DIAGNOSTICS AND ASSESSMENT IN ICT ORGANIZED MATHEMATICAL LEARNING - MITE PERSPECTIVE

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ABSTRACT
The assessment in a didactical technology for math learning which includes ICT should take into account a large set of indicators for progress. The traditional list of goals of a math lesson often is insufficient and incomplete when a computer-based part of the content is implied. In many cases such a list cannot be simply extended but should be totally reorganized to avoid eventual contradiction between traditional techniques and the ideology of the ICT organized didactical technology.
We introduce the concept of *spectrum of achievements* (SA), which in our opinion is mostly adequate to the requirements of a teaching-learning process where the computer plays a significant role. SA is called to solve at least a two-folded paradigma:

- Effectiveness of a didactical technology.
- Guidelines for learning and respective measuring tools for achievements.

The first step in constituting a SA is to compose a comprehensive list of indicators for progress. Such a procedure could help to clarify the place and the role of the key players in the teaching-learning process: student(s)-teacher-facilities. The next step is to attach benchmarks and scale to each indicator. A linear arrangement of the students' achievements could be obtained from a SA by the corresponding *index of the spectrum*. Such a two-stage organization of the evaluation provides flexibility in applying a didactical technology to various target groups.
Another advantage of using SA is the easy diagnostics which comes for free after the assessment. If the indicator-benchmark complex is properly composed, it allows to analyze immediately the gaps in students' knowledge and competences, and to put the appropriate corrections in the teaching-learning process.

INTRODUCTION

The MITE project was initiated in 2006 by a group of leading educators from the Institute of Mathematics and Informatics (Sofia), the Academy of Public Administration (Moscow) and The Center for gifted students DARYN (Astana).

The goal of this project is to develop applications of information technologies to assist school education in all subjects. The participants in such developments will be teachers, students, university professors, scientists from academic institutions. Under this project various events are organized regularly, like:

- competitions
- workshops to report the results achieved
- scientific conferences to discuss various project-related concepts and ideas and to experiment the developments

Up to now 4 meetings of MITE took place. At the first one which was held in January 2006 in Moscow the mission and vision of the project were declared, its goals and possible ways to achieve them.

The second MITE meeting was held in June 2006 and was attended by scientists and educators from Bulgaria, Russia and Kazakhstan. A lot of presentations were made on specific applications of information technologies in education.

There were two workshops acting at the 3rd meeting of MITE held in October 2006. The first one was dealing with shell systems for learning and assessment. The second workshop was 'experimental' – it aimed to design a general frame for generating didactical technologies based on the program package GEONEXT. Further we are going to discuss a part of the outcomes of this workgroup.

At the 4th workshop of MITE some intermediate results were reported. But the main event on this workshop was the final round of the first issue of the contest **Mathematics and Projecting** whose outcomes were used as a database for our conclusions. More than 300 presentations were received of students from Russia, Bulgaria and Kazakhstan. The best 50 works were presented at the final round by their authors during the meeting in Moscow in May 2007.

THEORETICAL GUIDELINES

The theoretical background of MITE activities was laid down mainly in the 2nd workshop of MITE held in Varna, 2006. The background for the further research, as well as for designing didactical materials was given in the following planar talks.

- Sergeeva gave a general structure of the didactical technology [3].
- Ganchev presented a methodology of using dialogue teaching programs in educational process that could be used both for teaching and assessment.
- Grozdev gave an example of the application of a geometric exploration environment based on the dynamic software GeoNext.

- Lazarov pointed the possible ways of implementation of program packages at school based on a new paradigma for mathematical teaching-learning process [4].

THE COMPETENCE APPROACH

The joint report [1] of the European Council and the European Commission about the progress of the **Education and Training 2010** work programme reiterated in the 2004 the request of the Barcelona Council for enhancing the **European dimension** in education. It gave preference of the terms *competence* and *key competence* to *basic skills* which was considered too restrictive as it was generally taken to refer to basic literacy and numeracy, and to what are known variously as survival or life skills. The key competence refers to three aspects that should be fulfilled:

- personal fulfilment and development throughout life (cultural capital): key competences must enable people to pursue individual objectives in life driven by personal interests, aspirations and the desire to continue learning throughout life

- active citizenship and inclusion (social capital): these key competences should allow everybody to participate as an active citizen in society;

- employability (human capital): the capacity of each and every person to obtain a decent job in the labour market.

