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E-Learning: Let's Look Around

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Abstract: The evolution of e-learning systems put them in almost all areas of human life. E-learning can be considered in context of continuous societal and technological development. Current trends lead to creation of virtual society, alongside the physical world. As new information communication technologies are developed, it is possible to extend the domain and usability of existing e-learning methodologies. E-learning technologies are used and developed by educational institutes, governmental organisations as well as commercial content vendors and large business corporations.
This papers briefly reviews the evolution of learning paradigms and methodologies. With focus on modern e-learning tools and platforms, in the second part, different approaches in organising learning delivery are presented. In the third part, characteristics of e-learning tools and platforms are reviewed. According to the ISO software quality measure standards 9126 and 25000 and available assessing methods for learning systems, we propose a set of important characteristics for descriptive evaluation of e-learning systems. Furthermore, we analyse the impact of developing IT areas on selected characteristics.
Keywords: e-learning, e-learning systems, e-learning systems evaluation, e-learning tools, Content management systems

1 Introduction & background

To effectively understand current trends and approaches in learning delivery, it is important to give a brief overview of historical development of different philosophies and understandings of learning mechanisms. Today, four different approaches are differentiated: behaviourism, cognitivism, constructivism and connectivism [47, 28]. Although there are other classifications of learning theories and approaches [32], given classification still remains essential. This classification follows historical development of human cognition of the nature of the human brain and learning processes. The Table 1 describes five main aspects of four major learning paradigms [46, 48]. It is worth to mention that behaviourism and cognitivism were often referenced as an instructivistic paradigm.

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Table 1: Learning theories aspects

1. How does learning occur? 2. What are main influencing factors? 3. What is the role of memory? 4. How does transfer occur? 5. Which types of learning are best explaining?		
Behaviourism	1	Black box - observable behaviour main focus
	2	Nature of reward, punishment, stimuli
	3	Memory is the hard-wiring of repeated experiences - where reward and punishment are most influential
	4	Stimulus, response
	5	Task-based learning
Cognitivism	1	Structured, computational
	2	Existing schema, previous experiences
	3	Encoding, storage, retrieval
	4	Duplicating knowledge constructs of ”knower”
	5	Reasoning, clear objectives, problem solving
Constructivism	1	Social, meaning created by each learner (personal)
	2	Engagement, participation, social, cultural
	3	Prior knowledge remixed to current context
	4	Socialisation
	5	Social, poorly defined contexts
Connectivism	1	Distributed within a network, social, technologically enhanced, recognising and interpreting patterns
	2	Diversity of network
	3	Adaptive patterns, representative of current state, existing in networks
	4	Connecting to (adding) nodes
	5	Complex learning, rapid changing core, diverse knowledge sources

Beside this classification of learning theories paradigms, there are thoughts about their mutual dependencies and interconnections. Although there are strong criticisms between defenders of different learning theories paradigms, the fact is that all of them still coexist in practise. Therefore, arguments that learning paradigms do not supersede each other; instead of that, they complement one another (fig. 1, [51]), should not be neglected.

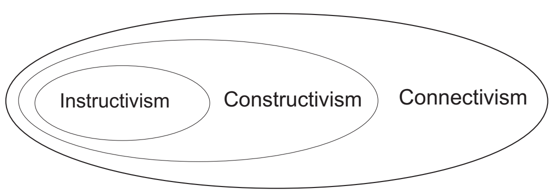

Fig. 1: Major learning theory paradigms in complementary relationship

A look back in history reveals that ’e’ in ’(e-)learning’ went out of the brackets many decades before other ’e’-es found their way in front of nouns ’commerce’, ’government’ or ’society. In 1920, a machine that could be used for tests preparation and assessments was Sydney Pressey’s testing machine [28]. Since that time, another 40 years have had to pass until first machine-based learning systems were made. In 1958, B.F. Skinner built a teaching machine, the ”Skinner box” which could lead learners through programmed instructions and give feedback. The moment when e-learning was formed is in correlation with development of first computers and introduction of Internet and world wide web (WWW). Since that time, it was recognised how innovations and technologies could be used in learning and education.

Process of continual improving and advances in (e-)learning systems is led by scientists and universities. Governmental or political initiatives are also strong driver toward progress in methods, tools and platforms for learning. This process becomes global concern with interest and participation of highest political instances worldwide.

