



Adaptive Theory and Learning: Creating an Adaptive Learning Environment in Higher Education

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The aim of the study is to investigate the use of adaptive learning (AL). The concept of adaptive learning is discussed. The basic principles offered by the theory of adaptation in education and the components of the adaptive learning is clarified. The system of the adaptive learning is mentioned, as well. All of the issues are explained in relation with the higher education.

Key words: *Adaptive theory, higher education, adaptive learning (AL)*

1-Introduction and Background

Traditional education systems prefer to follow a "one size fits all approach" and deal in the same way for all students. This poses many concerns, however, since they are learners with various levels of experiences, interests, expectations, features, learning habits and multiple intelligence (Kelly, 2005).

As the rapid change in life and technology, education faces many obstacles, including high costs, decreasing funding, large student diversity, and high attrition, recently. Some educational leaders and software vendors have argued that one-to-one tutoring could meet different student needs, and such tutoring could be delivered on a scale by adapted learning systems. Adapted learning systems are rules-based or based on algorithms. From the science of big data analytics pioneered by companies such as Google, Amazon, and Facebook, algorithm-based systems were developed. Research on intelligent tutoring systems, educational data mining and learning analytics, adaptive learning systems have been developed. In the adaptive learning area, over 30 software vendors have joined. Some of the larger and older suppliers include McGraw Hill Edu. Higher learning outcomes and better retention with adaptive learning have been shown by several researchers (Johnson, & Samora, 2016).



With the increase in the use of technology in college classrooms, many professors are open to creatively structuring their classrooms (Strayer, 2007). Current education patterns confirm that teachers are moving away from authoritarian and non-interactive classes. (Galy, & Johnson, 2011).

At the same time, significant social changes and educational modernisation are making new demands for the standard of preparation and the professionalism of specialists. The technical basis of such an open environment (intellectual adaptive learning system) is an educational system aimed at developing an adult adaptive learning system. This is the learning environment that can provide anticipatory opportunities for adult education (Desyatov, 2016).

Students as individuals with their differences, abilities, skills and thoughts are discussed in a synchronous and asynchronous environment. The teacher, as a result, will be able to know the students' understanding and provide them with immediate feedback. This makes the educational and learning process easy and more effective. It is a responsive process as well (Howard, Remenyi, & Pap, 2006).

Adaptive systems can be more effective and more efficient, in comparison to their non-adaptive, more user-friendly counterparts. (Khamis, 2015). Adaptive E-learning is a modern method of education that has been developed to provide a unique electronic learning environment adapted to each student's needs (Ramadan & Aleksandrova, 2018). To develop their abilities, knowledge and awareness of the globe, learners can use different interactive e-learning tools. Traditional education has come to be replaced by customised personal online learning systems that can be tailored to individual student differences. (Gohar and El-Ghool, 2016).

Furthermore, students can move at an accelerated or extended pace in the standard classroom or quadruple courses in an adaptive learning environment. Students repeat their choices in certain situations, return them, and help them achieve material mastery. What many teachers realize is that this increased versatility is an essential component of student success. (Moursund, 2004).

Thus, adaptive learning growth helps university students to react to tasks flexibly, turn and initiate them, and thus assume control over their learning. This is a valuable learning outcome of any educational organization. Faculty members should intentionally facilitate the advancement of adaptive learning for their students within a motivated classroom setting and environment. (Rohrkemper & Corno, 1988).

Over the past few years, as the use of adaptive learning in higher education has evolved, the cultures of science and practitioners seem to have united around a few unifying principles. For example, the Adaptive Learning Market Acceleration Software (ALMAP) was introduced by the Bill and Melinda Gates Foundation in 2013 with nine platforms that "use learning model

algorithms to monitor learner progress and recommend next steps in a learning path" (cited in Cavanagh, Chen, Lahcen, & Paradiso, 2020).