It is easy to see that such point of view on the goals of education corresponds to the *competence approach*. The accepted by MITE theoretical structure of a didactical technology refers to Sergeeva [3] where the competence approach presented in [6] plays a crucial role. Below we present briefly the viewpoint of the European Commission on the same point [1]:

> *Competence* was considered to refer to a combination of skills, knowledge, aptitudes and attitudes, and to include disposition to learn as well as know-how.
> *Key competences* represent a transferable, multifunctional package of knowledge, skills and attitudes that all individuals need for personal fulfilment and development, inclusion and employment. These should have been developed by the end of compulsory school or training, and should act as a foundation for further learning as part of Lifelong Learning.

Further, the three of eight key competences which are in our focus are

> *Mathematical literacy* (*and basic competences in science and technology*): the ability to use addition, subtraction, multiplication, division and ratios in mental and written computation to solve a range of problems in everyday situations; the emphasis is on process rather than output, on activity rather than knowledge.
>
> *ICT skills* comprise the use of multi-media technology to retrieve, store, create, present, sort and exchange information.
>
> *Learning-to-learn*: the disposition and ability to organise and regulate one's own learning, to manage one's time effectively; to solve problems; to acquire, process, evaluate and assimilate new knowledge; and to apply new knowledge and skills in a variety of contexts — at home and at work, in education and training.

Our attitude is that ***the outcome of a didactical technology in an ICT organized math education should be a synthetic competence***. It is clear that taken alone any of the listed above competences does not meet the requirements of the new dimensions in education declared in [1]. There exists an interaction of building key competences in a learning process that should be taken into account in designing an ICT organized didactical technology which means that the methodological component of such a didactical technology should contain a kind of ***synthetic competence approach***. A brief description of the synthetic competence approach is given as appendix 2. A similar approach could be accepted as a leading methodological principle in supervising student's work on mathematical project or other extracurricular activities. The synthetic competence could be defined as

The ability of use mathematical knowledge (concepts and methods) combined with a level of skills to use computer technologies for solving problems. The ability of analyze the initial data of a problem and to transform them in appropriate form to apply computer technology. The ability to evaluate the outcomes and to manage their application

It is clear that accepting such a key competence as an aim of the education will put the mathematics teaching and learning in a strong dependence on the information technologies as well as on the hardware and software equipment. But let we point that there is a precedent - some changes in math education already happens after the invention of pocket calculators: the modern curriculum is free of hard algorithms for taken square-roots and even of long division. On the other hand it is hard to reason mastering calculation skills for example to find a derivative for themselves and even for studying a function since via an available program package such calculations could be performed quick and easy. In our opinion math education should be set free from a great part of the heavy calculations as soon as possible.

PUTTING THE THEORETICAL RESULTS INTO PRACTICE

Currently there are two main streams in putting the MITE theoretical results into practice:

- introducing program packages into school practice;
- designing mathematics projects by school students.

Parallel to the practical implementation a theoretical research to evaluate the accepted theory and to make some amendments in the initial presumptions is going on.

Introducing program packages into school practice

A frame of didactical technology (FDT) for the Thales Theorem was among the outcomes of the 3rd workshop of MITE. Following [3] the didactical technology has the following elements:

- conceptual base
- methodology approaches
- principles of building the curriculum
- methodics
- diagnostics

The designed FDT includes all the elements of the general structure given in [3] and a complete collection of illustrative examples done by GEONEXT. But the FDT contains also enough free space to be filled up with elements that take into account the specifics of a particular national curriculum.
The first report for a good practice was given by Ultanbaeva [5]. She presented a didactical technology developed on the FDT and put into practice in ZERDE – school for gifted students in Astana.
We know about introducing into practice some other didactical technologies based on the FDT but the outcomes are not reported yet.

Designing mathematics projects by school students

An international contest for school students was organized by the Academy of Public Administration, the Moscow State University and the Institute of

Mathematics and Informatics – Sofia. In MITE perspective such a contest is a natural complement via a form of students' long-term extracurricular activeness to the didactical technologies developed for the classroom.
The 4th workshop of MITE held in May 2007 in Moscow was combined with the final round of the first issue of the contest.

DIAGNOSTICS – THE PRESENT STATUS

Following [3] the didactical technology presented in [5] contains a part labeled as *diagnostics of the quality of education*. This diagnostics is based on a rating scale in three levels:

1. Mathematical literacy of the student is on elementary level, which means the minimum level of knowledge and understanding;
2. Functional level of mathematical knowledge which means that the ability to use the theory is application and understanding;
3. Creative level on which learners solve non-standard problems and perform a kind of investigation.