Standardisation and usage of e-learning is supported by highest committees as European Union that promotes e-learning techniques under the EU Structural Funds (2007-2013), and within the framework of the "Lifelong Learning Program" (LLP). In the heart of all new approaches to delivering education is Bologna process. Starting from 1999. to 2010., the main goal was to create European Higher Education Area (EHEA). Some of main changes and aims in curriculum in higher education and courses delivery, defined by European Commission, have direct influence to e-learning [41]:

- improving the recognition of prior learning, including non formal and informal learning;
- creating more flexible, student-centred modes of delivery;
- developing flexible learning paths, allowing learners, for instance, to alternate between work and study; and
- widening access to higher education.

Investments in changes in educational system in United States have wide goals, but also specific goals related to learning methods, platforms and tools, i.e. to foster critical thinking, problem solving, and the innovative use of knowledge, as well as to involve state-of-the-art assessment and accountability systems that provide timely and useful information about the learning and progress of individual students, instead of "off-the-shelf" tests[40].

The third major motivating factor for changing learning is the influence of information communication technologies to the concept of workplace and collaboration. Competences development in face-to-face or virtual teams are today more important than accepting of learning materials. There is a tendency in developing educational systems based on competences development [54]. However, there are areas where using e-learning technologies is not preferred regarding competences development. Study done in [42] shows that, while numerous competences can be developed when working with virtual teams, development of some competences, such as ability to take decisions, solve problems and oral communication skills have to be addressed in face to face teams.

In the following section we will briefly explain some of popular learning methods. Than, supporting learning tools and platforms will be introduced. To address different characteristics of these systems, we will give overview of actual developing IT areas in learning and education. To summary, learning tools and developing IT areas will be described according to chosen set of characteristics.

2 (E-)learning methods

Within learning paradigms described in the previous section numerous learning theories are developed, and most of them were supported by learning methods, approaches and/or tools. Current tendencies are mainly directed towards implementation of constructivistic methodologies. Thus, learners knowledge forming is put in the centre. In this section, some specific approaches will be introduced. Although constructivism is in the focus, the connectivism is yet to become popular [47].

It is important to identify current and future directions in forming roles and responsibilities within learning systems. To do so, we start by taking into consideration traditional roles of learning actors. Table 2 tries to identify roles that learners and instructors took in a traditional learning principles.

Table 2: Traditional learners and teacher roles

Actor	Roles
Teacher	Makes structure of learning material, defines learning activities, supervises and assesses learners work and helps learners
Learner	Passively accepts and builds knowledge

Two most important classes of e-learning are experiential (significant) learning, and cognitive (meaningless) learning. Studies showed that learners better acquire knowledge when they take active role in educational process. The emphasis thus shifts from the instructor and content-centred approach toward the learner-centred approach [19]. Moreover, development of learner's competences, as primary goal, introduces radical changes in education organization. As stated in [35], teachers role is as the person who structures the learning process, the major player in education, as well as supervisor of the students work, whose knowledge he evaluates. In the vision centred in the student, the teacher is now a companion in the process of learning, which helps the studying to achieve certain competences. The role of the teacher moves increasingly toward an advisor, guide and motivator [35].

There are a lot of methods that can contribute to effective building of knowledge but many of them put project or problem-based learning as a central point of interest. Problem solving techniques named problem-based learning can be used to engage learners in active knowledge building. There are studies proving its usefulness in cognitive-constructivist environments especially in engineering and experimental sciences, as a research-oriented teaching methodology [35].

In [36] authors give results on project-based learning methods used in teaching project courses. Beside problem and project-based learning there are other similar learning methods including active learning, inquiry-based learning and service learning. Regarding active learning, to be actively involved in learning process, students must perform great effort in analysis, synthesis, and evaluation. That means that just listening is not enough. Active learning requires from learners to take active part in comprehension by discussing, writing, playing roles in simulation games and problem solving. In this context, it is proposed that strategies promoting active learning had be defined as instructional activities involving students in doing things and thinking about what they were doing [4]. Inquiry-based learning is based on recognition that science topics are question-driven, open-ended process and to understand this fundamental aspect of science, learners have to learn how to pose and refine questions, perform investigation and present obtain results [16]. Furthermore, inquiry activities provide a valuable context for learners to acquire, clarify, and apply an understanding of science concepts.