Some organizations took adaptive learning initiatives. Such initiatives, sponsored by the Bill and Melinda Gates Foundation, the Personalizing Learning with Adaptive Courseware of the Association of Public and Land-Grant Universities (APLU) describes that (a)adaptive courseware collects student data by evaluation, analyses the data and uses it to provide each student with customized learning paths or reports and suggestions to instructors Similarly, another initiative sponsored by the Bill and Melinda Gates Foundation, the Personalizing Learning with Adaptive Courseware of the Association of Public and Land-Grant Universities (APLU) describes that adaptive courseware collects student data by evaluation, analyses the data and uses it to provide each student with customized learning paths or reports and suggestions to instructors (Cavanagh, Chen, Lahcen, & Paradiso, 2020).

In certain contexts, but not in others, the efficacy and efficiency of adaptive e-learning has been demonstrated; related studies have shown beneficial effects of adaptive systems over others on certain domain information (Whittenburg, 2011).

2- Methods

Based on the research aim, we searched the literature for papers related to adaptive learning, published in English in the field of education, published in the academic peer reviewed journals. The literature search found 390 articles. Papers that were not peer reviewed journals, conference papers and editorials, were not included. By removing unrelated articles and non-English papers, a total of 26 papers met the aim was selected for the review. Figure 1 illustrates the data selection process.

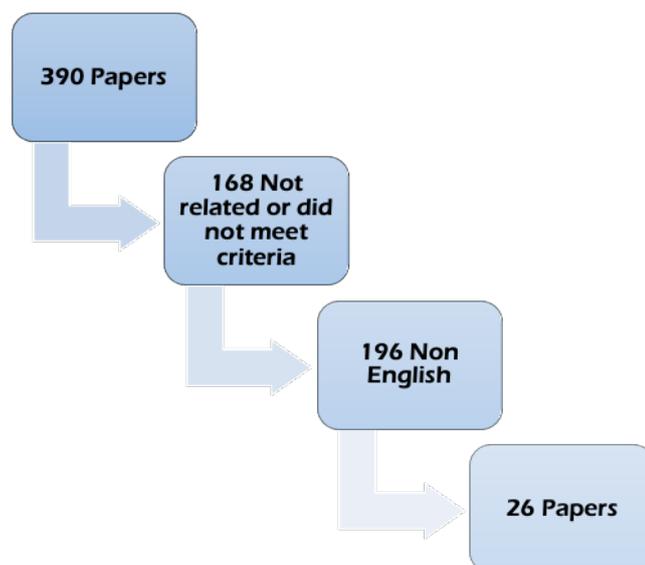


Figure 1: Data selection process.

3-The importance of this search

Over the past years, adaptive learning attracts both the fields of information technology and education in recent decades. In the meantime, different methods of evaluating learning styles have been suggested to enable teachers or educational researchers to better understand student characteristics (Tseng, Hwang, & Tsai, 2008). In certain contexts, but not in others, the efficacy and efficiency of adaptive e-learning has been demonstrated; related studies have shown beneficial effects of adaptive systems over others on certain domain information (Whittenburg, 2011).

The massive use of online learning that might depend mostly on personalized learning increases the importance of it. Adaptive learning is more personalized, technology-enabled, and a data-driven approach to learning that has the potential to deepen student engagement with learning materials, customize the pathways of students through curricula, and allow teachers to use class time in more concentrated and efficient ways. Adaptive learning seeks to make a major contribution to memory development and research assessment (Tyton,2021).

4- The concept of Adaptive theory

In the last few decades, attempts to personalize learning in educational settings have been extended to include computer-assisted instruction. Adaptive e-learning systems, tailored to students' individual strengths and characteristics, reflect a potentially powerful new tool and/or process for providing customized instruction to the right student at the right time (Whittenburg, 2011).

