Personalized and Adaptive ICT-Enhanced Learning: A Brief Review of Research from 2010 to 2019

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Abstract. Personalized learning is an up-to-date trend of formal and informal education development. Its main peculiarity is the maximum consideration of the person's educational needs. Nowadays, personalized learning involves development of student model based on personal characteristics; customized learning content, as well as intellectual information and communication technologies. These approach is considered as adaptive learning. Research results in the field of personalized and adaptive learning are presented in numerous publications. Thus, it was decided to perform the search in Scopus and Web of Science Core Collection, as well as the electronic libraries of the Institute of Electrical and Electronics Engineers and Association for Computing Machinery. The study consisted of two stages: 1) search by a set of key phrases; 2) search by a custom search query. The results of the analysis of the generated sample by years of publication, countries of origin of authors, number of citations are presented in tables and diagrams. Moreover, the review of some significant publications is given, and main areas of further studies are detected such as, the examining of teachers' experience in the field of use adaptive learning systems.

Keywords: personalized learning, adaptive learning, review.

1 Introduction

Increasing attention to a person-centered learning approach, widespread use of information and communication technologies in formal and non-formal education become a factor of the intensive research in the field of learning individualization and personification. The scientific results are reflected in numerous publications. In particular, methodological approaches and aspects of using information and communication technologies for personalized learning are presented in [1; 2; 3; 4; 5; 6].

As Turčáni and Balogh mention, personalized learning recognizes learners' diversity, cognitive and physical differences and the overall individuality. It includes various learning styles and approaches: from focused on the educational content to focused on supporting the learners by communication, discussion, cooperation [7, p. 47-48].

So, it is important to study the current state of research of the problem by reviewing literature sources. It is a common method of analysis, so there are a lot of articles presenting the reviews of publications on various aspects of personalized and adaptive learning.

Akbulut and Cardak [8] made a content analysis of studies describing adaptive educational hypermedia (AEH) with a focus on learning styles. They searched publications from 2000 to 2011 in several electronic databases, namely Ulrich's Periodicals Directory, ISI Web of Knowledge, EBSCOhost Web, SpringerLink, ERIC, Google Scholar and others. For research purpose different key words and phrases were used, eg. "adaptive/adaptable e-learning", "adaptation", "personalized e-learning", "learning styles". Authors selected 70 papers of such types as peer-reviewed articles, full-text proceedings of international conferences, symposia and workshops, and dissertations in English. These publications were classified under several categories, namely Publication type, Main focus, Purpose, Study nature, Variables used for adaptivity, Learning style model, Student modeling, Tool for modeling, Tools for dynamic modeling, Research settings, Participants, Type of empirical studies, Data collection tools. As a result, authors identified some expectations of AEH using in education.

We examined some other papers dedicated to literature review on personalized learning and adaptive learning systems. A systematic literature reviews were conducted to study individual differences accommodating in adaptive learning systems (Nakic, Granic, and Glavinic [9]); using competence-based recommender systems (Yago, Clemente, and Rodriguez [10]); personalized electronic learning models as a combination of learning theories, techniques and tools (Jando et al. [11]); characteristics, applications, and evaluation methods of intelligent tutoring systems (Mousavinasab et al. [12]); personal traits in adaptive learning environment and learners' models (Normadhi et al. [13]); challenges in the online component of blended learning (Rasheed, Kamsin, and Abdullah [14]).

The main motivation which encourages us to conduct this study is necessity to define methodological foundations and appropriate means of development of personalized adaptive learning system for professional training at universities, within the research on request of the Ministry of Education and Science of Ukraine, registration number 0120U101970. To achieve this goal needs to select pool of theoretical and applied papers.

Furthermore, there are two research questions in our study. First, "are issues of personalized and adaptive ICT-enhanced learning up-to-date?". Second, "what are the ICT-means for personalization of learning?". This study was conducted through a review relating to personalized and adaptive ICT-enhanced learning of papers published from 2010 to 2019.