Service learning is a form of experiential learning involving community oriented service to enrich learning experience and further understand learning content. Thus, learners are more interested in learning materials with introduced elements of civic education. As a result, service learning makes positive impacts on learners personal, attitudinal, moral, social, and cognitive outcomes. Authors in [6] outline what are main phases and actions in implementing service learning, identifying main institutions and their roles.

Study [27] of new teaching strategies discussed following teaching methods:

- Laboratory instruction
- Tutorial strategies
  - subject's tutorial
  - degree's tutorial
  - adviser's tutorial

For laboratory instruction, strategy called ”Studio teaching method” provides tight integration of theory and practise, giving students possibilities to introduce concepts and make experiments at the same time. Several universities have implemented this strategy [27, 13]. In tutorial strategies, three different strategies are discussed.

In subject's tutorial learners do much of the work, role of the teachers is to make rich tasks, challenge students work with misconceptions, and make active working atmosphere. Degrees tutorial included meeting sessions to provide constant challenges and opportunities for both instructors and students. Also, several sessions were conducted to deal about students' major concerns regarding the whole organisation aspects. Personal advising was there to try to help all other issues that could influence achieving academic goals.

Beside these radically new approaches for delivering of learning process, questions arise regarding assessment of students activities. Development of such systems usually consists of phase of developing of items, implementation, delivery and scoring or reporting systems. A key term here is CAA, or Computer Aided Assessment [7]. It encompasses usage of computers to deliver, mark and analyse assignments or examinations. Such systems usually analyses optically captured data from OMR, or Optical Mark Readers. Opposite to this, CBA or Computer Based Assessment means usage of terminal to interact with the user. Moving from traditional written tests and assessments, authors usually deal with so called Unit banks [12], as a collection of questions grouped by topic, difficulty or type of skill. It is frequently discussed as CAT or Computer-Adaptive Testing. Based on learners previous responses, system automatically issues questions and tests to test limits of learners ability [12].

3 Supporting technologies

In order to analyse software tools available for learning support, two planes could be distinguished: e-learning tools and systems.

Software tools provide realisation of certain activity during learning, and some of commonly used categories are: hypertext, tutorials, video lessons, simulators, drills, educational games, slide presentations, electronic tests, chat, forum, wiki, blogs, e-mail, instant messaging etc. On the other hand, e-learning systems integrate and interconnect different e-learning tools into one integrated platform for learning.

Based on communication characteristics of software and resources for e-learning, three different e-learning environments could be distinguished:

- Self-study,
- Asynchronous, and
- Synchronous.

This classification is due to existence of different spatial and temporal restrictions in learning process. For these reasons, until recently it was possible only for self-study and asynchronous e-learning to be realised. This means, participants in learning process do not interact at all or their learning activities are not bound by time. Self study approach is oriented to tools and material prepared in advance which are used by learner itself, without later interactions intended. Typical examples of self study software tools are: tutorials, e-books/hypermedia, drills [2]. Also, simulations, educational games, open-ended learning environments could be designed as self study oriented. Asynchronous e-learning is usually facilitated by the tools that do not require for participants to be present at the same time to enable work relations. Examples of asynchronous e-learning include watching a video lesson, taking an online exam or posting questions to a message board. For synchronous learning to be realised, participants have to join the virtual sessions in the same time, due to real time characteristics of synchronous e-learning style. Table 3 summaries technologies and tools used to support asynchronous and synchronous e-learning [28, 23] and lists some main characteristics of asynchronous and synchronous e-learning [23]. There is a number of supporting e-learning tools for synchronous e-learning. In [20] a functional evaluation of 20 synchronous e-learning tools is presented. Some of explained are WebEx Training Center, Centra Symposium, Microsoft LiveMeeting, LearnLinc etc.

Table 3: Synchronous and asynchronous e-learning. Adopted from [23]

E-learning type	Asynchronous	Synchronous
Supporting tools and technologies	email, discussion boards, Web-based training, Podcasting, Computer aided systems	Instant messaging, shared whiteboards, audio-video conferences, Online chat, Live webcasting, Web conferencing
Characteristics	Intermittent on-demand access Previously recorded or preproduced Just in time Individual or poorly collaborative Independent learning Self-paced	Real-time Live Scheduled Collaborative Co-presence of learners and instructor Concurrent learning

Merck introduced blended learning which extends classic learning methods with e-learning elements. Suitable approaches to forming of blended e-learning materials are presented in [50].