The adaptive theory arose in the 1990s (Mödrischer, 2008). There are many studies which developed the adaptive theory like (Murray, 2003; Azevedo et al., 2010; Molenaar et al., 2011), but close attention should be paid that the systems of adaptive theory stay limited. Carroll (1963) clarified that the idea of adaptive learning is not new, but as an instructional modality, and more advanced online platforms make it increasingly viable. The use of this technology is partly explored by educators and researchers due to an increase in performance indicators and funding linked to the ongoing need to enhance student achievement and retention. (Dziuban, 2018)

The word "adaptive theory" is seen as changing and generative as models, structures and conceptual schema. Adaptive theory claims that the construction of theory can and should be subject to continuing change - often gradual, sometimes radical (Bessant, & Francis, 2005).

The concept of adaptive theory was originally introduced by ecologist C. S. Holling in 1978, at the International Institute for Applied Systems Analysis in Vienna, to facilitate and support the management of natural resources under uncertainty (Hoffman and Zellmer, 2012).

Adaptive theory is defined as a method for gathering the talents, skills and data of all students to enhance their subjects or assignments. It is a great accomplishment to deliver educational opportunities through strategies such as reviews and the use of innovative techniques to create active environments to meet the immediate needs of university students. The theory of adaptation requires the methodology of learning through technology, which induces dramatic modifications in the learning process.. In addition, it eliminates any barriers that lack the versatility of time and space in conventional ways and then transforms them into great ways (Rosenlund and Damark-Bembenek, 1999).

Therefore, adaptive theory is a technique that promotes the continuous relationship between the previous theory and the emerging theory in the research phase, and any new theory that emerges. Both types of adaptive theory, influenced by experimental evidence, derive from study. It enables the theory of life (theoretical models) as well as those that unfold (which are implemented in) to have a dual impact. A permanent feature of the research method is adaptive theory (Kennedy, 2016).

5- The basic principles offered by the theory of adaptation in education.

According to Tóth (2014), he mentioned the basic principles offered by the theory of adaptation in education as follows:

- 1- Interprets learning as a relationship between the individual and the environment.
- 2- Learning is interpreted as a holistic process of adaptation to the environment.
- 3- Learning is seen as an organized process rather than a result condition.
- 4- The student's current knowledge and experience plays a crucial role in the processing of new information.
- 5- Piaget's adaptive theory is the basis of learning. Adaptation has two forms, namely absorption and accommodation.
- 6- Learning is defined as the process of building knowledge, and the result that presents itself as a relationship between community knowledge and individual knowledge.

6-Adaptive learning theories and Educational theory

There are some theories related to the adaptive learning. Two of them will be mentioned (Deubel, 2003):

- **Behaviorist Concepts:** This theory is the foundation for developments such as computer-assisted learning, mastery learning, minimal testing of abilities, transparency for schooling, situated cognition, and even social constructivism. The primary tenet of behaviorism is that a stimulus and the response it generates have a predictable and reliable relation. If behavior is predictable, students must master subskills that contribute to a learned behavior and then choose stimuli and presentation techniques

that create subskills if behavior is predictable. Designers hope that an educational technique that has had a certain influence in the past would do so again.

- **Cognitive Concepts:** A major assumption is that learners are not just passive entities that respond to stimuli in the environment. By doing, witnessing, and participating in trial and error, learners learn. What has been taught, under what circumstances, and the effects that help or sustain the learned conduct all work together and must be visible and measurable. A major assumption is that learners are not just passive entities that respond to stimuli in the environment. By doing, witnessing, and participating in trial and error, learners learn. What has been taught, under what circumstances, and the effects that help or sustain the learned conduct all work together and must be visible and measurable. A major assumption is that learners are not just passive entities that respond to stimuli in the environment. By doing, witnessing, and participating in trial and error, learners learn. What has been taught, under what circumstances, and the effects that help or sustain the learned conduct all work together and must be visible and measurable.

7-Adaptive learning components

At least three components are used in adaptive learning: a model of the subject structure to be mastered (a content model), a means of interpreting student skills (a learner model), and a way of matching the content and how it is delivered to the student in a dynamic and customized manner (an instructional model) (Oxman, Wong, & Innovations, 2014).