2 Methodology

In the course of our study, we relied on the methodological foundations of the literature review as a research method outlined in [15; 16; 17], as well as materials of scientific publications Akbulut and Cardak [8], Nakic, Granic, and Glavinic [9], Yago, Clemente, and Rodriguez [10], Jando, Meyliana, Hidayanto, Prabowo, Warnars, and Sasmoko [11], Afini Normadhi, Shuib, Md Nasir, Bimba, Idris, and Balakrishnan [13], Rasheed, Kamsin, and Abdullah [14].

We analyzed the scientific publications in the abstract and citation databases Scopus (https://www.scopus.com) and the Web of Science Core Collection (www.webofknowledge.com), as well as the libraries of the Institute of Electrical and Electronics Engineers (IEEE, https://ieeexplore.ieee.org) and the Association for Computing Machinery (ACM, https://dl.acm.org/). These electronic resources were selected since they contain international scientific sources of high impact-factor. In order to select the most up-to-date and thorough research, it was decided to introduce additional restrictions, namely: articles in periodicals and proceedings of scientific conferences, as well as books and parts of books published in 2010-2019.

Web services of Scopus and Web of Science Core Collection abstract and citation databases provide a strong search functionality. In particular, we used filtration by subject area / category. Since our research was mainly related to the educational process, the subject area "Social Sciences" was selected for search in Scopus, and the category "Education educational research" in Web of Science Core Collection. The search was performed under the Title, Abstract and Keyword fields.

On the first stage, in order to determine the general level of scientific interest in the field of adaptive and personalized learning, we conducted a search in three categories, which can be defined as: *"personalization of learning", "adaptation of learning", "information systems for learning"*. In the process of keyword selection, we relied on works [9; 13; 18]. Three key phrases were selected for each area, namely:

- "personalization of learning": "personalized learning", "individual learning", "direct instruction";
- "adaptation of learning": "personalized e-learning", "adaptive learning", "intelligent tutoring";
- "information systems for learning": "personalized learning environment", "adaptive learning system", "intelligent tutoring system".

On the second stage, for the selecting of publications, which present the results of experimental studies in the field of adaptive learning systems, we composed a search query consisting of four parts, combined by the logical operator AND:

1. keywords to select publications that address adaptive and personalized learning: *(adapt* OR personali*)*;
2. keywords to select education related publications: *(education* OR "tutoring" OR instruction* OR course*)*;
3. keywords to select publications related to educational information systems: *("learning environment" OR "learning system" OR "tutoring system")*;

4. keywords to select publications that show the results of surveying, questionnaire, and empirical studies and in the field of using adaptive learning systems: *(evaluat* OR empiric* OR experiment* OR survey* OR questionnaire)*.

Given the specifics of the query language of databases, as well as the additional limitations pointed out, search queries were as follows:

for search in Scopus:

TITLE-ABS-KEY (adapt* OR personali*) AND TITLE-ABS-KEY (education* OR "tutoring" OR instruction* OR course*) AND TITLE-ABS-KEY ("learning environment" OR "learning system" OR "tutoring system") AND TITLE-ABS-KEY (evaluat* OR empiric* OR experiment* OR survey* OR questionnaire) AND (LIMIT-TO (DOCTYPE,"ar") OR LIMIT-TO (DOCTYPE,"cp") OR LIMIT-TO (DOCTYPE,"ch") OR LIMIT-TO (DOCTYPE,"bk")) AND (LIMIT-TO (SUBJAREA,"SOCI") OR EXCLUDE (SUBJAREA,"MEDI") OR EXCLUDE (SUBJAREA,"HEAL")) AND (LIMIT-TO (PUBYEAR,2019) OR LIMIT-TO (PUBYEAR,2018) OR LIMIT-TO (PUBYEAR,2017) OR LIMIT-TO (PUBYEAR,2016) OR LIMIT-TO (PUBYEAR,2015) OR LIMIT-TO (PUBYEAR,2014) OR LIMIT-TO (PUBYEAR,2013) OR LIMIT-TO (PUBYEAR,2012) OR LIMIT-TO (PUBYEAR,2011) OR LIMIT-TO (PUBYEAR,2010))

for search in Web of Science Core Collection:

