

Approaches to the choice of tools for adaptive learning based on highlighted selection criteria

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Abstract. The article substantiates the relevance of adaptive learning of students in the modern information society, reveals the essence of such concepts as “adaptability” and “adaptive learning system”. It is determined that a necessary condition for adaptive education is the criterion of an adaptive learning environment that provides opportunities for advanced education, development of key competencies, formation of a flexible personality that is able to respond to different changes, effectively solve different problems and achieve results. The authors focus on the technical aspect of adaptive learning. Different classifications of adaptability are analyzed. The approach to the choice of adaptive learning tools based on the characteristics of the product quality model stated by the standard ISO / IEC 25010 is described. The following criteria for the selecting adaptive learning tools are functional compliance, compatibility, practicality, and support. By means of expert assessment method there were identified and selected the most important tools of adaptive learning, namely: Acrobatiq, Fishtree, Knewton (now Wiley), Lumen, Realize it, Smart Sparrow (now Pearson). Comparative tables for each of the selected tools of adaptive learning according to the indicators of certain criteria are given.

Keywords: adaptability, adaptive learning, adaptive learning tools, selection criteria

1. Introduction

The main trends in global online education are related to the development of computer technology and increase of diversity and accessibility of education. Information and communication technologies, in particular learning management systems (LMS), serve as a means of improving the effectiveness of learning, its individualization and differentiation. LMS provides access to data and tools to support the learning process, accumulates information about the courses taken by students and the results of final tests [1, 18, 19, 29, 33, 37, 38, 40]. However, the effectiveness of such systems usually depends on the adaptive capabilities of the educational process with consideration of psychological characteristics of students and subject area. However, sometimes educational content is quite simple for more prepared students, and for less prepared it can be almost inaccessible. On the other hand, most LMSs provide ample configurable capabilities, but adaptability has not been a priority in the architecture of such systems.

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The main approach to solving this problem is the use of adaptive learning tools as one of the promising areas in modern education.

Philosophers, educators and psychologists have paid attention to the problem of adaptive learning. In particular, the experience of Ukrainian researchers is relevant in the context of consideration of adaptive learning systems based on programming, algorithmization and use of web technologies [10, 28].

Pavlo I. Fedoruk considers the problems of theory, methodology and techniques and construction of intelligent adaptive systems of individual distance learning on the basis of the latest Web-technologies [9]. Igor V. Gritsuk devoted his work to adaptive testing in educational electronic environment of maritime higher education institutions [7]. Functioning peculiarities of intellectual adaptive educational systems were investigated by Andrii M. Striuk [32, 39]. Adaptive learning on the basis of modern information technologies is considered by Viacheslav V. Osadchyi [26]. Approaches to the introduction of cloud adaptive technologies in teacher training are explored by Yuliia H. Nosenko [16, 23].

Noteworthy are the studies [5, 24, 25], which present the results of scientific publications for 2010–2020, on the problems of personalized and adaptive learning and analyzed the ergonomic indicators of training courses and their compliance with the principles of educational design in adaptive learning systems. A number of researchers [22, 23] conducted a comparative analysis of adaptive learning systems according to the scope, type of adaptive learning, functional purpose, integration with existing learning management systems, application of modern technologies for generation and recognition of natural language and curriculum characteristics.

The scheme of designing an adaptive learning system can be found in the work of Chang Ming Liu, Yan Jun Sun and Hai Yu Li [15], which describe computer learning platforms.

E-learning systems that provide personalized content to users with the gradual adaptation of educational material based on the results of student progress are considered by Ana-Maria Mirea and Mircea Cezar Preda. They provide different types of adaptation that take into account the content and navigation in the course, explore the student's profile and model learning activities [20]. In [8] it is proposed to use intelligent methods for automatic adaptation to dynamic changes in student behavior in real time during learning.