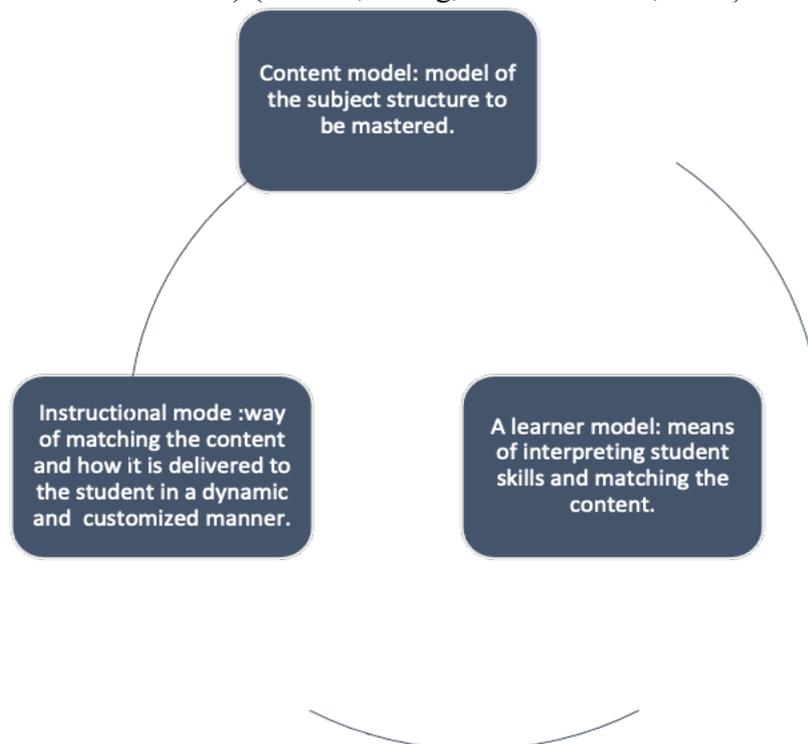


Fig. 1: The three components used in adaptive learning (Oxman, Wong, & Innovations, 2014)

On the technological side, VaNTH ERC has developed an adaptive learning technology infrastructure that consists of two primary components. They are: A repository-based authoring technology for adaptive web-based courseware (CAPE), an online learning platform (eLMS) (Howard, Remenyi, & Pap,2006).

8-Adaptive Learning Systems

Computer technology has long been seen as a solution to individualized instruction scalability and expense. In the 1970s, experiments with technology-supported instructional guidance occurred in the form of computer-assisted instruction (CAI). These rule-based systems interactively changed the sequence of progression through a series of questions on the basis of student responses. These systems have given way to a community of smart learning systems known as smart tutoring systems (ITS). To mimic the teacher-guided learning experience, these computer-driven systems use artificial intelligence, modifying instructional techniques based on student interaction (Murray, & Pérez 2015).

9-Adaptation classes in learning environments

Adaptive behavior may have multiple forms on the part of a learning environment (Paramythis, & Loidl-Reisinger, 2003). They classified adaptive environments into three categories as follows:

1. **The first category is Adaptive Interaction:** to modifications that occur in the system interface and are intended to facilitate or support user interaction with the system, without, however, modifying the "content" of learning in any way. Examples of adaptations at this level include employing graphical systems. While interstitial adaptations can generally be regarded as independent of the material or "content" provided in a learning environment, this is not typically the case with learning activities - the primary differential factor is the emphasis in the previous case on ensuring and enhancing the achievement of "content" as opposed to concentrating on promoting the process in the case of activities.
2. **The second category is the provision of adaptive training:** constitutes a set of the most common and most widely used adaptation methods applied in today's learning environments. In particular, the term is used to refer to modifications aimed at designing a course (or in some cases, a series of courses) for an individual learner. It is a compilation of the most common and most commonly used methods of adaptation implemented in the learning environments of today. In particular, the term is used to refer to adjustments intended for an individual learner to design a course (or, in some cases, a series of courses). The goal is to enhance the "fit" between the content of the course and user features/requirements, so that the "optimal" learning result is obtained, while the time and interactions spent on the course are "minimized" at the concert. In this sense, in addition to the economy of time and effort, the key reasons behind the adoption of adaptive

strategies include compensating for the human teacher's shortage (capable of evaluating the skill of the learner, goals, etc., counselling on individual 'curricula'), and enhancing learners' self-assessment of courses. The most common examples of modifications in this category are: Adaptive navigation support and adaptive selection of alternative course materials.

