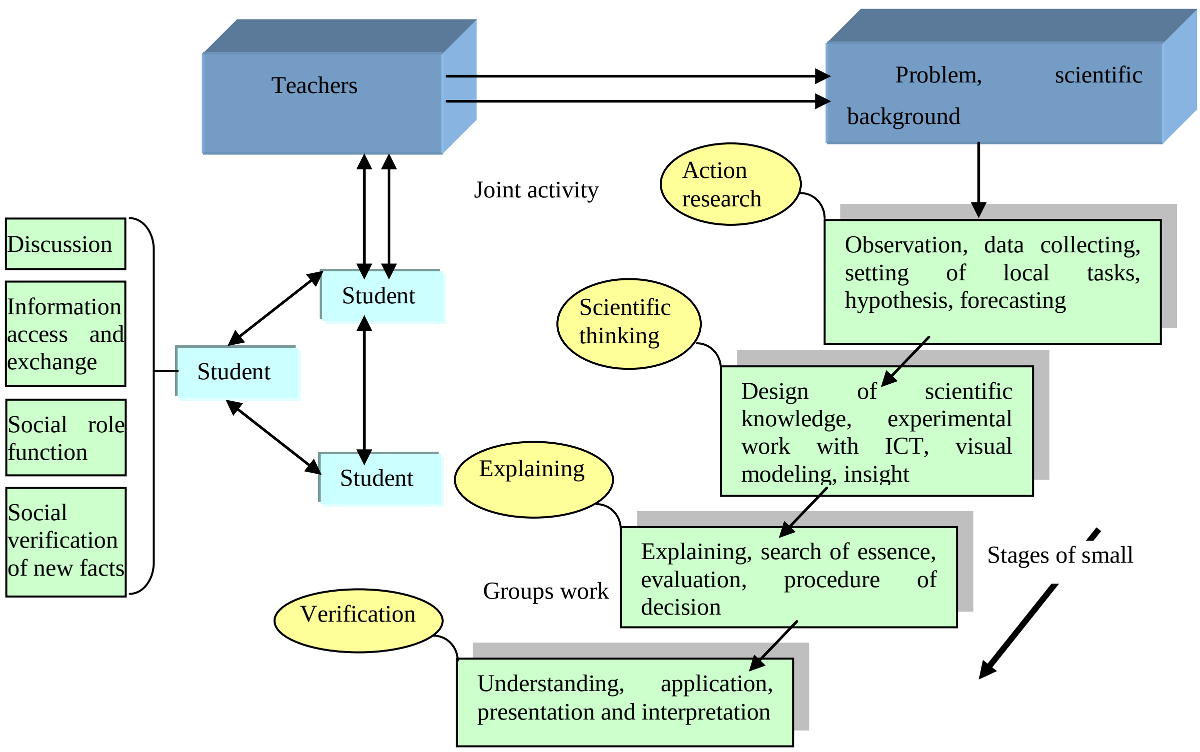


Figure 9. Students' action research activity with ICT.

Mathematics science mathematical science knowledge with RL 1 (2)--… knowledge engineering aims "resource lessons" 1 (2) …with ICT.

To our minds, one way to deal with the specified problems is to realize technology of visual modeling and conduct "resource lessons" at which the interrelation of learning material on science, informatics and mathematics is revealed to its full and individual activity of pupils grows (see Figure 9).

Stages Description of Projecting Procedure of "Resource Lesson With ICT"

The comparative analysis of curriculums in science, informatics and mathematics has been carried out: chronology of topics, allocation of topics with the resource, interactions, construction of structure of interrelations and their orientation, terminological coordination and bank of modeling situations.

The analysis of engineering experience's working patterns on science, informatics and mathematics using ICT in the world practice according to the criteria project's aims has been executed, and the project of the innovative contents of the inter-subject interaction has been constructed.

The future engineer have filled in the questionnaire on methods of science, informatics and mathematics coordination, and the students have been interviewed and asked to fill in the questionnaire. The analysis of pedagogical experience of in inter-subject connections in science, informatics and mathematics (the methods of conducting research, the bibliography on the problem, unity of teaching and methods of activization of students' cognitive activities, impact of activization of the mathematical or science and informatics resource on changes in motivation, thinking and personal development) have been carried out.

Psychological diagnostics and sample tests in experimental and reference forms have been carried out.

Diagrams reflecting coordination of topics and resources in certain sections of science, informatics and mathematics were constructed.

Scripts of some resource lessons have been made and trial lessons in university's classroom form based on the innovative methods have been carried out.