E-learning systems have a goal to create, manage e-learning courses and integrate learning resources and tools. E-learning systems can be classified as [43]:

- LMS - Learning Management System,
- CMS - Content Management System, and
- LCMS -Learning Content Management System

Figure 2a shows simplified structure of the LMS system. LMS provides interface to successful presentation of learning modules and trainings to learners. Moreover, there are mechanisms to manage user access control and user classifications. One important characteristic of such systems is ability to monitor progress of users activities and completion status [39, 43].

CMS is a family of software, when used as e-learning systems it enables content creators, instructors and teachers to store, manage, create and edit learning resources. By building shareable context, one aspect of such systems becomes important, so called RLO (Reusable Learning Objects) [39] or reusable content components. It is easy to separate content from its layout, by providing appropriate presentation methods [39]. Simplified structure of CMS system is shown in Figure 2b.

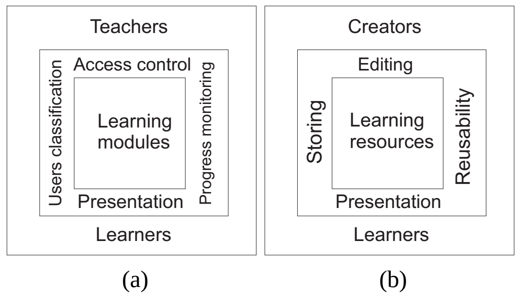

Fig. 2: Simplified structures of a) LMS b) CMS

LCMS are systems that integrate LMS and CMS. In such environments, that are often Web-based, there are possibilities to build learning content using elementary and reusable components, to manage access, track learners activities progress and manage presentation [39]. Simplified structure of LCMS is shown in the Figure 3.

There are a lot of works that deal with comparison of well known LMS and LCMS systems. Some useful comparisons are given in [33, 30]. With the aim to understand which characteristics of modern LMS and LCMS are suitable for competences development, it is useful to analyse which learning tools are suitable for competences development. Study from [53] lists some most important competences.

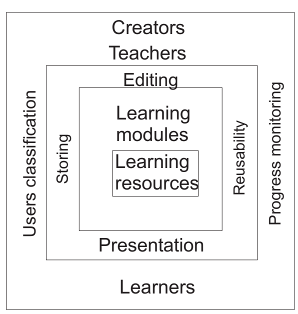

Fig. 3: Simplified structure of LCMS

Predictions about e-learning styles and systems are numerous. According to [56] the future of e-learning is in:

- growth in synchronous learning;
- prevalence of blended solutions;
- improved technology and access; and
- integration of information provision, performance support, peer collaboration and training.

With continuous development of communication technologies, it will be possible for learners to actively take part in learning process in every moment. This access is enabled by development of small handheld devices with networking capabilities. Using such devices, it will become possible to realise real time collaboration and information interchange on e-learning platforms, with strong peer collaboration and information provisioning systems.

4 Analysis of developing IT areas in e-learning

In order to analyse e-learning trends and tools in a systematic manner, different aspects could be taken into consideration. Having in mind that tools for e-learning are mainly software it is possible to evaluate their characteristics according to well established criteria for software quality. ISO 9126 - Software Quality Characteristics standard [17] and its successor ISO 25000 - Software product Quality Requirements and Evaluation [18] are possible starting points for making a set of criteria for analysis. Moreover, specific contexts for evaluation of educational software were developed and could be used. One of proposed methods is CIAO! [31]. The third starting point could be quality criteria classification for specific kinds of educational software such as criteria classification for evaluation of LMS-es proposed by Hall [25]. Evaluation according to CIAO! framework may provide accurate results, but requires data acquisition from actual users of e-learning software through interviews, questionnaires, tests and other similar means. These characteristics are hardly applicable in analysis of classes of e-learning tools.

