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TESTING IN ADAPTIVE LMS

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Abstract

For a number of years now, the research activity at the Department of Information and Communication Technologies at the Pedagogical Faculty of the University of Ostrava has been aimed at improving the quality of instruction. A team of experts has been assembled who can create new study materials that can be used in the electronic environment and are able to adapt to students' individual characteristics and needs. As feedback is an integral part of instruction (be it the e-learning or the classic one), the proposition of electronic adaptive testing has been included in the process. In the proposition, the authors ponder a number of alternative possibilities of adapting test tasks – suitably formulated tasks, suitable reactions to the student's correct and incorrect answers, suitable selection of individual test tasks. This paper aims to introduce the basic principles and rules of electronic adaptive testing and consider other adaptation options.

Keywords

adaptive testing, adaptive LMS, groups of questions, question status, difficulty level

Adaptive instruction

Before we proceed to electronic adaptive testing, let us introduce the basic principles and rules necessary for the proper functioning of adaptive instruction. What does the term adaptive instruction really mean?

Paramythis' description (2003) captures the essence of adaptive instruction. He argues that *"a learning environment is considered adaptive if it is capable of: monitoring the activities of its users; interpreting these on the basis of domain-specific models; inferring user requirements and preferences out of the interpreted activities, appropriately representing these in associated models; and, finally, acting upon the available knowledge on its users and the subject matter at hand, to dynamically facilitate the learning process".*

He also argues that there are four categories in the adaptive learning environment:

1) Adaptive Interaction

   The first category refers to modifications intended to facilitate or support the user's interaction with the learning environment. Examples of modifications at this level include the use of alternative graphical and color schemes, font sizes, etc. to accommodate the user's requirements.

2) Adaptive Course Delivery

   The second category constitutes adaptation techniques aimed at the adaptation of the course/instruction to the individual users. The intention is to optimize the fit between the course contents and user characteristics.

3) Content Discovery and Assembly

   The third category refers to the creation of an adaptive study material based on adaptive techniques and knowledge about users derived from previous "sessions".

4) Adaptive Collaboration Support

   The fourth and final category captures communication between people (so-called social interaction) and collaboration toward common goals. It is important to support communication, collaboration and cooperation as the individualist approach to learning can lead to complete isolation.

Different view offers us Spencer (2011), that there are 4 stages of personalization in the teaching (in the last two stages we see elements of adaptive learning):

1) Standardization

   This level includes the entire classroom (group): What does the classroom need? How to motivate the entire group? The teacher has one material for the entire classroom and hopes the majority of students will find it interesting and satisfactory.

2) Differentiation

   This level takes into account different levels of knowledge that are to be found in the classroom: What do the groups with different levels of knowledge need? Based on the students' skills and knowledge (or their learning styles), the teacher divides them into groups and works with them in a differentiated manner.

3) Adaptation

   This level offers an individual choice: How can I best determine the student's needs and adapt the instruction accordingly? Based on the teacher's recommendation, the student should learn exactly what they need.

4) Personalization

   The students learn on their own: What does each student need and how can they express those needs? It is based on respecting the individual's autonomy and identity; each student controls their own learning process.

All the levels can be taken as the gradual development of the teacher, their ability to improve their material-preparation skills, their skills regarding the organization of the education process.

Hill (2013) also distinguishes between types of teaching deals with the adaptive learning and points to some differences between the concepts of adaptivity and personalization:

1) Differentiated learning

   Differentiated learning is a kind of learning with a number of ways in which students approach a new curriculum. Students are divided into categories, with each category being different in the way of learning and approaching new information.

2) Personalized learning

   Personalized learning is a kind of learning where each student takes different paths to achieve their educational goals. Before the start of instruction, the student takes a pretest, which determines their individual "path".

3) Adaptive learning

   Adaptive learning takes into account the student's results during the entire time of instruction. It is a dynamic process as the student's "path" can be changing all the time.

Theory of Adaptive Education

For a long time, the theory of adaptive education (TAE) has been a research focus of a team of experts at the Department of Information and Communication Technologies at the Pedagogical Faculty of the University of Ostrava. The research results – system development (Drápela, 2013); system fine-tuning using simulation (Kostolányová, 2013); proposition, creation and implementation of rules (Takács, 2014); verification through an experiment in instruction (Horký, 2014), supporting the holistic approach to the curriculum using a semantic network (Šeptáková, 2016) – have been published as diploma theses, dissertations and habilitations. The theory is being further developed as new aspects are constantly emerging.