The resource lesson with ICT and video data has been analyzed. A video clip and comments to it have been made.

Good Practice Using ICT (Graphic Calculator, Maple) on "Resource Lesson"

The analysis of curriculum on physics and mathematics has shown that the mismatch of sections learning and have defined the "resource lesson" and "coordination graph" technologies constructions. We looked on two lessons in Russian schools concerned with "resource lesson" methodology. Testing applying to more than 1,000 pupils of secondary schools has shown strong influence the volume of mathematics in science on pupils' motivation. At the same time, it will be grown the level of "scientific thinking" and research activity of pupils.

First one is the title "fall of the body" for ten class of secondary school (integration of ICT, physics and mathematics) using the graphic calculator (see Figure 10).

Purposes and Problems

The purposes and problems are as follows:

(1) Using Newton Second Law to research the real physical processes (the building physical, informatics and mathematical models (as shown in Figures 11, 12 and 13), structures acting power, procedures and mathematical dependencies);

(2) Using the numerical methods for the decision of the physical problem with ICT—graphic calculator (the method iteration, approximations, derived to differential relations);

(3) Using the graphic calculator for complex current calculations and visualizations stages of decision of the physical problem;

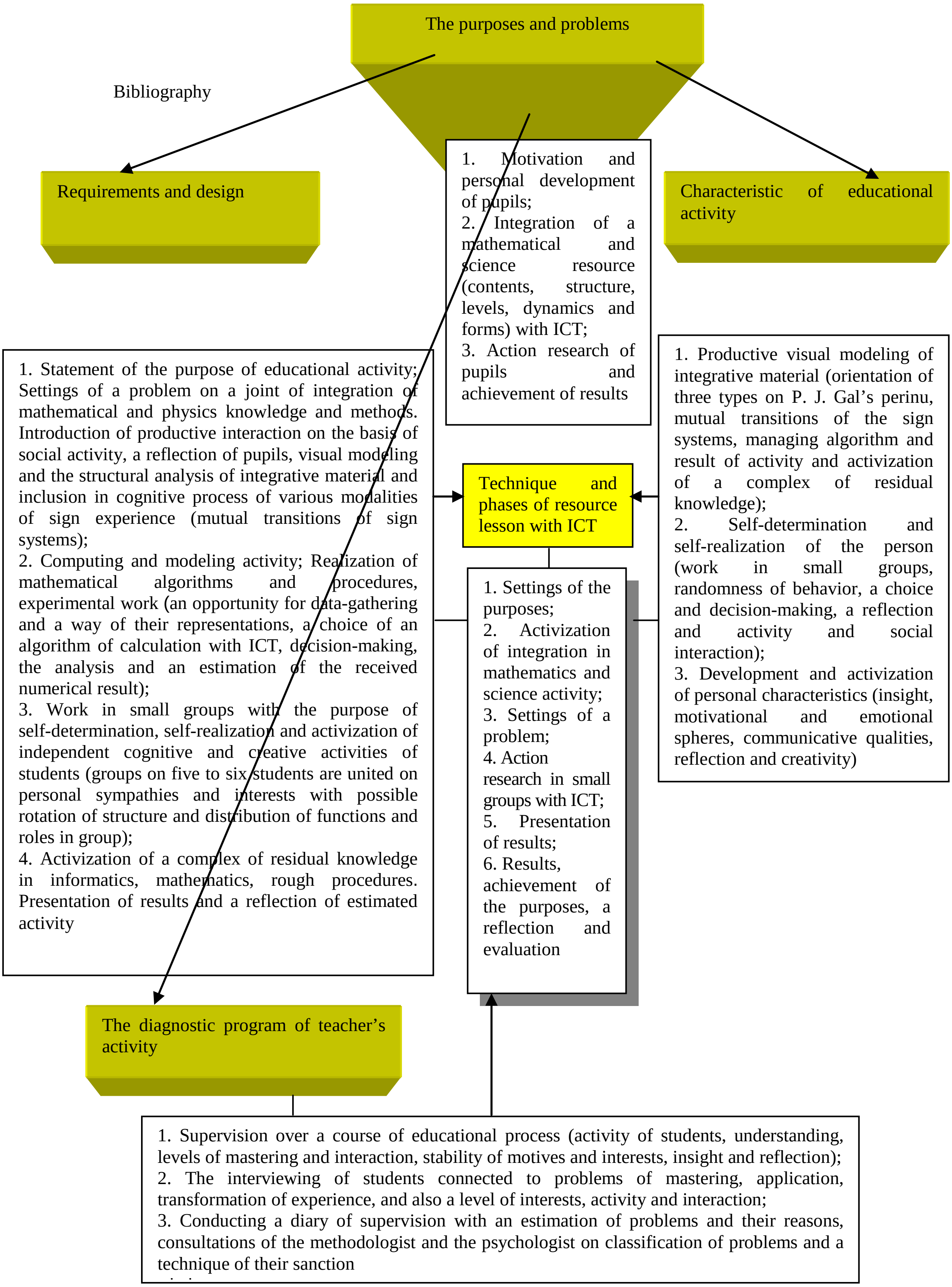


Figure 10. Technology and phases of resource lesson with ICT for action research.

(4) Substantial interaction of informative and physical resources (visual modeling, structure, levels, dynamics, forms and efficiency) using mathematical tools;

(5) Motivation to physics learning using informatics and mathematics for personal development of pupils.

Setting of the Problem