3. **The third category is content discovery and compilation:** to the application of adaptive techniques in the discovery and compilation of learning materials / "content" from sources / repositories of potential distribution. The adaptive component of this process is the use of adaptive-oriented models and knowledge about users usually derived from surveillance, both of which are not available for non-adaptive systems that participate in the same process. At this point, we would like to make a clear distinction between the view of an individual student who wants to find the relevant material within a group (possibly limited) and the view of the author or 'collector' who is charged with collecting the course from established materials and targeting a particular audience or, differently, collect the material and design it to accommodate the user/context specific characteristics. While adaptation from both viewpoints may be very relevant, we will concentrate on the first, i.e., the synthesis of materials and their intended meaning for an individual learner, in the context of this paper. This helps us to think about the more complicated situations that occur when the personal learning and engagement experience of an individual can be used to establish the requirements for content collection and processing. Supporting adaptive cooperation, the fourth and final level, seeks to gain adaptive support in learning processes involving interpersonal communication (and hence, social interaction) and, perhaps, collaboration towards common goals. This is an important factor to remember as we step away from "isolationist" learning methods, which are increasingly counter to what modern learning theory emphasizes: the importance of teamwork, collective learning, groups of learners, social negotiation and vocational training in learning (Paramythis and Loidl-Reisinger, 2004).

10-Models in adaptive learning environments

Many searches and experts refer that providing the same learning methods lead to decreasing the performance of students (Smith-Jentsch et al., 1996). In recent years, studies on the development of learning environments based on variations in styles of learning have gained significance. In assessing individual variations, learning styles are one of the most important criteria. Traditional web-based learning environments have therefore been replaced by individualized, adaptive e-learning environments on the basis of more creative learning styles (Özyurt, & Özyurt, 2015).

1. The domain model: Since most current ALEs are based on adaptive course delivery, a representation of the course being offered is typically the domain or application model. However, in those cases where there is support for more general learning activities, the

domain model can also include information on workflows, participants, tasks, etc. The most important feature of adaptive-course models is that they are generally focused on the recognition of relationships between elements of the course, which are then used to decide on adaptations (in Paramythis, & Loidl-Reisinger, 2003).

2. The learner model: The term learner model is used to refer to user model situations, customized for the learning domain. The basic modelling approach can differ across adaptive learning environments. Nevertheless, almost all current systems share at least one characteristic: the model can be modified at contact time, to add elements or traces of the interaction history of the user. In other words, in ALEs, the learner model not only encapsulates general user knowledge, (e.g., demographics), “but also maintains a “live” account of the user’s actions within the system.
3. Group models: Community models, similar to user / learner models, aim to capture the features of user / learner classes. The key distinguishing factors between the two are: (a) group models are normally dynamically constructed, rather than dynamically “filled in,” and (b) group models are focused on the recognition of groups of learners that share similar attributes, behavior, etc. As such, the model of groups is used to decide and “describe” what makes students “similar” or not, and whether two students may belong to the same group. In collaborative filtering and product recommendations, this complex approach to defining groups and user involvement in them is already widely used and bears great promise in the context of e-learning.
4. The adaptation model: The adaptive theory of an ALE, at various levels of abstraction, integrates this model. The (possibly implicit) adaptation model clearly describes what can be adapted, as well as when and how it should be adapted. The levels of abstraction at which adaptation can be specified vary from basic programmatic rules governing run-time conduct to general logic specifications.
5. The abstraction levels at which adaptation can be specified range from basic programmatic rules governing run-time behavior, all the way to general logical relationship requirements between ALE entities that are automatically enforced at run-time.