TS=((adapt* OR personali*) AND (education* OR "tutoring" OR instruction* OR course*) AND ("learning environment" OR "learning system" OR "tutoring system") AND (evaluat* OR empiric* OR experiment* OR survey* OR questionnaire))
Refined by: WEB OF SCIENCE CATEGORIES: (EDUCATION EDUCATIONAL RESEARCH) AND DOCUMENT TYPES: (ARTICLE OR BOOK CHAPTER OR PROCEEDINGS PAPER)
Timespan: 2010-2019. Indexes: SCI-EXPANDED, SSCI, A&HCI, CPCI-S, CPCI-SSH, BKCI-S, BKCI-SSH, ESCI

Search results are presented through tables and diagrams.

3 Research Results and Discussion

To answer the first research question, "are issues of personalized and adaptive ICT-enhanced learning up-to-date?", the search in electronic libraries and databases was done.

Analysis of data collected through selecting publications in abstract and citation databases, as well as electronic libraries by the key phrases *"personalized learning", "individual learning", "direct instruction", "personalized e-learning", "adaptive learning", "intelligent tutoring", "personalized learning environment", "adaptive learning system", "intelligent tutoring system"*, leads to the conclusion that over the last decade, researchers have paid considerable attention to the theoretical and practical aspects of personalized and adaptive learning, in particular to using of information and communication technologies for provision of education adaptability (see Table 1).

Table 1. Generalization of search results.

Key phrases	Resource			
	IEEE Xplore® Digital Library	ACM Digital Library	Scopus	Web of Science Core Collection
personalized learning	411	550	720	448
individual learning	399	709	1056	596
direct instruction	26	171	505	312
personalized e-learning	70	29	65	28
adaptive learning	1351	972	782	385
intelligent tutoring	860	973	916	523
personalized learning environment	22	31	75	25
adaptive learning system	83	46	139	45
intelligent tutoring system	291	348	859	235

The data got from the Scopus and Web of Science Core Collection abstract and citation databases reveal the dynamics of scientists' publication activity in the field of personalized and adaptive learning by years. The results are given in the Table 2 and Fig. 1-3. We can state a stable scientific interest for these issues. In particular, the number of publications on most of the key phrases analyzed significantly increased in 2014.

Table 2. Distribution of publications on problems of personalized and adaptive learning by years.

Key phrase	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Web of Science Core Collection										
personalized learning	19	15	24	27	23	49	88	86	72	45
individual learning	52	43	46	50	40	82	76	82	71	54
direct instruction	15	21	19	20	17	46	35	42	53	44
personalized e-learning	2	2	2	2	4	3	3	2	5	3
adaptive learning	25	20	18	28	24	35	65	68	55	47
intelligent tutoring	45	24	29	42	41	45	99	79	54	65
personalized learning environment	2	1	1	2	1	2	5	4	4	3
adaptive learning system	0	3	2	4	1	7	8	2	10	8
intelligent tutoring system	22	8	13	18	14	27	47	31	24	31
Scopus										
personalized learning	46	35	55	50	48	78	75	91	110	132
individual learning	97	99	100	97	96	124	95	108	112	128
direct instruction	40	31	49	46	38	60	44	50	65	82
personalized e-learning	7	5	6	8	6	5	6	3	8	11
adaptive learning	63	55	52	63	57	70	99	93	123	107

Key phrase	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
intelligent tutoring	92	68	81	89	90	89	122	98	94	93
personalized learning environment	8	5	6	8	5	9	10	7	7	10
adaptive learning system	4	5	9	16	15	11	21	17	22	19
intelligent tutoring system	80	63	76	86	83	84	114	90	92	91