The body by the mass 70 kg falls with the big height. The power of the air resistance is finding by the equation $F_{re} = Av + Bv^3$, where factors A and B are defined of the body size. Let these factors are the following values: $A = 5Hs/m$ and $B = 10^{-2}\ Hs^3/m^3$. We must find the velocity depending on time, passed after begin falls. Trace the graphics $v(t)$ and $s(t)$.

Organization Work in Small Groups

Features. Features are as follows:

(1) Dialogue, discussions and criticism in behaviors and thinking of pupils;

(2) The analysis, information interchange, presentation of physical and mathematical results;

(3) Integration of graphic calculator using and estimated and algorithmically activities of pupils.

Procedure. Work in small groups with the purpose of self-determination, self-realization and activization of independent cognitive and creative activity of pupils (groups of five to six pupils are united on personal sympathies and interests with possible rotation of structure and distribution of functions and roles in group):

$$m\frac{d^2x}{dt^2} = mg - (Av + Bv^3)$$

We should use the method of sequential approximation in this procedure for calculating the values of $v(t)$ and $s(t)$ as functions from time. The students can change the values of A, B (parameters), m (mass), t (time) for view (by using the graphic calculator opportunities) on dynamics of process. They can answer the questions: Is a function $v(t)$ monotone? Can you find the time of body landing? What happened with time landing, velocity landing if the body will have the different initial velocity? How can you see that happened with velocity and time landing if the mass will be different? And so on.

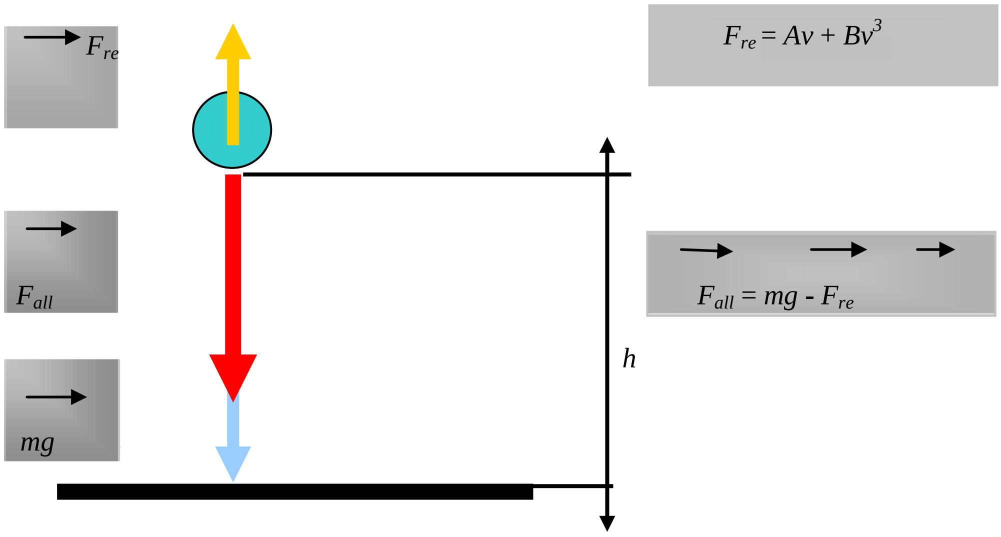


Figure 11. Physical model.

The students can fill the table of values, view the graphics and try to find the analytical decision of the problem.

Activity of pupils. Distribution of social roles in small group is an individualization of educational activity (planning, forecasting, acceptance of decisions, selection of the data and modeling, managing of graphic calculator using and registration of results) (see Table 2).