Ideally, therefore, adaptive education systems should not only build a student profile that contains as many features as possible, but should also take into account the interdependencies between these features. (Popescu, 2010).

11-Adaptive leaning and higher education

In higher education, the use of adaptive learning has been slower to evolve, and barriers that have possibly led to slow adoption remain. Whereas in elementary and secondary education,

curriculum choices are often taken at the district or school level, individual faculty members usually choose learning materials in higher education. The earliest implementations of adaptive learning, therefore, tended to be as non-credit remediation and placement tools as opposed to courseware. Despite these challenges, adaptive learning is beginning to accelerate very rapidly in higher education courses, partly/largely driven by partnerships between publishers and adaptive learning companies. For example: Kaplan acquired Grockit (an adaptive test-prep start-up) at a point where every major publisher producing online material for higher education will need to have some form of adaptive learning system as part of their offering. And while some LMS providers may incorporate specific adaptive learning capabilities, it is more certain that they will need to enable all the new systems from publishers and client schools to work with their existing platform. It will be fascinating to observe how these systems integrate with each other, and with publishing material. How these systems run has also changed cloud computing and computational approaches for handling big data. When large quantities of student performance data can be generated rapidly and consolidated for analysis, a cognitive theory about the structure of student comprehension or a content domain is no longer required. This type of big data framework, such as Knewton, compares learning performance rates correlated with specific content and combines it with data on the capacity level of a student on that topic of content (Oxman Wong, & Innovations, 2014).

12-Challenges facing adaptive learning in higher education.

Increasingly, higher education institutions are interested in using adaptive learning as a creative approach to teaching powered by data. However, the actual use of adaptive learning in courses remains low. This is despite the optimistic attitudes of institutional leaders towards its implementation and the encouraging outcomes of early research on its efficacy. However, there are some changes that might face the application of adaptive learning in higher education.

In their study (Mirata, Hirt, Bergamin, and van der Westhuizen (2020) related the challenges to technological, teaching and learning, and organizational issues. They are: “(a) infrastructure, hard- & software, (b) perceptions and beliefs about adaptive technology, (c) instructional & curriculum elements, (d) learner characteristics, (e) lecturer characteristics, (f) institutional strategies, (g) management, (h) resources”.

Results and discussion:

Adaptive instruction refers to instructional approaches aimed at accommodating individual student differences effectively while helping each student acquire the information and skills needed to learn a task (Lee, & Kim, 2012).

The new adaptive teaching theory reflects the social dynamics of classrooms to clarify what teachers do to fix learning-related student differences. Teachers respond to learners as they function by teaching adaptively. To diagnose needs on the fly, teachers read student signals

and tap previous experience with similar learners to respond productively. Adaptive teachers use their technical expertise (Corno, 2008); this seeks to improve learning environments with new and active learning procedures. The authors note that adaptive learning systems adapt to learner interactions and demonstrated performance, and then anticipate the types of content and resources that learners need at a specific time to make progress (Partners, 2013). The adaptive model integrates, by combining the field model with the student model, an adaptive principle of an adaptive e-learning system. The selection of representative nodes starts with adaptive modelling by evaluating student needs from the student model. Nodes can be divided into various categories of knowledge: basic knowledge, including comprehension of meanings, formulas and other materials; procedural knowledge; handling of step-to-step relationships; and conceptual knowledge, referring to relationships between concepts that put a larger picture into detail. Each form of knowledge involves various techniques, so learners in different costumes will be offered the contract. The next step is to decide on the educational items that need to be represented by the nodes, so that students can use them before the node is completed. The last step is to repeat the process until every node is completely chosen. (Shute and Towle, 2003).

Conclusion

The research concludes that adaptive learning can support university students by meeting their individual differences and needs. With the availability of all of the adaptive learning requirements and faculty efforts, adaptive learning will be created successfully.