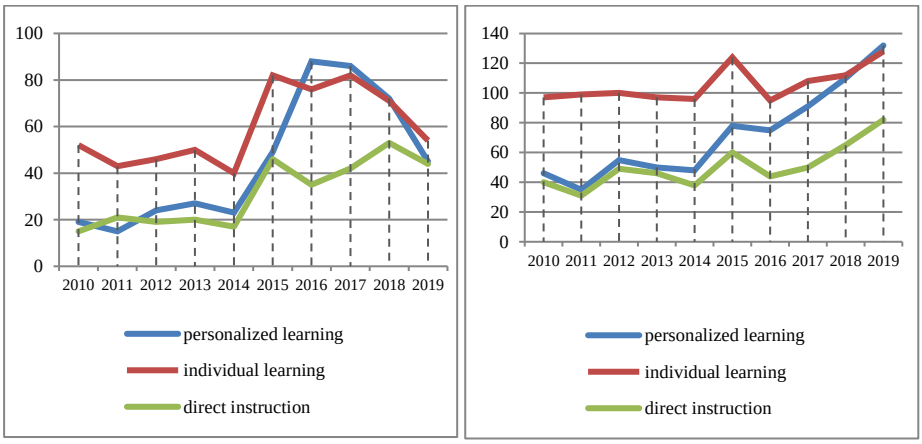


Fig. 1. Dynamics of publication activity on the problems of personalized and individual learning, according to Web of Science Core Collection (a) and Scopus (b) abstract and citation databases (accessed March 25, 2020).

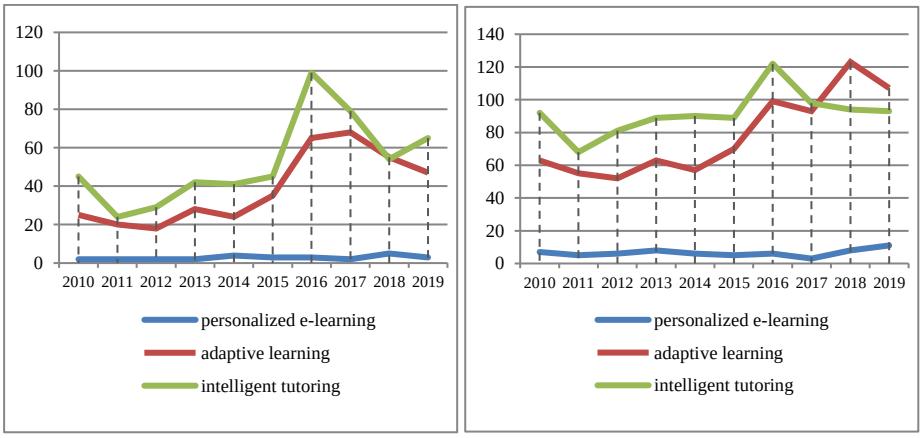
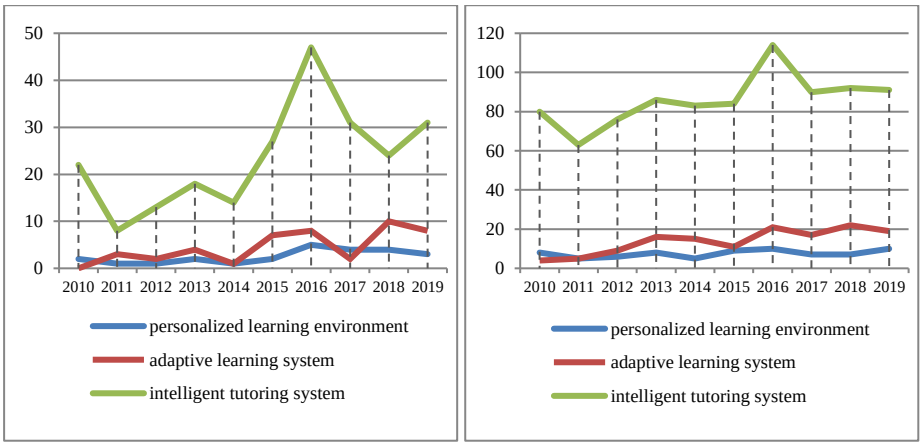