The effectiveness of the use of adapted online training courses depends on the feedback, on the current learning outcomes of the proposed content [32, 41, 42]. Andrew Thomas Bimba, Norisma Idris, Ahmed Al-Hunaiyyan, Rohana Binti Mahmud and Nor Liyana Bt Mohd Shuib considers different feedback options in an adapted educational environment based on dialogue, intelligent e-learning systems and adaptive hypermedia systems [2].

Thus, nowadays the development of technologies for adaptive learning occurs in different forms and contexts. The share of adaptive learning technologies in higher education in Ukraine is small. In our opinion, technical solutions in the field of adaptive learning that would allow to implement it are not fully studied.

The purpose of the article is to highlight the approaches to the choice of adaptive learning tools based on the selected criteria and indicators of its selection.

2. Theoretical fundamentals

Adaptability is interpreted as the possibility of adaptation, coordination of the learning process, taking into account the choice of learning pace, diagnosis of the achieved level of mastering the material, providing the widest range of different learning tools that would make it suitable for a wider range of users [34]. Adaptive learning system able to adapt to human, age and psychological characteristics, in addition, adaptive training should consider and agree with the general stage changes which experience the knowledge and ways of cognitive actions of students during their studies. Given this, adaptive learning is a dialectical unity of two processes: a child's adaptation to learning and adaption of learning to the individual characteristics of the child and provides for adaptation to modern time requirements of all the elements of pedagogical systems: objectives; content; methods, ways, means of learning; forms of organization of cognitive activity of students, diagnostics of results.

According to [11], adaptive learning system is a new model of learning organization, which is characterized mainly active independent activity of students, which is controlled by curricula and control programs, network plans and self-accounting schedules.

Adaptive learning is that an individualized learning method will help the student learn faster, more effectively and with greater understanding. Typically, components of adaptive learning include: monitoring activity, interpretation of results, understanding of the requirements and benefits of learning new topics to facilitate the learning process. The main purpose of adaptive learning is to make the learning process most effective by transferring the educational process to the electronic environment [21].

In modern information educational systems, the problem of adaptive learning is considered in two aspects: methodological and technical. The methodological aspects of adaptive learning in information training systems include planning and organization of the educational process, determination of the types of tasks, their levels of complexity, the sequence of submission of material, conduction of various types of control, definition of evaluation criteria for each type of task. The technical aspects include: an algorithm that offers to move to a new level with the correct execution of most of the tasks or return to the previous level, taking into account errors made during the tasks; algorithm for assessing student achievement, etc. [3].

Let's dwell in more detail on the technical aspect.

The origins of adaptive learning are the first software algorithms of B. F. Skinner, Norman A. Crowder and Gordon Pask, which were used in 1950-1960.

Skinner's algorithm assumed that the training material should be divided into small fragments, the answers should be taken in an open form and all participants in the learning process take the same course regardless of individual characteristics [35]. This approach has been called a linear algorithm. Another approach was suggested by Norman A. Crowder, according to which the teaching material should be presented in the form of more complex tasks, which are broken down into smaller ones in case one of the students cannot complete the initial one. Unlike Skinner's concept, Crowder suggested a closed form for receiving answers (choose the correct option out of the offered), feedback appears (after answering the question, the program explains why the answer was correct or where a mistake was made). But the most significant is the emergence of individual learning trajectories [14]. This approach is called branched. The concept of adaptive learning, laid down by Gordon Pask, has become widespread.

According to the concept, curriculum must be constantly adapted to a person who interacts with it, adjust course, maintaining the optimal level of complexity [27]. In modern interpretations of adaptability, one can find examples of linear, branched and adaptive algorithms. The latter was the most widely used in computer training systems.

Currently, the e-learning market has enough systems that use the term “adaptive learning” in the description of their product. In order to individualize learning, they actively develop adaptive learning tools – technologies that interact with the student in real time. They automatically provide individual support to each student.