Recommendations

For further research, it is included the suggestion to further explore the training of faculty members in adaptive learning. Although this research was not designed to explore such issues, there were intriguing hints that faculty members may be a stronger determinant of a successful learning environment.

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REFERENCES

- Azevedo, R., Johnson, A., Chauncey, A., and Burkett, C. (2010). Self-regulated learning with MetaTutor: Advancing the science of learning with MetaCognitive tools. In M. Khine and I. Saleh (eds.), *New Science of Learning: Computers, Cognition, and Collaboration in Education* (pp. 225–247). Amsterdam, The Netherlands: Springer.
- Bessant, J., & Francis, D. (2005). Transferring soft technologies: Exploring adaptive theory. *International Journal of Technology Management & Sustainable Development*, 4(2), 93-112.
- Cavanagh, T., Chen, B., Lahcen, R. A. M., & Paradiso, J. R. (2020). Constructing a Design Framework and Pedagogical Approach for Adaptive Learning in Higher Education: A Practitioner's Perspective. *International Review of Research in Open and Distributed Learning*, 21(1), 172-196.
- Corno, L. Y. N. (2008). On teaching adaptively. *Educational psychologist*, 43(3), 161-173.
- Deubel, P. (2003). An investigation of behaviorist and cognitive approaches to instructional multimedia design. *Journal of educational multimedia and hypermedia*, 12(1), 63-90.
- Dziuban, C., Moskal, P., Parker, L., Campbell, M., Howlin, C., & Johnson, C. (2018). Adaptive Learning: A Stabilizing Influence across Disciplines and Universities. *Online Learning*, 22(3), 7-39.
- Galy, E., Downey, C., & Johnson, J. (2011). The effect of using e-learning tools in online and campus-based classrooms on student performance. *Journal of Information Technology Education: Research*, 10(1), 209-230.
- Gohar, Rehab Hamadto Abu Al-Ghait, Reham Mohamed Ahmed El-Ghool (2016). Designing an Adaptive Learning Environment to Improve Writing Skills and Usability for EFL Students at the Faculty of Education, *International Journal of Internet Education*, ISSN: 1687-6482.
- Hoffman, C., & Zellmer, S. (2012). Assessing institutional ability to support adaptive, integrated water resources management. *Neb. L. Rev.*, 91, 805.
- Howard, L., Remenyi, Z., & Pap, G. (2006, July). Adaptive blended learning environments. In *International Conference on Engineering Education* (pp. 23-28).
- Johnson, D., & Samora, D. (2016). The potential transformation of higher education through computer-based adaptive learning systems. *Global Education Journal*, 2016(1).
- Kelly, Declan (2005). On the Dynamic Multiple Intelligence Informed Personalization of the Learning Environment, Doctor of Philosophy, Department of Computer Science, University of Dublin, Trinity College.
- Kennedy, Sara (2016). An exploration of empowerment amongst final-year undergraduate nursing students while on clinical placement in Ireland using Social Domain Theory, School of Nursing, Midwifery, Social Work & Social Sciences, University of Salford.
- Khamis, M. A. (2015). Adaptive e-learning environment systems and technologies. In *The First International Conference of the Faculty of Education, Albaha University* (pp. 13-15).
- Khouri, S. (2014, 1 24). How do you transform the learner from a passive.