The proposed TAE comprises three main sub-systems: *Student*, *Author* and *Virtual Teacher*.

- The *Student* module contains students' qualities and characteristics (those who participate in the course/instruction) based on which they are presented with personalized study materials.
- The *Author* module contains the adaptive study material, various texts, images, audio recordings, videos and other detailed information about the study material.

The most important part of the TAE, securing its proper functioning, is the *Virtual Teacher*. On the basis of the student's characteristics and the structure of the study material, the Virtual Teacher assigns the student an ideal way through the course. Moreover, it contains Event log, recording and storing the information about the student (the time spent on individual parts of instruction, answers to questions, their way through the course, etc.).

Four Stages of Learning

In what stage of knowledge acquisition can the TAE be used? Learning a new curriculum is a development process. First, the student *becomes acquainted with it* – reads the study material, focusing on the main chapters, headlines; tries to understand the curriculum as a whole, not focusing on the details.

Another step is the actual instruction, *re-reading the material*. The student tries to better understand the curriculum, focusing on the details. Highlighting the important parts and making notes is typical of this stage. In this stage, the student also tries to answer the questions and solve the tasks included in the study material or at the end of each chapter.

That is followed by *fixation of what the student has learned*. If the student feels they have mastered the curriculum, they can undergo the so-called "sample testing". That means that during testing, they can answer repeatedly, look inside the study material, or have the entire solving process displayed to them. Therefore, the feedback is immediate.

The final stage of the entire learning process is *self-testing*. In the previous stage, the student found out what they were good at and, on the other hand, what they need to improve and can now enter the final stage. They solve the test tasks without any help and learn the result at the end of the test (Prextová, Šarmanová, 2014).

From what we know, we can assume that the TAE is applied predominantly in the first two stages. In the remaining two stages, **adaptive testing** can be applied (Figure 1).

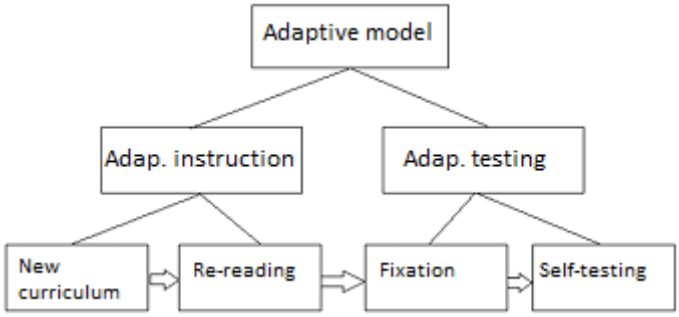

Fig. 1: Adaptive Model

Adaptive testing

In adaptive testing the selection of test questions is based on the current answer of the tested user. The user tested for the first time starts with a question of the medium difficulty. If there are 5 levels of difficulty (1 being the most difficult), they start with Level 3. If they answer the question correctly (as they did in Figure 2), the next question is more difficult. On the other hand, if they answer incorrectly, the next question is less difficult.

You can see the entire process in the following, simplified model:

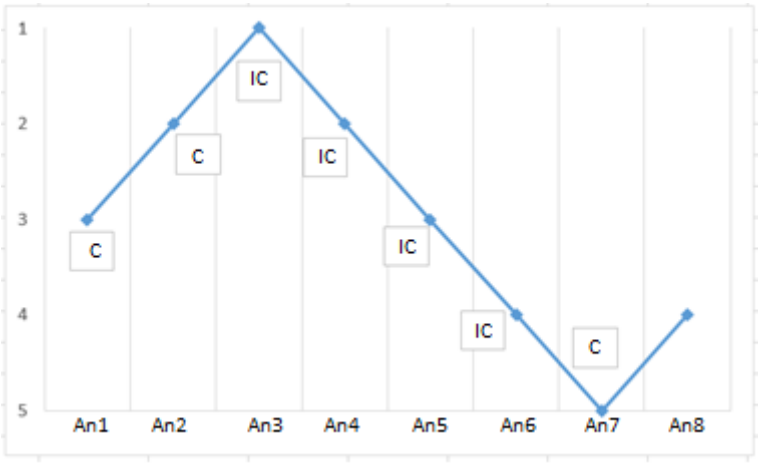

Fig. 2: Adaptive testing model

It is clear that an electronic system managing both adaptive instruction and adaptive testing will be necessary. Within the scope of the project "Adaptive Individualized Instruction in E-learning", the adaptive LMS Barborka (the current version is Barborka 4) was designed. It is a program system able to manage adaptive instruction, record and store user information and their way through the learning environment. It contains all three systems – Student, Author and Virtual Teacher (Šarmanová, 2011).