According to the mentioned ISO standards, main characteristics for software evaluation are: functionality, reliability, usability, efficiency, maintainability and portability. According to Hall, the following set of characteristics could be used for LMS evaluation: availability, usability, scalability, interoperability, stability and security [25]. We propose a new classification of criteria for evaluation of tools and approaches in e-learning. Criteria classification is derived from mentioned two classifications [17, 18, 25] as shown in Table 4. Functionality, efficiency, and maintainability were adopted from ISO criteria while availability and scalability were adopted from Hall classification. Stability and security can be considered within the frame of reliability aspect and they will be considered. By taking interoperability with grater importance for e-learning systems and tools, compared to portability, only interoperability will be considered. As a result, the adopted criteria presented in the third column of the Table 4 is used for the brief analysis in this section.

Table 4: Creation of classification criteria

ISO 9126/ ISO 25000 criteria	Hall criteria	Proposed criteria
functionality		functionality
	availability	availability
reliability	stability	stability
	security	security
usability	usability	usability
efficiency		efficiency
maintainability		maintainability
	scalability	scalability
portability	interoperability	interoperability

In this section, we will give an overview and summarise characteristics of developing IT areas according to the proposed classification.

Availability is one of the most important characteristics of e-learning systems. To deal with availability of e-learning resources, many different approaches are presented. Some are based on centralised architectures while others introduce distributed hierarchy. In [43], authors propose compromise between totally centralised and distributed systems to arrange offered services. A solution is to create a hierarchical structure (semi-centralised) and use software agents for merging search results.

Various methods are deployed to deal with efficiency of software based solutions in learning process[44]. For example, authors in [8, 9] discuss method and a tool to efficiently create simulation models that can be used both for presentation and for practising providing description and visualization of computer architectures.

Main problem in creating of open e-learning systems is interoperability between different platforms. There exist several standards that deal with standardisation of learning repositories queries, and interconnection of different repositories (SQI, OAI-PMH). Also, there are standards that define requirements for resource sharing between different e-learning platforms. The most popular are LOM, SCORM (Sharable Content Object Reference Model), specifications provided by IMS GLC, or PENS (Package Exchange Notification Services), or the oldest recommendations defined by AICC (Aviation Industry CBT Committee).

Various techniques are used by researchers to improve existing and to add new functionality to e-learning platforms. Agents based approach is used in machine learning or data-mining technologies from data stored in learners database to produce so called a "learning agent" [52]. Purpose of such agents is to predict a learner's final status in order to generate adaptive instructional messages to guide the learner [52]. Another usage of data mining technologies is to develop techniques for detecting of plagiarism in e-learning reports and evaluation of e-learning classes [11]. There are studies based on machine learning advances on predicting learner's final score using learner history data. Authors in [37, 52] compared the accuracy of machine-learning methods (decision-tree model, naive Bayes, and SVM (Support Vector Machine)) to predict a learner's final test score from the learning-history data in e-Learning. Authors in [37] proposed a method to classify students in order to predict their final grade based on features extracted from logged data in an education Web-based system. They designed, implemented, and evaluated a series of pattern classifiers and compared their performance on an online course dataset. They constructed multiple classifiers (CMC) from learning-history data in e-Learning, and they reported that a modified method using a genetic algorithm (GA) could improve the accuracy of prediction. In [57] authors tried to detect meaningful patterns of learning activities in e-Learning using the association rule. The goal was to make a tool to ease discover of relationships between learning activities that learners perform, sequential analysis to discover interesting patterns in the sequences of on-line activities, and clustering to group similar access behaviours. While this and similar works try to predict learner results, [52] tries to generate adaptive instructional messages to guide the learners.

Interesting study based on factor analysis identified minimum complete set of LMS tools that are required to achieve most important competences: hypertext, video-lesson, simulator, virtual library, graphical forum, virtual classroom, calendar, lecture and debate [53].

Data-mining technologies are used for personalisation of learning paths [10]. Personalisation of learning process is closely related to recommendation tasks in which the system analyses learners affinities and recommends items of interest. This means system can recommend lessons, links or concepts to the learner to lead him toward achieving learning goal. Commonly used techniques are prediction, classification, clustering, association rule mining and sequential pattern discovery. Authors in [45] use data mining techniques for links recommendation system. In [34] authors propose a solution that represents integrated learning activity-based mechanism to assist users with automatic material recommendation.