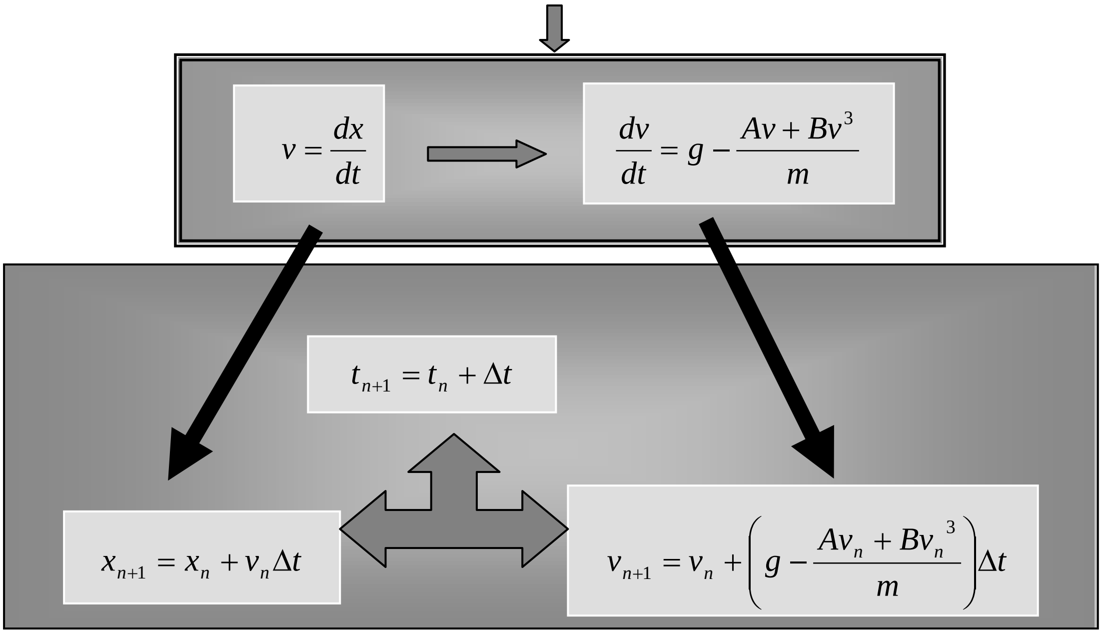


Figure 12. Mathematical model.

Table 2

Presentation of Research Results in Small Groups and Reflection

Group 1	Group 2	Group 3
INPUT M? 70 INPUT A? 5 INPUT B? 0.01	INPUT G? 9.81 INPUT N? 10 INPUT DELT? 0.1	INPUT T0? 0 INPUT V0? 0 INPUT X0? 0

Within the laboratory work, the decision of following design problems from calculus (Bogun, 2008; Velling, Thomson, & Lora, 2003) was carried out:

(1) The calculation of minimum numbers values on approach to a limit of numerical sequences $x_n = \frac{a_2 n^2 + a_1 n + a_0}{b_2 n^2 + b_1 n + b_0}$ (for $\varepsilon > 0$ $a_2 \neq 0$ $b_2 \neq 0$, $\left| x_n - \frac{a_2}{b_2} \right| < \varepsilon$) with using methods of a gold proportion, Fibonacci, a dichotomy and their comparative analysis (section “Limits and a Continuity”) (Bogun, 2008);

(2) Decisions of algebraic and transcendental equations using of dichotomy method, combined method of chords and tangents (Newton), iterations method and their comparative analysis (section “Differential Calculus”);

(3) Calculations of certain integrals values under formulas of average rectangles, trapezes, parabolic trapezes (Simpson) and their comparative analysis (section “Integral Calculus”);

(4) Decisions of ordinary differential equations of first order with using of Euler method, Runge-Kutta of the second, fourth usages of accuracy and their comparative analysis (section “Differential Equations”).