Apart from instruction (acquiring new information, building on the existing knowledge), the student, sooner or later, will have to take the test. The first stage of the creation of the adaptive system and the TAE was aimed mainly at adaptive instruction – what the study material should look like, to what student's characteristics it can be adapted, what the rules for assigning the optimal study material, finding suitable learning paths should look like, etc. Naturally, the testing is included in the system. However, only in the basic form used in schools. Therefore, up until now the testing was not adaptive.

Adaptive LMS Components

During the development of the adaptive study material and the Barborka LMS, we had to bear in mind that the education process needed to be adapted in various ways. As a result, the LMS is divided into smaller parts based on "classic" instruction (Figure 3):

Course: a typical school course.

Chapter: a thematic unit of a course.

Class: a typical class (45 minutes, 90 minutes).

Frame: an agent of the instructional information. There are several types of frames according to what sensory type of student they are intended for and how detailed they are.

Layer: the smallest element of instruction representing the individual stages of instruction. There are two large groups of layers in the TAE – instructional and testing. In adaptive testing, the focus is on the latter group.

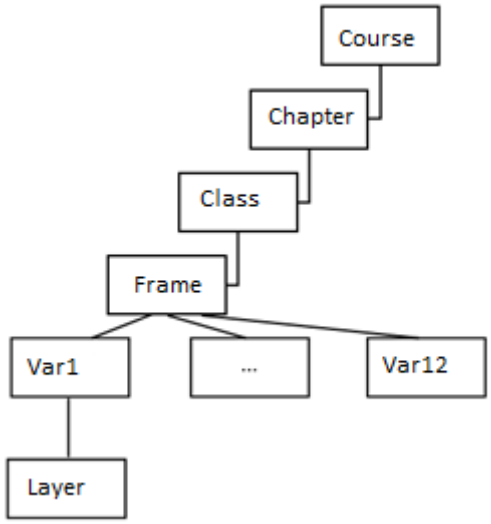

Fig. 3: Adaptive LMS

Types of Test Assignments

In the testing layer there are three types of test assignments:

Questions (Q): assignments aimed at the theory – remembering definitions, theorems, sentences.

Tasks (T): typical school assignments aimed at the application of theories, mostly without practical application.

Practical tasks (X): connecting the assignment to real life situations.

To prevent repetition, guessing the correct answer and to be adaptive, the set of test assignments should be large. Therefore, for each type (Q, T, X) and level of difficulty the author should create a **group** of test assignments. The following strategy has been proposed for suitable alteration of assignments in a group:

- In each group the author presets a set of assignments the students need to take. Those are **compulsory** (C). The remaining assignments are **optional** (O). As far as the C assignments are concerned, the student needs to answer them correctly at least once. As far the O assignments are concerned, those are equivalent assignments which do not differ much from one another (assignments with different formulations, different operators, numerical change, etc.). The O assignments are used to avoid displaying the correctly answered assignments when the student revisits the same curriculum.

- The system keeps records of each student's ***statuses*** – a strategy of assigning all test assignments (C, O). The C assignments are assigned first followed by the O assignments. The assignment ***statuses*** are as follows:
    1) O unanswered,
    2) O answered incorrectly one time,
    3) C unanswered,
    4) C answered incorrectly one time,
    5) O answered incorrectly several times,
    6) C answered incorrectly several times,
    7) O answered correctly,
    8) C answered correctly.