To study the existing adaptive learning systems, consider the existing classifications given in studies [6, 13, 30, 36], and describe how adaptability is implemented in such systems.

Depending on the complexity of the curriculum, there are three levels of adaptive learning systems: systems that provide “passive”, “active” and “intellectual” adaptability [36].

Systems that provide “passive adaptability”: the active role is delegated to the student: based on the recommended set of parameters, the student, based on their own interests, plans the trajectory of their progress in the material, the timing of the study of content. Such systems use passive schemes ‘if ..., → then ...’, simple hypertext systems.

Systems that provide “active adaptability”: the system itself determines the trajectory of his further study on the basis of already completed educational material and on the basis of the student’s answers to test questions. In such systems active schemes “if ..., → then ...” are used, programming is applied.

Systems that provide “intellectual adaptability”: a student profile is formed on the basis of both psychological characteristics and personal preferences, which is constantly expanding. Based on it, a trajectory of progress in the assimilation of content is created. Such systems use programming methods based on the use of big data analytics in the field of learning – Learning Analytics [17].

Lou Pugliese [30] divided adaptive systems into four types: machine learning systems, advanced algorithm systems, rule-based systems, and decision tree systems. Others classify systems based on a basic adaptive algorithm [13]. However, one particular adaptive algorithm is rarely identified with a single system.

EdSurge [6] determined that adaptivity can occur in one or more elements: content, assessment, sequence.

Tools with adaptive content allow you to identify material that the student does not understand or misunderstands and get tips, corrections and links to useful resources.

Content is “adapted” to the student within one skill, which, at the same time, is divided into components. That is, the student learns one component, then moves on to another – as a result, acquires a full-fledged skill. In this case, the teacher in real time can receive information about how fast the student is moving, at what stage he is and where he needs help.

Adaptation of assessment assumes that each subsequent question depends on what answer the student gave to the previous one. The better it is, the more difficult the tasks, and vice versa – if it is difficult for the student to complete, the questions will be easier until he learns the material.

Traditionally, assessments are made in two ways: fixed form or adaptive. Fixed form assessment is one in which the elements are pre-selected, and each student is tested on the same set of questions (for example, the final exam). In adaptive assessment, elements change based on

how individual students answer each question. This change is often the result of the level of complexity of the element. For example, if a student answers a simple question correctly, the next received option is a little harder, etc.

Adaptive assessment tools are usually used for periodic monitoring every few months. Students receive a relatively voluminous test task, the purpose of which is to check how well they have mastered the material in 2–4 months. After monitoring, data analysis is performed, and the results are used to further adjust the program and individual learning trajectory of each student. Therefore, one of the advantages of adaptive tests is detailed statistics.

Continuous data collection and analysis are inherent in sequence adaptation. That is, while the student completes the task, the adaptive program analyzes his answers and automatically selects the relevant content, level of complexity and order of learning the material. Adaptive sequence tools are the most complex, as they both analyze data and compose and adjust the student's individual trajectory in real time.

To make an individual learning trajectory, adaptive programs take into account many different indicators: the correctness of the answer; number of attempts; use of additional tools or resources; student interests.

Sometimes these tools take into account the social reaction to the student (comments and likes) and even his mood.

The adaptive sequence is implemented in three stages: to collect data, analyze it and adapt the sequence of presentation of material to the needs of a particular student.

The main advantage of a learning tool with an adaptive sequence is to fill gaps in knowledge. If a student misses a lesson or has not mastered the topic before, and now it interferes with the study of new material, the sequence of tasks and topics changes. Thus, student fills the gap in knowledge first, and then moves on to the current topic.

The adaptive sequence is used by Knewton, Fishtree, BrightspaceLeap.

Some developers of adaptive learning tools use several strategies at once. For example, the tools Aleks, ScootPad, SmartBook combine adaptive evaluation and consistency. Adaptation of both content and evaluation is carried out by I-Ready, Fulcrum labs, Mastering CogBooks, Mathspace, Smart Sparrow combine adaptive content and consistency.