There is a set of problems to recognize each level and a corresponding score system. For instance student's rating is formed gaining

- for problems that need to apply theory explicitly up to 50 points;
- for problems that need to apply theory implicitly up to 20 points;
- for nonstandard problems up to 15 points.

There is a linear scale which turns student's rating into five-point scale mark.

The diagnostics in fact is a kind of summative assessment. It is not clear how it works in any of both paper-and-pencil technique and computer-based solutions and investigations.

ASSESSMENT AT THE CONTEST *MATHEMATICS AND PROJECTING*

As an example we will consider the assessment of presentations submitted for the international contest for school students ***Mathematics and Projecting***. The students had to make presentations (mainly on one of the three major topics: Mathematical Models of Real Processes, Geometric Miniatures, and Mathematics and Art. The International jury estimated the merits of a presentation as follows:

- Felicitous choice of content (0-10 points)
- Ingenuity and creativity (0-5 points)
- Mathematical methods involved (0-10 points)

- Consistency of content and topic (0-10 points)
- Substantiation of conclusions (0-10 points)
- Design (0-5 points)
- Adequacy of the software used (0-5 points)

The final mark of a project was a simple sum of the points given to any of the above criteria. It is easy to see that the variety of specifics of a project cannot be represented by that single number which is the final score. However, this variety is clearly seen if the mark is given in a vector format.

ASSESSMENT AND DIAGNOSTICS – THE DESIRED FUTURE

First let we clarify the accommodation of the assessment and the diagnostics along a didactical technology:

- the assessment of students' achievements is a part of methodics adopted in the didactical technology;
- diagnostics is a structured part of the didactical technology for evaluation of the effectiveness of the teaching-learning process (Appendix 3).

Such a location of the assessment calls a revision of the principles of assessment for learning [2]. Below we propose another list of general principles that face mainly the mathematics education in ICT environment.

1. **Assessment should cover all areas of educational activity.** The entire teaching-learning process should be decomposed into elements which allow to any of them an ***indicator for progress*** to be attached. The indicators for progress in learning should be clearly stated to both teacher and students. The assessment procedure should be used to enhance all learners' opportunities to learn in all areas of educational activity. In a complex didactical technology indicators should cover the entire spectrum in learning, i.e. to be stated a ***spectrum of achievements*** (SA).

2. **Assessment should take into account the large variety of goals in the teaching-learning process.** To organize an assessment one needs a quantitative expression for any indicator from the SA, i.e. the indicator should act via ***benchmarks*** that arrange students' performance in the range of the indicator. The benchmarks are scales assigned to the indicators that give quantitative expression of the students' progress. In a complex methodics stating benchmarks should be flexible. A simple reference on the educational standards could restrict the understanding of the

educational goals and could bring back the teaching-learning process in the narrow frame of the traditional education.

3. **Assessment should takes into account the dual nature of the process of evaluation**. One the one hand the ***vector of the values*** assigned to the indicators could answer the complexity of the educational process. According to the benchmarks student receives marks with respect to the SA which give a multidimensional characteristics of his/her achievement. On the other hand the outcomes of the assessment are expected to be linear. Thus it is convenient to introduce the ***index of the spectrum*** which is a sum with weights of the benchmarks. The index of the spectrum is a technical media for turning the vector-mark into scalar mode.

4. **Assessment should provide guidelines for further learning.** The assessment procedure should be used to enhance all learners' opportunities to learn in all areas of educational activity. It is possible if the learners receive adequate feedback about their effort. The vector of values is the instrument that shows students how far they are gone in any particular area.

5. **The proper design of the SA and corresponding benchmarks and index should be regarded as a key professional skill for teacher**. The implementation of a didactical technology of flexible type could be risky business. To specify the important parts of a topic and to separate them in a form that allows measuring is advanced didactical skill. However, some hints could be gotten fro the standards but for both mathematics and informatics education. The art here is to analyze the topic for stating indicators but the spectrum of separate indicators should give a synthetic characteristic of the learners' achievement. Teachers should be supported by the theory in developing these skills through initial and continuing professional development. It is not technology's but teacher's duty to ensure that learners understand the goals they are pursuing and the criteria that will be applied in assessing their work

6. **Assessment should be constructive but humanistic despite of the routine character of the didactical technology.** Since any assessment has an emotional impact on the students, the individual approach accepted in methodology should be oriented to encourage students to broken the limits of the routine mastering skills in mathematics. However, the implication of SA-assessment should be as constructive as possible in the feedback that it gives.