Fig. 2. Dynamics of publication activity on the problems of personalized e-learning, adaptive learning and intelligent tutoring, according to Web of Science Core Collection (a) and Scopus (b) abstract and citation databases (accessed March 25, 2020).



a) data source: Web of Science Core Collection b) data source: Scopus

Fig. 3. Dynamics of publication activity on the problems of personalized learning environment, adaptive learning system and intelligent tutoring system, according to Web of Science Core Collection (a) and Scopus (b) abstract and citation databases (accessed March 25, 2020).

The Web of Science Core Collection and Scopus abstract databases also provide an opportunity to analyze the distribution of authors by country. Based on the analysis of relevant data, we can conclude that these problems are relevant for educational systems of different countries. The most scientists represent the United States of America. The leaders' list includes researchers from China, Spain, Germany. In the Table 3, three countries with the highest authors of publications percentage are shown for each of the key phrases.

Table 3. Distribution of publications on personalized and adaptive learning by country.

Key phrase	Percentage of the total number of authors of publications indexed in the abstract database		
	1st	2nd	3rd
	Web of Science Core Collection		
personalized learning	USA 24.8%	China 18.3%	Spain 7.8%
individual learning	USA 13.4%	Germany 9.9%	China 6.0%
direct instruction	USA 36.9%	Indonesia 6.7%	Germany 6.4%
personalized e-learning	Australia 14.3%	Greece 14.3%	China 10.7%
adaptive learning	USA 19.2%	Taiwan 7.5%	Spain 7.3%
intelligent tutoring	USA 36.1%	Taiwan 8.0%	Spain 6.5%
personalized learning environment	USA 20.0%	Spain 12.0%	Greece 8.0%
adaptive learning system	USA 17.8%	Taiwan 17.8%	China 13.3%
intelligent tutoring system	USA 34.0%	Spain 8.5%	Canada 8.1%
	Scopus		
personalized learning	USA 24.2%	China 13.6%	United Kingdom 8.1%

Key phrase	Percentage of the total number of authors of publications indexed in the abstract database		
	1st	2nd	3rd
individual learning	USA 19.3%	Germany 11.1%	United Kingdom 9.8%
direct instruction	USA 47.7%	Australia 6.3%	Canada 5.5%
personalized e-learning	Greece 10.8%	Spain 9.2%	United Kingdom 9.2%
adaptive learning	USA 22.6%	China 9.3%	Taiwan 6.6%
intelligent tutoring	USA 39.7%	Germany 6.6%	China 5.8%
personalized learning environment	USA 18.7%	Germany 9.3%	United Kingdom 6.7%
adaptive learning system	USA 19.4%	China 15.1%	Taiwan 7.9%
intelligent tutoring system	USA 39.7%	Germany 6.5%	China 5.9%

The analysis of publications indexed by Scopus and Web of Science Core Collection by criterion of authors' affiliations also shows that the United States is the leader (Scopus – 12.3%; Web of Science Core Collection – 11.0%).

Selecting of papers in electronic libraries and abstract databases within the search query *"(adapt * OR personali *) AND (education * OR "tutoring" OR instruction * OR course *) AND ("learning environment" OR "learning system "OR" tutoring system ") AND (evaluative * OR empiric * OR experiment * OR survey * OR questionnaire)*" gave such results: IEEE Xplore® Digital Library – 402; ACM Digital Library – 3215; Scopus – 1280; Web of Science Core Collection – 573. Most of these materials have been published in influential international scientific journals, including Computers and Education, International Journal of Artificial Intelligence in Education, International Journal of Emerging Technologies in Learning, Interactive Learning Environments, British Journal of Educational Technology, Educational Technology & Society.

The distribution of publications by years according to Scopus and Web of Science Core Collection is given in Table 4 and shown in Fig. 4. Note, that the number of publications indexed in Scopus is gradually increasing, and the Web of Science Core Collection is changing slightly.