It is worth noting the study of the evolution of the market of adaptive learning “Learning to adapt 2.0” [4], which analyzes the adaptive learning technologies for the following opportunities (features):

- content source (OER, developer content, customer-generated content),
- technical support services,
- opportunities for communication and cooperation between participants in the learning process,
- adjustment functions (for example, teachers can set a scale for evaluating technology or indicators).

These classifications will be useful for understanding how technology can collect data and adjust adaptability. These technologies will be most effective if they are combined in one tool.

3. Results

In order to determine the most important tools of adaptive learning, the method of expert evaluation was used. The examination involved 20 people among teachers, teachers of educational institutions who have experience and research the implementation of elements of personalization of e-learning and understand the prospects for its use in the educational process. To select the tool of adaptive learning, a questionnaire was developed in which teachers distributed the selected tools by assigning a rank number. The tool that can, according to the expert, implement adaptive learning technologies as fully as possible (regardless of the discipline), was assigned the rank $N = 14$, the least – 1.

The concordance coefficient (W) or coefficient of agreement is used to assess the objectivity of the opinions of experts [31]:

$$W = \frac{12S}{m^2 \cdot (n^3 - n)}, \quad (1)$$

where S is the sum of the squares of the deviations of the sums of ranks from the average value of the sum of ranks for a given object of study (\bar{R}).

Then

$$\sum \bar{R} = \frac{1}{2} \cdot m \cdot (n - 1), \quad (2)$$

$$S = \sum (\sum R_i - \bar{R})^2. \quad (3)$$

where R_i – ranks assigned to each tool by i -expert; m – number of experts; n – the number of indicators.

After performing the calculation using formulas based on experimental data, we obtain certain value W . The coefficient of concordance varies in the range $0 < W < 1$, and at $W = 0$ agreement of experts is absent, and at $W = 1$ agreement is complete. If the value of concordance coefficient exceeds 0.40–0.50, the quality of the assessment is considered satisfactory, if $W > 0.70 - 0.80$ – high.

The significance of the concordance coefficient is checked using the statistical criteria χ^2 . It is significant and differences in expert assessments are not significant if the inequality holds $m \cdot (n - 1) \cdot W \geq \chi_{critical\ value}^2$ ($\alpha = 0.05$).

The results of expert surveys are listed in table 1.

The value of the coefficient $W = 0.79$. It indicates a strong consensus of experts. Let's check its significance by the criterion $\chi^2 : 210.6 \geq 36.2 = \chi_{0.05}^2$. Therefore, at a significance level of 0.05%, the calculated concordance coefficient is taken as significant.

As a result, 6 adaptive learning tools were chosen: Acrobotiq, Fishtree, Knewton (now Wiley), Lumen, Realize it, Smart Sparrow (now Pearson).

Taking into account the possibilities of adaptive learning technologies, we will formulate the criteria for selecting an adaptive learning tool.

Under the criteria for selecting tools for adaptive learning we will understand the features and properties of adaptive learning tools necessary for the holistic use of the learning process and its successful operation.