Usability of e-learning systems can be improved by using the most powerful and advanced visualisation tools supported by modern ICT solutions. In order to make learning materials more interesting for learner Augmented Reality (AR) can be deployed. Such an application is addressed in [1] where authors introduced definition and explained features and usage of AR technology to support experiental learning. Authors also describe AR usages in other disciplines of education and give examples of Virtual environments.

Another usage of data mining technologies is in greater exploitation of video presentations. According to [14], this process can be done in two steps, video segmentation process and video annotation data extraction and organisation. To address specific characteristic of learning domains, this method proposes multi-ontology annotation model.

Security aspect is very important in development of e-learning platforms. Authors in [22] implemented whole distributed e-learning platform, based on OpenSSH library, to provide security measures in both online and offline learning scenarios.

Scalability of e-learning systems can be addressed in respect to the number of e-learners as well as to the e-learning infrastructure. When incorporating a number of e-learners in the same place, it is possible to make collaborative e-learning environments. To design collaborative and highly interactive tools [38] proposed CIAM(Collaborative Interactive Application Methodology) as a methodological framework. Problems of conceptual modelling of such tools are addressed in [38]. Another form of collaborative e-learning is based on MUVE (Multi-User Virtual Environments), that encourages instructors and teachers to use it as a platform for student classes. By introducing of the broadband access and modern GPU-s (Graphics Processing Units), possibilities to spread Computer Supported Collaborative Workgroups especially Collaborative Virtual Environments (CVE) are increased. The most popular virtual environment used to improve collaboration is the Second Life [55]. Due to it's nature, it is often used in realization of practical activities in natural sciences. There are studies [5] that show usability of such environments for performing of lab exercises, solving problems with rich virtual interactions. To go further, authors in [3] proposed XML based, configurable framework for Computer Supported Collaborative Workgroups to produce different virtual environments based on rich graphical environments. All aspects of systems can be easily modified using XML based configuration utilities.

Stability of e-learning systems can support organisational functioning in a effective and reliable manner. It often depends on underlying infrastructure and technical characteristics of learning and supporting systems.

There are a lot efforts to build and organize learning resources, so it could be used by disabled people. Web Content Accessibility Guidelines (WCAG) 2.0 - is referenced by many other standards and shows guidelines for developing e-learning interfaces that can be easily used by disabled people. Though, building usable user interfaces is not enough. Introducing mobile platforms, it is more convenient to put efforts in developing tutoring systems targeting mobile devices. According to this, intelligent tutoring system developed in [29] uses mobile platform. Appropriate task handler is developed. It can be operated by the users (tutors and relatives), making itself easily configurable by characteristics of the operational tasks and the different kinds of disabilities. System is supported by Human Emotions Measure modules that relies on machine learning and artificial intelligence technologies to measure and predict complex user activities. Conclusions from [29] can be easily adopted to any tutoring system and user interface that addresses needs of disabled people. To be useful, these systems should be designed to:

- have task management system to deal with different profiles, and data sources;
- be supported by mobile platform, PDA or mobile phone;
- contain friendly, reliable, flexible, and ergonomically adapted user interface;
- integrate into system some kind of emotion prediction module;
- be easily managed by people without deep technical knowledge; and
- be adaptable to different end user profiles.

The accent is put on usage of mobile devices in learning, resulting with a new stage of e-learning [21]. To increase availability of e-learning platforms, e-learning resources can be nowadays accessed by mobile and handheld devices. With miniaturisation of powerful graphical units, it is possible to render complex virtual environments on mobile device screens. However, a lot of efforts addressed design of user interfaces that can fit in mobile devices screens. In the same time it has to be usable interface and acceptable for different users profiles. An example of experimental incorporation of mobile computing paradigm in learning is discussed in [38]. Authors proposed usage of model-based approach for the development and evolution of the graphical user interface of CSCL (Computer Supported Collaborative Learning) applications. In the context of Web-based e-learning application, it is worth to mention integration of Web 2.0 technologies in modern e-learning platforms. Although this process is still in progress, there are studies on effectively usage Web 2.0 technologies in creating so called "e-learning 2.0" [24, 49, 15]. Maintainability of e-learning systems is nowadays important design aspect. With development of new types of e-learning tools, learning resources grow in complexity. Thus, changing and updating e-learning materials can become a challenge. To address maintainability and expansibility, e-learning systems are usually multi-layer structured. To address these issues, authors in [26] proposed knowledge point based metadata model which is used to create educational resources content management system.

