

# Intelligent Adaptive E-Learning Systems: Current Approaches, Architectures, and Applications

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**Abstract:** Considering the weakness of traditional e-learning, a multiple of e-learning systems attempt to get individualization into the process of learning by offering learner-centered instruction, the adaptive E-learning system (AES) is seen as one of the more famous models. An AES can tailor its response to different circumstances. Various types and platforms in E-Learning systems have been discussed and explained such as blended, adaptive, and educational e-learning. Architectures, functions, and challenges also illustrated in details in this paper. Mostly focused on the Adaptive e-learning concept and importance for the learners. AES concentrates on adaptively delivering learning materials. This paper discusses some studies that approved the importance of adaption in the e-learning system in the years (2018-2023), and introduced some challenges faced by this system.

**Keywords:** E-Learning, Blended, Adaptive, Intelligent, Education

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## 1. E-Learning:

The term e-learning is a term that looks like a blending of the learning process with technology. It is well known that technology has become an integral part of many aspects of the personal and social life of everyone, including education and learning. E-learning concept evolved in the early nineties where it had a great impact in developing the educational process as it provided various technologies that facilitated communication, collaboration, resources sharing, and allowed providing education bypassing time and place constraints.

It appears from the research that there are several definitions of e-learning. Some like Keller and Cernerud (2002) defined e-learning as any learning that is based on using internet or implying learning by means of digital media such. Other researchers like Longmire (2001) expend the concept of e-learning as he stated "e-Learning covers a wide set of applications and processes such as computer-based learning systems, Web-based learning systems, virtual classrooms, and digital collaborative learning GroupWare packages. E-Learning content is mainly delivered via Internet, intranet/extranet, audiotape, and videotape; satellite broadcast, interactive TV, DVD and CD-ROM, and the still to emerge wireless application protocols (WAP)".

Sangrà et al (2012) reviewed the definition of e-learning from literature published between 2005 and 2012 and as a result four general categories of definitions were identified:

1. Technology-driven: definitions of this category considered the use of technology as the most important characteristic of e-learning.
2. Delivery-system-oriented: this category focusses on the accessibility of resources
3. Communication-oriented: this includes definitions that expect interaction and collaboration as the most important part of e-learning.
4. Educational-paradigm oriented this type of definitions considers e-learning as an improvement to the existing educational models.

A. Pauline Chitra et al (2018) stated that "The term e-learning comprises a lot more than online learning, virtual learning, distributed learning, networked or web-based learning. As the letter "e" in e-learning stands for the word "electronic", it would incorporate all educational activities that are carried out by individuals or groups working online or offline, and synchronously or asynchronously via networked or standalone computers and other electronic devices".

Flora Amity (2020) described two types of e-learning:

1. A synchronous learning which includes the environment or a specific online platform where the teacher and the students meet and communicate about a lesson.
2. Asynchronous e-learning which gives the students accessibility to the class material all the time and provide more flexibility in activities submission.

The increasing development in e-learning technologies and their widespread use is accompanied by the emergence of challenges summarized by Liu, M. and Yu, D (2022) in five reasons those are: The growing number of e-learners and course work, the huge amount of interactive information resulting from the exchange of information electronically, Resources are isolated due to their different types, Control methods and security policies are needed to handle personal and confidential information and the huge amount of data generated by e-learning must be well stored and managed. To meet these challenges, it is necessary to develop appropriate technologies that facilitate the collection, processing and analysis of the huge amount of data being collected from various sources, which led the e-learning applications developers to move toward some artificial intelligence techniques.

### 1.1 Blended – Learning

Many researchers defined blended learning over the last decades. The definitions vary where the old ones focus on adding helpful content stored on different medias to support learning at class. the widespread use of the Internet and the development of effective and safe e-learning environments, researchers have turned to a new concept of blended learning, which simply means to mix the face-to-face classroom learning with e-learning. The idea emerged in the early 2000s as a call to enable learners to make the most of online resources and tools in addition to classroom learning which makes it different from e-learning, in which the learner relies entirely on an online learning system. Allison Littejohn and Chris Pegler (2007) stated “The word ‘blended’ may refer to a blend within the ‘e-learning mix’ of media, or a blend of the e-learning with other approaches”.

The steady development of electronic technologies has contributed to raising the efficiency of blended learning as it is characterized by the peculiarity that any new technology can easily be integrated, providing the best individual learning experience.