Table 1
Ranking of adaptive learning tools

Experts	Acrobatiq	Aleks	Brightspace by D2L	Cerego	CogBooks	Drillster	Fishtree	Fulcrum Labs	Knewton (now Wiley)	LearnSmart	Lumen	Open learning initiative	Realize it	Smart Sparrow (now Pearson)
1.	11	10	2	3	4	1	5	9	13	6	8	7	12	14
2.	9	8	4	5	3	2	6	10	14	1	11	7	13	12
3.	12	9	3	6	2	5	4	8	11	1	14	7	10	13
4.	10	8	1	7	2	5	6	9	14	3	13	4	11	12
5.	12	11	4	8	1	3	9	10	14	2	6	5	7	13
6.	11	8	2	4	5	1	14	7	13	3	10	6	9	12
7.	9	8	1	3	5	2	12	7	10	4	11	6	13	14
8.	8	10	5	2	1	4	13	6	14	3	9	7	11	12
9.	10	6	1	2	3	5	13	8	12	4	9	7	11	14
10.	9	7	2	4	5	1	12	8	10	3	11	6	13	14
11.	12	4	1	6	5	3	14	9	11	2	8	7	10	13
12.	12	8	2	6	5	4	13	3	14	1	10	7	11	9
13.	10	8	1	5	4	2	11	6	7	3	13	9	12	14
14.	9	10	3	6	1	4	12	5	11	2	8	7	14	13
15.	11	7	4	12	2	1	8	5	9	3	10	6	14	13
16.	10	8	1	5	4	2	12	6	11	3	9	7	13	14
17.	10	8	4	7	1	3	13	5	12	2	9	6	11	14
18.	9	7	2	3	4	1	11	6	12	5	10	8	15	14
19.	9	7	1	4	5	2	12	6	14	3	10	8	11	13
20.	10	9	2	6	1	3	8	5	11	4	12	7	13	14
\bar{R}	203	161	46	104	63	54	208	138	237	58	201	134	233	260
$R_i - \bar{R}$	53	11	-104	-46	-87	-96	58	-12	87	-92	51	-16	83	110

It should be noted that nowadays there are no complete and fairly detailed structured descriptions of the characteristics of adaptive learning tools in Ukraine. There are also no scientifically sound methodological approaches to the selection of such tools and evaluation of their quality. One way to validate software properties is through certification. It is carried out on the basis of current standards.

The most common is the international standard ISO/IEC 25010 [12], which defines two quality models:

- 1) a quality model in use, consisting of five characteristics that relate to the results of product interaction when used in a given context,

- 2) product quality model consisting of eight characteristics relating to the static properties of the software and the dynamic properties of the computer system.

The analysis of the characteristics of the product quality model described by the ISO/IEC 25010 standard and the specific features inherent in the tools of adaptive learning, allowed to identify the following selection criteria:

- (i) functional compliance – the degree to which the system provides functions of adaptive learning, which are implemented using this tool;
- (ii) compatibility – the degree of ability of the adaptive learning tool to share information with other products or systems;
- (iii) practicality – the degree of applicability of the tool of adaptive learning by users to achieve the goals with efficiency, effectiveness and satisfaction in a given context of use;
- (iv) support – determines the quality of support for the tool of adaptive learning by developers.

Each of the criteria is disclosed (deepened) in the following indicators:

- (i)
 - The “content adaptability” indicator suggests that content can be adjusted to student knowledge.
 - The indicator of “opportunities for joint work” involves the ability of students and / or teachers to interact with each other in the learning process.
 - “Socio-emotional state” indicator describes the use of the feedback and intervention based on student’s socio-emotional state.
 - The indicator “organization of knowledge assessment” characterizes the completeness of the presented tools for the development of various certification units.
- (ii)
 - The “LMS compatibility” indicator provides integration with known learning management systems (LMS).
 - The “standard compliance” indicator determines the types of standards for exporting the courses.
 - The “cost” indicator is responsible for the availability of a free tariff plan (even with limited functions).
- (iii)
 - The “learning autonomy” indicator assumes that students can influence or expand (deepen) learning based on their own choice.
 - The “accessibility” indicator takes into account the needs of all potential users, including those with disabilities.
 - The indicator “support for different forms of learning” provides the opportunity to organize learning with the tool of adaptive learning in various forms.
- (iv)
 - The “setting” indicator suggests that teachers and course developers can change the content of training or assessment.
 - The “content source” indicator characterizes the full range of opportunities for management and use of educational material.
 - The “documentation” indicator characterizes the completeness and quality of documentation for the tool of adaptive learning.