Diagnostics becomes an easy structural part of the didactical technology when the assessment in methodics is organized with respect of the above six principles. Teachers should be aware of the impact that comments, marks and grades can have on learners' activeness. The *vector of values* after a formative assessment provides enough data to analyze the weak places in learner's building the synthetic competence. A proper set of indicators allows the effectiveness of the didactical technology to be evaluated by components and as a whole after having the vector of values of students in a class.

SAMPLE SET OF INDICATORS FOR LEARNER'S PROGRESS

Below we propose a set of indicators for learner's progress which could be used to design a spectrum of learner's achievements.

1. Ability to reproduce mathematical definitions.
2. Ability to identify whether a mathematical object or relation has certain features and belongs to the scope of the concepts defined.
3. Ability to use PSP for running the presented examples.
4. Ability to recognize a mathematical concept among PSP operators.
5. Ability to restate the theorems considered.
6. Ability to understand the theorems and to know how to apply them
7. Ability (either alone or with the help of the teacher) to operate with mathematical concepts at the level of PSP application
8. Ability to use PSP for creating own applications and examples.
9. Ability to use PSP for solving mathematical problems and generate hypotheses
10. Ability to use mathematics for proving statements generated via PSP.

We do not claim that the list above is comprehensive but it is easy to see that a vector of the values based on it gives a picture of learner's synthetic competence.

CONCLUDING REMARKS AND OPEN QUESTIONS

The greatest part of the classroom activities are a kind of assessment – practically any interaction between teacher and learner. Thus the asssessment should be recognised as a milestone of a didactical technology. Further, it is easy to evaluate the effectiveness of the didactical technology by a set of criteria stated in a close relation with the assessment technique. As analytical is such a technique as precise could be the evaluation of the effectiveness. Our complex of spectrum of achievements as a set of indicators is an attempt to calibrate the fuzzy process of building synthetic competence for the diagnostic purposes. But in the same time to provide learners some information and guidance in order to plan their next steps in learning**.**

Since the didactical technologies developed on the MITE theoretical outcomes are still in progress we cannot give any statistical evidences for their effectiveness in sense of building synthetic competence. But our believe is that it worth to plan in advance the criteria for effectiveness taking into account the assessment principles given in the presented paper.

We have no idea yet about how to assess the building of a synthetic-team-competence which is important at least as building an individual synthetic competence. The work of a team on a project could be assessed from outside by a jury but perhaps it could be better assessed by peer and self-assessment of the team members.

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APPENDICES

1. Founders of MITE

Sava Grozdev
Tatyana Sergeeva
Ivan Ganchev
Nikolas Rozov
Sholpan Kirabaeva

2. Synthetic competence approach

While establishing synthetic competencies based on Professional Software Products (PSP), the presentation of theoretical matters is released from a vast set of circumstantial deadwoods. In return for this, the main ideological problems of math education take clear shape:

- To provide opportunities for the learner to build up a terminology basis directly related to mathematical methods;
- To provide opportunities for the learner to build up a basis if mathematical methods focused directly on the solving of specific problems;
- To provide opportunities for the learner to build up competencies with respect to the scope of application of certain mathematical method;
- To provide opportunities for the learner to build up competencies with respect to the realization of certain mathematical method through PSP
- To provide opportunities for the learner to build up competencies with respect to the quality interpretation of the results obtained after the application of certain mathematical method

The above five stages in math education contain the essence of the synthetic competence approach (SCA). Its components are the communication competencies (specified as 1 and 2 in [1]), mathematical competencies (specified as 3 in [1]), computer skills (specified as 4 in [1]). In addition, the flexibility and adaptability to a new environment are contributory to successful education.

3. Components of a didactical technology

Conceptual basis;
Methodological approaches;
Educational content;
Methodics;
System of diagnosing the quality of education

4. Authors' relation to MITE

Borislav Lazarov:

Invited speaker at the 2^{nd} Workshop of MITE,
Chairman of the workgroup at the 3^{rd} Workshop of MITE,
Chairman of the Bulgarian National Panel of Judges of the Contest Mathematics and Projecting
Member of the International Panel of Judges of the Contest Mathematics and Projecting

Albena Vassileva

Co-author of an invited talk at the 2^{nd} Workshop of MITE,
Coordinator of the National round of the Contest Mathematics and Projecting