Liu, M. and Yu, D (2022) classified three models of blended learning based on its aim: Skilled-driven let students to gain specific knowledge and skills based on teachers’ feedback and guidance, Attitude-driven model: enables learners to gain new behaviors or attitudes through learners-teachers interaction and collaboration, Competency-driven: In which the learner acquires knowledge implicitly by observing and interacting with experts at work.

### 1.2 Adaptive e-learning (AEL)

Contemporary educational studies tend to move from the unified learning style to in which a common content is delivered to all students in the same way to more personalized experience in which students' levels and their preferred learning styles are considered which enhance their performance. According to Luangrungruang, T. and Kokaew U (2022) the effective e-content of adaptive e-learning which is suitable for different learners’ styles and preference, would improve their skills acquisition, experiences, and critical thinking skills.

According to Kolekar et al (2018), adaptive learning is classified to macro and micro adaptive e-learning. The adaptive approach is the student profile to determine the e-learning process procedures. whereas in micro adaptive approach, students’ behavior is monitored and found from quantitative information in an e-learning system.

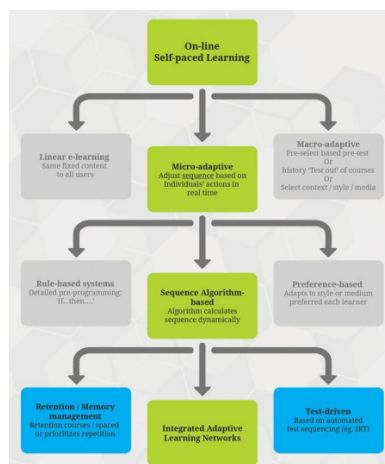
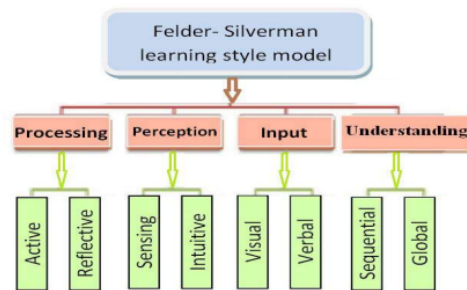


Figure 1: Type of E-learning

## 2. Literature Review

Yulia Vainshteina et al (2018) developed adaptation algorithm for the mathematical educational content by selecting an optimal edition of the material that best suits the individual characteristics of the student. The developed system uses three level adaptation algorithm: introductory content adaptation (an adaptation of the content of introductory materials of the discipline based on the initial level of students) - "current adaptation of the content" (an adaptation of the mathematical content based on current effective actions of students in the electronic course) - "appraisal-correcting adaptation" (an adaptation of normative parameters of the level of assimilation of materials, taking into account the results achieved by students). The proposed system allows implementing personal educational space of mathematical educational content for each student that adapts to its level of mastering the material.

Kolekar et al (2018) claimed that it is beneficial to provide a customized user interface for adaptive e-learning portal. They proposed a rule based adaptive user interface AUI. The proposed approach is based on Felder-Silverman Learning Style Model (FSLSM) which defines eight learning styles. There is a set of learning components provided through AUI. The idea is to decide users learning style dynamically by tracing his usage data. The learning components that are suitable for the users learning style are generated.



**Figure 2: Felder-Silverman Learning Style Model**

Bhawna Dhupia and Abdalla Alameen (2019) proposed a framework to implement an adaptive e-learning system that consists of three basic models:

1. Domain Model which contains course content and all related details.
2. Learner Model includes learner related information such as his level of knowledge, learning pattern .It also tracks learner records; learners' performance may also be measured through this model.
3. Adaptive Model this part is responsible for analyzing learner activities and behavior to identify his style. This will be done through a Predictive model and will allow the adaptive engine to offer the best learning technique and. The model also keeps reviewing learners' patterns for changes if any and updates the learning styles accordingly through an intervention engine.

Victoria Shershneva et al (2019) described an adaptive e-learning system considering basic principles:

- Allow students to have an individual learning experience and create personal educational material.
- Variability by presenting content in various forms.
- Automatic return to the studied topic content in different forms.
- Reduce the knowledge and skills gap.
- Student involvement in the learning process
- Focus on achieving learning outcomes.
- Build a comprehensive understanding of the discipline.
- The content should be suitable for learners and related to their future expected professional activities.
- The teacher's role is the learning process organizer and coordinator.