The Table 5 summarises discussion from this section. It contains remarks on specific selected e-learning systems characteristics. Irrelevant aspects of specific areas were omitted from the discussion. The main remarks can be summarised as follows: distributed environments contribute to great scalability but maintainability and security of such environment could be a problem, m-learning is well accepted due to its availability, but designing useful user interfaces for mobile platforms can be a challenge, using data mining techniques in personalisation of learning paths and learning material recommendation can become an issue in fast growing and large systems.

5 Conclusions

Historical evolution and new trends of learning systems are reviewed in contexts of learning paradigms and supporting methodologies. Literature review on selected learning methods, which promise to bring new qualitative changes in learning, is presented. Technologies, software tools and systems supporting learning are reviewed, with special accent on LMS, CMS, and LCMS. We created a set of e-learning system characteristics where the impact of developing IT areas can be easily evaluated in a descriptive manner. The impact of the most important developing IT areas (mobile technologies, data mining, agent systems, distributed architectures, artificial intelligence, and virtual environments) on E-learning system characteristics is analysed.

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Table 5: The impact of developing IT areas on selected characteristics of e-learning systems

Developing areas						
M-learning	**Data Mining**	**Agents systems**	**Distributed architectures**	**AI (Machine Learning, Natural Language Processing)**	**Virtual (augmented reality) environments**	**Selected characteristics**
High *Learning at any place, at any time is the main motivation for m-learning*		**Increasing** *by employing mobile agent technologies*	**High** *Distributed systems are less prone to failures and better optimized*	**High** *Depends on underlying systems.*	**Moderate** *Ability to offer access at work, at home or elsewhere is not fully achieved.*	**availability**
Increasing *Small screen sizes rise usability problems, but they are increasingly addressed*	**High** *Learners guidance and prediction of results lead to a new level of usability*	**High** *Usability can be increased by adaptive instructional messages - “User agents”*	**Increasing** *due to better performance of distributed architectures*	**High** *Intelligent tutoring systems, real time interactions, diagnosing of learners profiles*	**Moderate** *Usually expressed in terms of realized user interface and interactions that are being improved.*	**usability**
High		**High** *Distributed repositories searching have strong effect to scalability*	**High** *Designed to be more scalable than client server and p2p systems, in respect to number of users, resources and processing power.*	**High** *Adaptive behaviour and machine learning algorithms, experts systems are highly scalable*	**High** *In respect to number of users and size of virtually created environments.*	**scalability**
Potentially *high if applications are web-based, or content is delivered in standardized formats*	**Moderate** *Progress is towards creating interoperable eLearning repositories using semantic technologies.*	**High** *The usage of agent systems has a goal to increase interoperability*	**High** *Distributed architectures are designed to be interoperable*		**Moderate** *It is trend to network different virtual environments and provide sharing of virtual objects.*	**interoperability**
		Moderate *It can be inreased by distributing and replicating parts of the system to agents.*	**High** *Due to distributed resources, distributed architecture are more prone to downtimes.*		**High** *Depends on supporting technologies and architecture design.*	**stability**
Potentially high High security is achievable		*Can be high with usage of multi-agent monitoring systems*	**Problematic** *Security can be a problem in large systems.*		**Moderate** *Methods are required to define legal and ethical responsibilities of all participants. Personal data protection.*	**security**
New functionality is the main motivation for m-learning	*New functionalities introduced*	*New functionalities introduced by “Learning agents”*	*Designed with this goal*	*Adaptive user interfaces, software agents, bots*	*Increasing with development of supporting technologies*	**functionality**
Problematic *Efficiency can be a problem due to usability problems and performance limitations of mobile platforms*	*Decreases in large systems*	**High** *Faster retrieval of spatially distributed data. Distribution of computations.*	**High** *With distributed resources scheduling*	**High** *Algorithms have to be very efficient to be used in practice. Can be a problem in large systems.*	**Moderate** *Increasing with development of communication technologies, collaboration and graphics engines.*	**efficiency**
Can be a problem			**Problematic** *Can be a problem, depends on system architecture*		*Depends on design*	**maintainability**

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