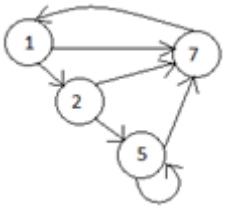

Fig. 4: Status transition in C assignments

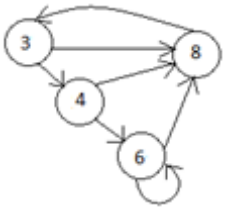

Fig. 5: Status transition in O assignments

- To make the testing adaptive, the testing assignments need to be distinguished according to the level of difficulty, making it possible to select a suitable variant. These are levels of difficulty (the author chooses the number of levels; we chose 5, Level 1 being the most difficult).

Types of Test Answers

Technically, various types of answers can be created. Each assignment can have one or more correct answers. The Barborka LMS currently contains two types of answers – ***closed*** and ***open***. In closed answers, the student ticks the correct answer. In open answers, the student needs to form the correct answer (also the assignments with more than one correct answer). The Barborka LMS currently contains the following types:

Closed answers	
Closed answers with one correct answer	– no change of sequence
Closed answers with one correct answer	– change of sequence
Closed answers with more than one correct answer	– no change of sequence
Closed answers with more than one correct answer	– change of sequence

Tab. 1: Closed answers

Open answers
Number
Set of numbers separated by commas; sequence is not important
Vector of numbers separated by commas, sequence is important
Word without diacritical marks = string of characters with commas and spaces
Set of words without diacritical marks separated by commas
Vector of words without diacritical marks separated by commas
Word with diacritical marks = string of characters with commas and spaces
Set of words with diacritical marks separated by commas
Vector of words with diacritical marks separated by commas

Tab. 2: Open Answers

Types of Reactions to Test Answers

As has been mentioned above, adaptive testing can be applied mainly in the fixation and self-testing stages (Figure 1). The aim of the fixation stage is for the user to remember the curriculum, be able to use it in further study and not to be discouraged by incorrect answers. That is why in this stage they should be able to answer more than once. The LMS's ***reactions*** to their answers also help the student. Based on the number of incorrect answers to the same question, the reactions are as follows:

a) Correct answer – ***system message***: answer is correct.

b) First incorrect answer – ***system message***: answer is incorrect.

c) Second incorrect answer – ***Reaction***: notifies of expected errors, displays a small "help".

d) Third incorrect answer – ***Reference***: refers to a layer or study material (e.g. in PDF form) containing the respective curriculum or demonstration, which may help the student solve the task.

e) Fourth incorrect answer – ***Help***: one of the possible solving processes with the correct result.

Rules

When there are this many possibilities, there also need to be certain if-then-type rules determining the way the system works and assigns different types of assignments based on the user's success rate or different reactions based on the user's answers. Before the rules can be created, the following data need to be formulated:

SUsp – *user's success rate* in the interval from 0 to 100.

OBod – *level of difficulty* in the interval from 1 to n.

Bzmen – *change of success rate after a correct answer and first incorrect answer*.

Bopak – *change of success rate after repeated incorrect answers*.

The relation between SUsp and OBod has been preset to n of intervals of the X = 100/n size; meaning that ⟨0,X-1⟩,⟨X,2*X-1⟩, ⟨2*X, 3*X -1⟩, …, ⟨(n-1)*X,100⟩, Bzmen =X/2, Bopak =1.

- Rules determining the relation between SUsp and OBod:
  - If the SUsp value is $\in \langle 0, X-1 \rangle$, then display a task from Obod = 1.
  - If the SUsp value is $\in \langle X, 2*X-1 \rangle$, then display a task from Obod = 2.
  - …
  - If the SUsp value is $\in \langle (n-1)*X, 100 \rangle$, then display a task from Obod = n.
- Rules determining the SUsp value for a correct and first incorrect answer:
  - If the answer is correct, then SUsp = SUsp + Bzmen.
  - If the answer is incorrect, then SUsp = SUsp – Bzmen.
- Rules determining the SUsp value for repeated incorrect answers:
  - If the answer is incorrect two times, then SUsp = SUsp – Bzmen – Bopak.
  - If the answer is incorrect three times, then SUsp = SUsp – Bzmen – Bopak – Bopak.
  - If the answer is incorrect four times, then SUsp = SUsp – Bzmen – Bopak – Bopak – Bopak.
- Rules determining the reaction of the system to a correct answer:
  - If the answer is correct, publish a system message on the correctness of the answer.
- Rules determining the reaction of the system to repeated incorrect answers:
  - If the answer is incorrect one time, publish a system message on the incorrectness of the answer.
  - If the answer is incorrect two times, then:
    - Publish Reaction; if it is not available, omit it and continue to Reference.
  - If the answer is incorrect three times, then:

- Display Reference; if it is not available, omit it and continue to Help.