Table 2
Criterion “functional compliance” and its indicators

Indexes Adaptive learning tools	Content adapt- ability	Opportunities for joint work	Socio- emotional state	Socio- emotional state	Manifestation of the criterion
Acrobatiq	2.00	1.42	1.33	2.42	60%
Fishtree	1.50	1.33	1.08	2.08	50%
Knewton	2.25	2.58	1.58	2.33	73%
Lumen	2.17	2.75	2.25	2.67	82%
Realize it	2.33	1.92	1.67	2.58	71%
Smart Sparrow	2.83	2.17	2.67	2.58	85%

Table 3
Criterion “compatibility” and its indicators

Indexes Adaptive learning tools	Compatibility with LMS	Standards com- pliance	Cost	Manifestation of the criterion
Acrobatiq	2.42	2.67	1.17	69%
Fishtree	2.67	2.58	1.67	77%
Knewton	2.33	1.92	1.58	65%
Lumen	2.67	2.00	1.17	65%
Realize it	2.25	2.42	1.83	72%
Smart Sparrow	2.42	2.50	2.17	79%

Table 4
Criterion “practicality” and its indicators

Indexes Adaptive learning tools	Learning auton- omy	Accessibility	Support of var- ious learning forms	Manifestation of the criterion
Acrobatiq	1.58	2.50	2.58	74%
Fishtree	1.67	1.75	1.92	59%
Knewton	2.00	2.50	2.75	81%
Lumen	2.42	2.67	2.58	85%
Realize it	2.42	2.58	2.67	85%
Smart Sparrow	2.75	2.67	2.33	86%

Another group of experts (12 people) was involved in the selection of the most important tools for adaptive learning. Manifestation of each criterion was determined by the assessment of its indicators: 0 points – the indicator was not met; 1 point – the indicator is no longer observed than it is observed; 2 points – the indicator is more adhered to than not adhered to; 3 points – the indicator is fully complied with. In addition, the indicator was considered positive if the value of the corresponding coefficient – the arithmetic value of its parameters – was not less than 1.5.

Table 5
Criterion “support” and its indicators

Indexes Adaptive learning tools	Settings	Content source	Documentation	Manifestation of the criterion
Acrobatiq	2.25	2.50	1.42	69%
Fishtree	1.58	2.42	1.50	61%
Knewton	2.42	2.50	2.00	77%
Lumen	2.50	2.58	1.75	76%
Realize it	1.75	2.58	2.25	73%
Smart Sparrow	2.67	2.50	2.33	83%

The criterion was considered insufficiently manifested if less than 50% of its indicators were positive; critical manifestation of the criterion – 50–55%; sufficient manifestation – 56–75%; high manifestation – 76–100%.

Consider in more detail the results of each of the tools of adaptive learning. Tables 2–5 show the indicators of the defined criteria for each of the selected tools of adaptive learning.

Thus, according to the research, among the suggested tools of adaptive learning Smart Sparrow (now Pearson) and Lumen meet the most relevant criteria.

4. Conclusions and prospects of further research

The results of the study showed the importance of adaptive learning in the organization of the educational process, as it ensures the coordination of the learning process, taking into account the pace of learning, diagnosing the achieved level of mastery, providing the widest range of different learning tools, which would make it suitable for a wider audience.

The use of adaptive learning in higher education is a new area for learning. An important aspect is the choice of adaptive learning tool. Analysis of the characteristics of the product quality model described by ISO/IEC 25010, and specific features inherent in adaptive learning tools, allowed to identify and describe the criteria and indicators that should be followed when selecting adaptive learning tools: functional compliance; compatibility; practicality and support. According to the results of the study of adaptive learning tools according to these criteria, we can conclude that Smart Sparrow (now Pearson) and Lumen are best implemented the ability to show adaptability.

Prospects for further research are in-depth analysis and research of methodological aspects of adaptive learning, as well as the development of guidelines for the use of certain criteria for the selection of tools for adaptive learning.

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