Table 4. Distribution of publications on problems of application of adaptive learning systems by years.

Data source	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Scopus	88	91	109	124	120	142	140	140	153	173
Web of Science Core Collection	5	3	6	4	3	12	12	6	8	12

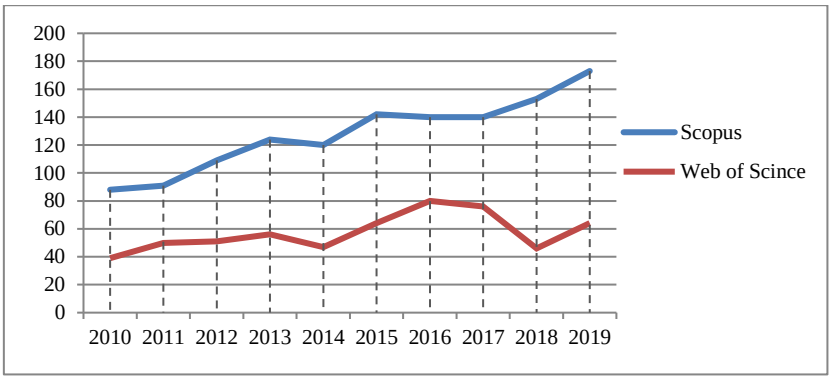


Fig. 4. Dynamics of publication activity on the problems of using adaptive learning systems personalized and adaptive learning according to Web of Science Core Collection (a) and Scopus (b) abstract and citation databases (accessed March 25, 2020).

One of the indicators of the interest of scientists in the presented materials, as well as the degree of influence of these publications in the field of research on the problems of adaptive learning in the educational process is their citation. The distribution of publications selected by search query by the number of citations is given in Table 5. The table is based on Scopus and Web of Science Core Collection data, so the number of citations in materials indexed in Scopus and Web of Science Core Collection is taken into account.

Table 5. Distribution of publications on problems of using adaptive learning systems by number of citations.

Data source	0 citations		1 – 49 citations		50 – 99 citations		100 or more citations	
	number	%	number	%	number	%	number	%
Scopus	352	27.5	876	68.4	38	3.0	14	1.1
Web of Science Core Collection	271	47.3	284	49.6	14	2.4	4	0.7

The findings of the studies implied that scientists are interested in issues of personalized and adaptive ICT-enhanced learning. So, we can state their significance for theory and practice of education.

To answer the second research question "what are the ICT-means for personalization of learning?", we examined some scientific papers devoted to using ICT for personalization of learning from the list selected on the previous exploring stage.

In [19], Su J-M. develops the a rule-based self-regulated learning (SRL) assistance scheme to intelligently facilitate personalized learning with SRL-based adaptive scaffolding support for learning computer software [19, p. 536]. He defines five adaptive scaffolding strategies and rule sets which are corresponding to planning, controlling, monitoring, and reflecting phases [19, p. 540]. Moreover, researcher describes intelligent learning environment built on these strategies, and gives examples of rule sets use. Through an experimental research, he points out advantages of using approach

offered. In particular, one of them is the scaffolding strategies can be manageable and extensible to support different learning subjects of computer software courses [19, p. 553].

In [20], Rohloff, Sauer, and Meinel discuss the problem of content and learning paths personalization in Massive Open Online Courses (MOOC). They state, that MOOC platforms are oriented on providing knowledge numerous learners. But, this approach is not very effective, and a lot of learners are not achieve their educational goals. Researchers offer tools to integrate personalized learning objectives into MOOC platform and facilitate students activities. Through the special interface, learners select learning objectives which are subsequently supported by guiding the learning with respect to the selected objective [20, p. 9].

In [7], Turčáni and Balogh are considering a methodology for creating a personalized e-course with the possibility of adapting to the learner in a special environment. They offer an AdaptiveBook module for LMS Moodle which collects data about students' activities and helps to build personal learning way.