The applied system consists, as in the previous proposal of the content model, the learner model, the adaptation model and in addition an assessment model. The content model integrates the methods of Voishvillo's logical-and-gnoseological concept analysis with graph theory methods. Course concepts are structured hierarchically as the discipline's concepts tree. This allows visualizing the logical structure of the material, determining its study

sequence, and mastering the control over the results of course. The adaptive model then provides each term into three levels of details and presentations. The assessment model determines the level of subject competence development of the student by assessing all its components.

Mohamed Boussakssoua, Bader Hssinab and Mohammed Erittali (2020) a also developed an adaptive e-learning system. They used the Q-learning algorithm which is a reinforcement learning algorithm based on set of states with set of possible rewards were an agent passes from a state to another aiming to maximize the collected reward. The states and rewards of the suggested system were derived from the course content based on Bloom's taxonomy. List of actions was also created, as the agent pass from a state to another by performing an action. Reward matrix is constructed for the possible state-action combination from which the students best path to learn the course is known.

Some researchers have tried to study the effectiveness of using adaptive learning systems in different scientific fields. For example, Ali, N.A et al (2019) suggested using an adaptive approach in identifying learners learning styles to enhance their performance to get ICDL certificate without fail. The model was applied to a group of learners and the results compared to the results of another group whose members didn't use the model. The model used to provide the suitable learning objects based up on their identified learning style. The results approved that a high percentage of learners who used the adaptive system succeeded in achieving ICDL certificate without any fail compared with those who didn't use it.

Mathias Bauer, Jacqueline Schuldt and Heidi Krömker (2020) tested the effect of using adaptive e-learning platform in fostering students learning motivations. They compared the results of using a version of an existing e-learning platform for micro- and nanotechnologies with another version that was transformed into an adaptive e-learning system through multiple stages. The results of comparing the adaptive version to the non-adaptive version didn't identify a significant benefit.

A similar study was delivered by Nkemcho Ojeh et al (2020) who compared the usage of an online adaptive platform (Firecracker) to another assessment software. The objectives of this study were to determine: Firecracker usage rates, its formative quizzes performance, compare the performance of Firecracker with the performance at summative course assessments, and assess students' satisfaction with Firecracker usage. Data was collected and analyzed, and results were summarized as follows Most students welcomed the use of the Firecracker platform, as they considered it beneficial, and its use was associated with better academic performance. These findings suggest that the platform used could be useful in continuous monitoring of students' progress in other courses.

An approach by Mohammed Megahed, Ammar Mohammedcombines (2020) used convolutional neural network CNN and fuzzy logic. CNN model is used to detect a learner's facial expressions and fuzzy system is used to determine the next learning level based on the extracted facial expression states from the CNN and several response factors by the learner. Applying the proposed system to chosen groups showed suitable adaptive learning flows to the learning capabilities of all learners. Moreover, the approach allows decision makers to monitor the learning performance for each learner.

Hassan A. El-Sabagh (2021) conducted a study to investigate the impact of adopting adaptive e-learning environment on the students' engagement development. The developed platform is based on VARK learning styles shown in the figure below. Those styles were used to define four content paths in which all the learning objects fall.

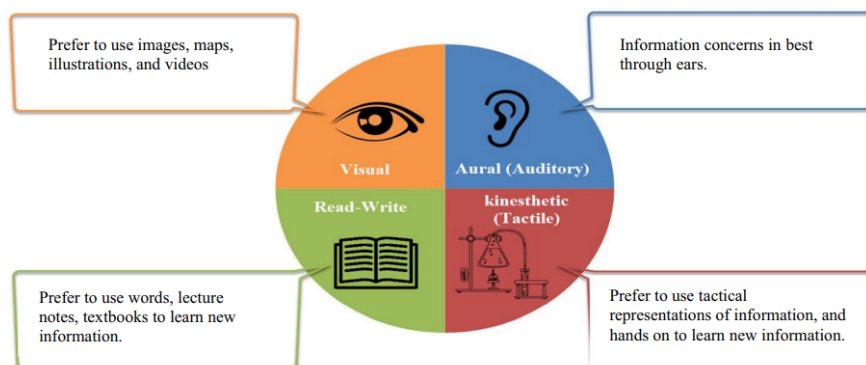


Figure 3: VARK Learning Styles

The proposed adaptive environment was used to measure student engagement in the “Learning Skills” course. A group of students used the proposed platform, and the results of the group were compared with the results of another group that did not use the mentioned environment. Results of this study revealed a significant difference in learning outcomes between the two groups with positive results for adaptive e-learning students, indicating that it may be helpful to adopt this technology in higher education.