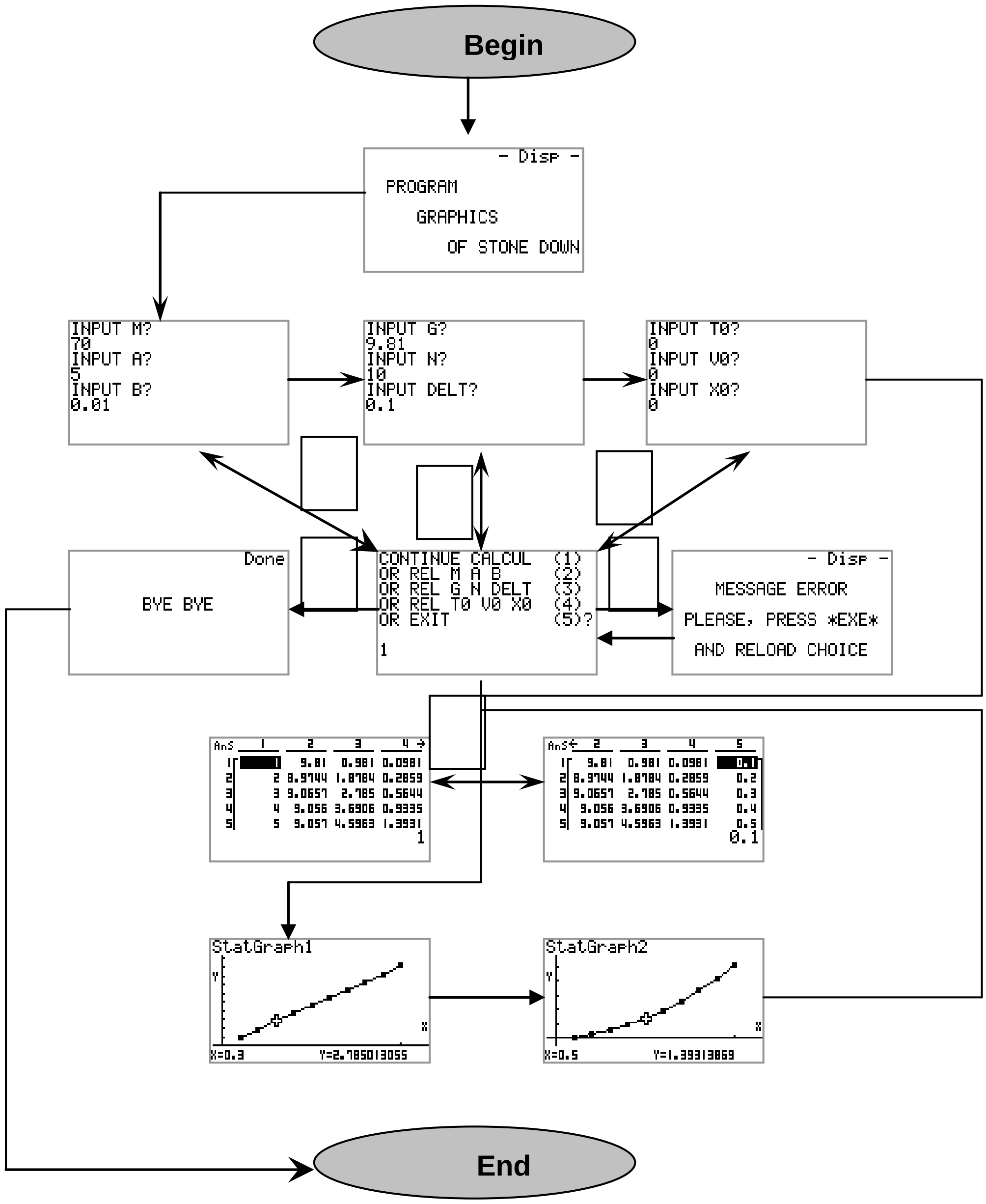


Figure 13. Information model.

Further realization of unique integration of above-stated tendencies of ICT development within of educational activity thanks to developed information system of REP monitoring of students in secondary and higher school using an access to given environment is offered. Thus, interactive activity is possible as from personal computers through Internet global network and was certain representatives of small resources of information (mobile phones, smart phones and communicators) on the presence of GPRS technology supposing of HTTP report. It finally will allow for realizing the uniform environment of remote training of students in high schools, uniting all participants of educational process without dependence as from the presence of display class and geographical position of educational process participants on realization of independent activity and monitoring of students' educational activity by the teacher.

Conclusions and Suggestions

The analysis of these results made us feel confident that the hypothesis concerning the opportunity to increase motivation in learning of science (mathematics) by incorporating into science (mathematics) lessons of suitable mathematics (science) material is consistent and logical. It can be achieved by means of development of "resource lessons" and activization of cognitive activities of engineering students by visual modeling and group work activity. The conducted research has shown the importance of the chosen topic and partially confirmed the put forward hypothesis about the significance of the integrated approach to interaction of science and mathematics with ICT in engineering education. Research of the innovative approach in visual modeling of science, informatics and mathematical processes, activation of motivational and cognitive processes have promoted positive changes in personal development and successful mastering (learning) of teaching material. Resource lessons with ICT as basic form of realization of interaction of science, informatics and mathematics have shown its efficiency and opportunity for further research. It is recommended to develop the cycles of resource lessons with ICT in learning science and mathematics at university and carry out a detailed analysis and feasibility of the technological innovations.