  - If the answer is incorrect four times, then:
    - Display Help; if it is not available, omit it and display only the correct result.

- Rules determining transition between statuses for C:
  - If the task is in Status 1 and the answer is correct, then proceed to Status 7, otherwise to Status 2.
  - If the task is in Status 2 and the answer is correct, then proceed to Status 7, otherwise to Status 5.
  - If the task is in Status 5 and the answer is correct, then proceed to Status 7, otherwise to Status 5.
  - If the task is in Status 7 and there is not an answer with a status lower than 7, then proceed to Status 1.
- Rules determining transition between statuses for O:
  - If the task is in Status 3 and the answer is correct, then proceed to Status 8, otherwise to Status 4.
  - If the task is in Status 4 and the answer is correct, then proceed to Status 8, otherwise to Status 6.
  - If the task is in Status 6 and the answer is correct, then proceed to Status 8, otherwise to Status 6.
  - If the task is in Status 8 and there is not an answer with a status lower than 8, then proceed to Status 3.

Discussion and Conclusion

The Barborka adaptive LMS with adaptive assignment of test tasks was tested on the sample of 53 9th grade elementary school students – the stage was "*fixation of what the student has learned*" and the subject was Mathematics. The tasks were based on the following thematic areas: Number and variable; Terms and formulas; Data, graphs, and tables; Functions; Plane geometry; Space geometry.

First, the students took an entry test which contained tasks of different levels of difficulty based on the abovementioned thematic areas.

Then, they spent several classes working in the Barborka system, in the "*fixation of what the student has learned*" mode. All of the tasks in this mode were in compliance with the abovementioned principles: they were of different types – Q, T, X, they were divided into C and O and into 5 difficulty levels; test answers, too, were of different natures – closed and open; for each assignment reactions to possible answers were created – Reaction, Reference, Help; the if-then-type rules were applied (however, neither *statuses* nor *rules determining transition between statuses for C and O* were part of adaptive testing).

Finally, the students took the final test which consisted of the tasks equivalent to those in the entry test.

Please note that this paper is not aimed at the course of the actual testing, but that it aims to introduce the principles of adaptive testing and ponder possibilities that may present themselves or those arising from the results. That is why the actual testing is mentioned only briefly; it is, however, described in detail in the paper *"Adaptive Testing in Practice"* (Prextová, 2014).

The analysis of the entire testing revealed the following:

The tested students' final test results were better than their entry test results.

The final test results of the students with the average grade in Mathematics of 3-4 were better than their entry test results.

There was not a significant difference between the entry and final test results of the students with the average grade in Mathematics of 1-2.

Having observed and interviewed the tested students and their teachers, we arrived at the following results:

- The tested students appreciated that they could submit their answer more than once. They stated that the uncertainty resulting from their limited knowledge of Mathematics often led to their being absent-minded, nervous, incorrect understanding of the task, choosing the incorrect answer by mistake, etc.
- They also appreciated the PDF materials (Reference) which helped them find the information needed to solve the task. The teachers also appreciated the PDF materials as they could not be in two places at once.
- The students also liked that when they had difficulty solving the task, they could see the entire solving process and the correct result (as – again – the teacher cannot be in two places at once).
- The teachers also appreciated the students' motivation to improve. The students were told that the testing was adaptive and that the tasks were being presented to them on the basis of their answers. Ambition and determination to surpass the better classmates were important factors. The students knew that the easy tasks were always going to be followed by the more difficult ones. It was interesting to see that, as the time passed, everyone started to work alone, did not let anyone bother them, was making notes and was trying to find another solution than the presented one.
- The elements of gamification can be seen – the students do not get badges or points, but collect more and more difficult tasks and examples.

It needs to be determined if, or to what degree, this improvement was influenced by the adaptive system since it can be assumed that the final test results will always be better than the entry test results. However, our research results show that the implementation of the adaptive system could be purposeful as it motivates the students to improve. Even the teacher knows that this system can be used not only in instruction, but can also be a part of students' homework.

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