A recommendation module of an adaptive and intelligent web-based programming tutoring system – Protus is described in [21]. As Klašnja-Milićević et al. state, tutoring systems can contain two categories of adaptivity tools: (1) adaptive hypermedia for course adaptation to learners' individual learning styles; (2) recommendation techniques to suggest the most appropriate learning activities to learners [21, p. 886].

The recommender framework offered by researchers contains three modules: (1) a learner-system interaction module, which gathers data of learners activities to build appropriate models; (2) an off-line module, which recognizes learners' goals using learner models; (3) a recommendation engine for producing a recommendation list [21, p. 888]. To investigate learning styles across four dimensions (Information Processing, Information Perception, Information Reception, Information Understanding), authors use data collection tool - Index of Learning Styles by Felder and Soloman [21, p. 889]. To evaluate benefits of using this recommendation module, researchers performed an experiment while studying programming. They conclude, that experimental results show positive effect of using proposed module.

Some other approaches to personalization of learning are considered in [22; 23; 24; 25; 26].

The following conclusions can be drawn from the results of the analysis:

- a person-centered approach is well developed in educational theory and practice. However, researchers are looking for new ways to implement it in order to achieve the highest degree of accordance learning content and means to person needs and opportunities and to provide conditions for lifelong learning;
- personalized and adaptive learning envisages the organization of the educational process when a comprehensive study of learner is carried out, then a model of one's possible development is constructed, and subsequent influences and interactions are built taking into account this non-static editable model;
- development of learner model is based on data about the learning style and other personal characteristics. Its collecting and further processing are complex process

that requires the involvement of specialists in various scientific fields, as well as the use of information and communication technologies;

- organizing the distance learning process updates research on the issues of adaptive learning systems, among which we consider it advisable to highlight areas such as: improving the functionality of existing learning management systems, including the extended Moodle platform, to provide them with the means of personalizing learning (student analysis, personal characteristics) formation of individual educational routes, adaptive delivery of educational content and assessment, etc.); professional training of specialists (psychologists, teachers, tutors) for the application of these systems in formal and non-formal education institutions.

At the end, it is necessary to emphasize that individualized and adaptive learning have an important significance for life-long learning development. There are some reasons of this statement. Firstly, these approaches are based on learning styles models, and suppose satisfaction of persons' educational needs in different circumstances. Secondly, using information and communication technologies helps to give access to learning to widespread strata of the population.

4 Conclusion

The article presents the results of studying the state of research into the problem of organizing personalized and adaptive learning, as well as the use of adaptive learning systems. The study was conducted using the method of extensive search in electronic databases.

The analysis covered scientific publications for the years 2010-2019, presented in the abstract and citation databases Scopus and Web of Science Core Collection, as well as the electronic libraries of the Institute of Electrical and Electronics Engineers and Association for Computing Machinery. The study consisted of two stages: 1) search for a set of key phrases: *"personalized learning", "individual learning", "direct instruction"*; *"personalized e-learning", "adaptive learning", "intelligent tutoring"*; *"personalized learning environment", "adaptive learning system", "intelligent tutoring system"*; 2) search on a custom search query *(adapt* OR personali*) AND (education* OR "tutoring" OR instruction* OR course*) AND ("learning environment" OR "learning system" OR "tutoring system") AND (evaluat* OR empiric* OR experiment* OR survey* OR questionnaire)*. The results of the analysis of the generated sample by years of publication, countries of origin of authors, number of citations are presented in tables and diagrams.

The resulting sample covers publications in influential scientific publications. The refinements applied (time period, databases, key queries, search categories, etc.) limit its scope and facilitate processing, but narrow the analyzed area somewhat.

Taking into account the above perspective areas of research, further intelligence is aimed at conducting a systematic review of literary sources, which presents the experience of teachers in the use of adaptive learning systems, as well as studying the level of preparedness of teachers and higher education students in the field of knowledge "Education / Pedagogy" in their use in educational process.

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