On the basis of the model and the method of research, the authors have worked out ideas on the series of "resource lessons" with ICT for engineering students (also using computer mathematical system: Maple, MathCad, Mathematica, and so on), on the laboratory work on science or lessons in mathematics or science including remote e-learning environment. Together with teachers and teacher educators, we had to design more lessons, carry out those lessons in classrooms and analyze the lessons and the knowledge of the students. We also wanted to design lesson activities in which engineering students can learn more scientific problems by means of computers as a learning tool. The experiences are very promising and the authors are like to investigate the use of simulations and computer-based laboratory work in relation with "resource lessons" in mathematics and science.

In the conclusion, it is necessary to notice that unique possibility of creation of high-grade uniform environment of remote training of students in high schools is organized educational process on the basis of dynamic level realization of settlement educational projects with access possibility to the information through local and global networks and using of small resources of information in forms of cellular telephones, smart phones and communicators.

References

Anisimov, A. M. (2009). *Work in system of remote training Moodle: Educational manual* (2nd ed., p. 292). Kharkov.

Arnold, V. I. (2000). *Soft and strong mathematical models* (p. 32). Moscow.

Bogun, V. V. (2004). The research of limiting processes for numerical sequences with using of graphic calculators. *Yaroslavl Pedagogical Bulletin, 4*, 179-189.

Bogun, V. V. (2006). A technique of graphic calculator using in teacher training in mathematics (p. 245) (Doctoral Dissertation, Pedagogical Sciences/V.V. Bogun.-Yaroslavl).

Bogun, V. V., & Smirnov, E. I. (2008). *Using of graphic calculator in teacher training in mathematics* (p. 231). Yaroslavl: Publishing House JAGPU.

Bogun, V. V., & Smirnov, E. I. (2009). Evident modeling in teachers training in mathematics with using of small resources of information. *Yaroslavl Pedagogical Bulletin, 4*, 45-54.

Deacons, V. P. (2002). *Modern foreign micro calculators* (p. 400). M: SOLON-R.

Ibragimov, I. M. (2007). *Information technology and means of remote training: Studies* (2nd ed., p. 336, I. M. Ibragimov, & A. N. Kovshov, Eds.). M: Publishing centre "Academy".

Isakov, V. N. (2003). *Elements of numerical methods* (p. 192). M: Academy.

Salmina, N. S. (1988). *A sign and a symbol in teaching* (p. 288). M.: Publishing house of the Moscow State University.

Mrotchek V., & Philippovitch, F. (1910). *Pedagogic of mathematics* (p. 380). T.1. St. Petersburg.

Motivation in Science Education (International project Russia, Austria, Holland—MISE) (p.180). (2003). (printed in Russian with CD in Russian and English), IIEI, Herzen State Pedagogical University, St. Petersburg.

Savenkov, A. I. (2006). *Psychological foundation of research approaches in education* (p. 480). Manual, Moscow: Os-89.

Shadrikov, V. D. (1996). *Psychology of activity and abilities of the person* (p. 318). M.: Logos.

Shadrikov, V. D. (2002). Teacher training in mathematics: Innovative approaches (p.383). Moscow: Gardarika.

Smirnov, E. I., Bogun, V. V., & Ostashkov, V. N. (2007). *Visual modeling in Mathematics: Theory and practice* (p. 450). Yaroslavl: Indigo.

Smirnov, E. I., Shadrikov, V. D., Povarenkov, Y. P., & Afanasyev, V. V. (2002). *Teacher training of mathematics: Innovative approaches* (p. 323). Moscow: Gardariki

Smirnov, E. I. (1998). *Technology of teaching mathematics using visual modeling* (p. 323). Monograph, Yaroslavl State Pedagogical University.

Voogt, J, Gorokhovatsky, J, & Almekinders (Eds.). (2003). I*nformation and communication technology in rural schools: Innovative didactics in physics teaching* (p. 114). Holland: University of Twente.

Velling, T., & Lora. (2003). *Working out of Web-appendices by means of PHP and MySQL* (2nd ed., p. 800). M: Publishing House "Williams".