Sayed S. Younes (2021) selected the students of the studies as a target group to know the impact of using this category to adaptive e-learning on the development of creative design skills for digital content. Research results concluded that, the proposed adaptive e-learning environment positively affected developing both cognitive achievement and practical performance of digital content creative design skills of students regardless of their learning styles whether global or sequential.

An adaptive e-learning approach based on learning style and knowledge level was proposed by ALBER S. AZIZ, REDA A. EI-KHORIBI and SHEREEN A. TAIE (2021). The model works in three phases. An English course material was selected and divided into units and then points. Each point was mapped to learning object and questions stored in a question bank. The learner starts the system and fills a dynamic questionnaire that determines his learning styles based on Felder-Silverman Learning Styles Model. Learning objects that match learners’ style are presented and he learns where his logs and activities are recorded. The learner then is required to take a pretest to determine his level of knowledge. This time the system will recommend suitable learning objects according to learning style and the updated level of knowledge. In the third phase the learner will take a post exam and his level of knowledge is updated. The results showed that using the proposed model increased the overall performance for the students significantly.

In addition to learning style and knowledge level, Oyuga Anne and Elizaphan Maina (2021) considered the learner’s affective state. they proposed a model that uses a questionnaire designed to extract learning style according to VARKs learning. An affective state extraction model was also designed, based on existing natural language processing libraries with several steps to identify, prepare, divide, train, classifying and training dataset. Q-learning reinforcement algorithm was followed to create adaptivity. The researchers claim that results show better adaptivity with models based on multiple learner characteristics rather than single characteristic. They recommend including more characteristics in further research.

Norah Dhafer Alqahtani (2021) reviewed several titles related to AES, such as the role of this type of system and its importance, in addition to the techniques used to enhance its performance and the most important challenges facing it. Four types of adaptivity were defined:

- Course content related: concerns providing the best content matching learner properties.
- Interaction related: in this type, adaptation appears in the interface where content is not changed.
- Collaborative Support: it supports communication between participants to achieve common goals.
- Implementing adaptive techniques to detect contents that matches the student's properties.

challenges like dealing with real data, trust and usability development and system scalability were also discussed.

A study conducted by Maha E. Attia, Mohamed A. Arteimi (2021) applied fuzzy logic to modify the domain model of an AES for computer programming language teaching as some topics are prerequisites for others. The proposed system manages learning material relationships through concept maps. It also measures students’ knowledge using fuzzy logic by converting student's grade to membership functions. the learning material is divided into concepts where a fuzzy Related-Concepts Network displays the knowledge relationships between them. This depicts the learning material's structure as well as the concepts' knowledge dependencies. This relates knowledge level of a connected topic to the knowledge level of a domain concept. meaning that if a topics level of knowledge increases the level of knowledge of the concept also increase and the other way around. The approach implemented as a plugin to MOODLE which resulted in improving student's learning and provided their satisfaction.

A new architecture for piloting and customizing adaptive learning paths was introduced in Sabeima, Massra and Lamolle, Myriam & Nanne, Mohamedade (2022). considering users’ profile, training domain and the available learning resources. It also includes synchronizing collaborative mode which allows learners to collaborate with each other. The proposed architecture is based on Semantic Web for knowledge representation and multi-agent system that manages the different events in the system.

### 3. Conclusion

E-learning is not just a technological development. Rather, it is a reason for changing the ways of transferring knowledge and the skills that the learner needs to receive knowledge. The involvement of more learners in various e-learning platforms, exceeding the constraints of space and time, led the designers on these platforms to work hard to improve their performance continuously, taking into account the needs and satisfaction of learners. Current trends in e-learning use adaptive technologies to provide a customized experience for each learner due to learners' differences in level, interests, cultural background, etc. in the past few years many approaches evolved proposing different ways to enhance adaptability in e-learning in terms of architectures, algorithms or characteristics used to identify learners needs. Studies performed between 2018 and 2023 has been demonstrated. This topic is vital and renewable, which makes it a target for more in-depth studies due to its great benefit associated with learning, which is a basic requirement on the one hand, and its reliance on artificial intelligence techniques, which are the latest technologies of the current era, on the other hand.

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