- Lee, J., & Kim, D. G. (2012). Adaptive Learning System Applied Bruner'EIS Theory. *IERI procedia*, 2, 794-801
- Mirata, V., Hirt, F., Bergamin, P., & van der Westhuizen, C. (2020). Challenges and contexts in establishing adaptive learning in higher education: findings from a Delphi study. *International Journal of Educational Technology in Higher Education*, 17(1), 1-25.
- Mödritscher, F. (2008). Adaptive e-learning environments: theory, practice, and experience. VDM, Müller.
- Molenaar, I., van Boxtel, C. A. M., & Sleegers, P. J. C. (2011). Metacognitive scaffolding in an innovative learning arrangement. *Instructional Science*, 39, 785- 803. doi:10.1007/s11251-010-9154-1.
- Moursund, D. G. (2005). Planning, forecasting, and inventing your computers-in-education future.
- Murray, M. C., & Pérez, J. (2015). Informing and performing: A study comparing adaptive learning to traditional learning. *Informing Science: The International Journal of an Emerging Transdiscipline*, 18, 111.
- Murray, T. (2003) MetaLinks: Authoring and affordances for conceptual and narrative flow in adaptive hyperbooks. In P. Brusilovsky and C. Peylo (eds.), *International Journal of Artificial Intelligence in Education* 13 (2-4), Special Issue on Special Issue on Adaptive and Intelligent Web-based Educational Systems, 199-233.
- Oxman, S., Wong, W., & Innovations, D. (2014). White paper: Adaptive learning systems. *Integrated Education Solutions*, 6-7.
- Özyurt, Ö., & Özyurt, H. (2015). Learning style based individualized adaptive e-learning environments: Content analysis of the articles published from 2005 to 2014. *Computers in Human Behavior*, 52, 349-358.
- Paramythis, A., & Loidl-Reisinger, S. (2003). Adaptive learning environments and e-learning standards. In *Second european conference on e-learning* (Vol. 1, No. 2003, pp. 369-379)..
- Paramythis, Alexandros and Susanne Loidl-Reisinger (2004). Adaptive Learning Environments and e-Learning Standards, *Electronic Journal on e-Learning*, Vol. 2. Issue 1.
- Partners, Tyton (2021), "Learning to Adapt: A Case for Accelerating Adaptive Learning in Higher Education ". retrieved from [Learning to Adapt: A Case for Accelerating Adaptive Learning in Higher Education - Tyton Partners \(via Tyton Partners\) ~ OLM Educator Hub \(csu.domains\)](#), on 3,2,2021
- Popescu, E. (2010). Adaptation provisioning with respect to learning styles in a Web-based educational system: an experimental study. *Journal of computer assisted learning*, 26(4), 243-257.
- Rosenlund, C. H., & Damark-Bembenek, B. (1999). Assessing the effectiveness of an online program. *Nurse Educator*, 24(1), 5–6.
- Ramadan, A. M., & Aleksandrova, E. A. (2018). Computerized Adaptive Testing. In *Информационные технологии в образовании* (pp. 446-449).



- Rohrkemper, M., & Corno, L. (1988). Success and failure on classroom tasks: Adaptive learning and classroom teaching. *The Elementary School Journal*, 88(3), 297-312.
- Shute, V., & Towle, B. (2003). Adaptive e-learning. *Educational psychologist*, 38(2), 105-114.
- Smith-Jentsch, K. A., Jentsch, F. G., Payne, S. C., & Salas, E. (1996). Can pretraining experiences explain individual differences in learning? *Journal of applied Psychology*, 81(1), 110.
- Strayer, J. (2007). *The effects of the classroom flip on the learning environment: A comparison of learning activity in a traditional classroom and a flip classroom that used an intelligent tutoring system* (Doctoral dissertation, The Ohio State University).
- Tóth, P. (2014). The role of individual differences in learning. *Acta Polytechnica Hungarica*, 11(4), 183-197.
- Tseng, J. C., Chu, H. C., Hwang, G. J., & Tsai, C. C. (2008). Development of an adaptive learning system with two sources of personalization information. *Computers & Education*, 51(2), 776-786.
- Tymofiy, Desyatov. (2016). Adaptive adult education in terms of active use of information technologies. *International Letters of Social and Humanistic Sciences*, 67.
- Wang, T. I., Wang, K. T., & Huang, Y. M. (2008). Using a style-based ant colony system for adaptive learning. *Expert Systems with applications*, 34(4), 2449-2464.
- Whittenburg, J. B. (2011). *Adapting to adaptive e-learning: Utilizing adaptive e-learning programs within educational institutions*. University of Southern California.