International Journal for Quality Research 15(1) 45–72
ISSN 1800-6450

Rabee Alqahtani[1]
Narentheren Kaliappen
Mohammed Alqahtani

Article info:
Received 10.06.2020
Accepted 22.10.2020

UDC – 37.014.6
DOI – 10.24874/IJQR15.01-03

A REVIEW OF THE QUALITY OF ADAPTIVE LEARNING TOOLS OVER NON-ADAPTIVE LEARNING TOOLS

Abstract: *This paper provides a systematic review of the quality of adaptive learning tools over non-adaptive learning tools. A search using the relevant keywords in Google Scholar yielded 66 usable papers. These were categorised based on the works and the countries where most of the research has taken place. Perceived problems were identified and a framework / model as a suitable solution was developed - both adaptive and non-adaptive. Adaptive learning is an interactive experience which leverages technology and provides a responsive teacher to the student. The advantages over non-adaptive methods are numerous and mentioned here. A review of these showed their superiority also in terms of quality over the existing methods. Learning styles are the prominent points of discussion and form the basis for developing frameworks or models. This research has implications on the quality of learning capability of the students and also on the quality of delivery of teaching. Infrastructural limitations in schools are possible but can be overcome through smartphones / other technologies. For future research, it would be worthwhile to compare the adaptive learning tools with non-adaptive learning tools using a quantitative methodology.*

Keywords: *Adaptive learning; Systematic review; Quality of learning capability.*

1. Introduction

Adaptive learning is a method of learning suited to the individual learning needs rather than a generalised highly tailored method like classroom learning. Modern ICT facilitates direct learner approaches for learning without the need for the physical presence of a teacher. Adaptive learning can be described as the implementation of personalized learning experiences that tackle individuals ' individuality through feedback, routes, and opportunities rather than a single-size learning experience (Smartsparrow, 2018).

"We define adaptive learning tools as education technologies that can respond to a student's interactions in real-time by automatically providing the student with individual support. … Adaptive learning tools collect specific information about individual students' behaviours by tracking how they answer questions. The tool then responds to each student by changing the learning experience to better suit that person's needs, based on their unique and specific behaviours and answers" (Pearson, 2016).

In this paper, a systematic review of adaptive learning tools is presented. The focus will be only on adaptive learning tools used in

[1] Corresponding author: Rabee Alqahtani
Email: bilirabbi@yahoo.com

education and not on adaptive learning itself. The paper is structured as follows.

1.1 Methodology

Google Scholar was used as the search engine. The terms “quality + adaptive + non-adaptive + learning tools” were used for searching the first five pages first using Anytime as the time frame and then another five pages using 2015-2019 as the period of search. Only English sources were selected. Books were excluded, however, full texts of chapters available from books have been included. The search done in this manner yielded 66 usable papers, which are discussed under the appropriate sections below.

2. Results

2.1 Selected papers and their findings

Carver Jr, Howard, and Lavelle (1996) documented the outcome of a project to improve student learning with course hypermedia and adaptive design hypermedia. The first attempts at the U.S. Military Academy to create networked hypermedia created a wide variety of tools. Both methods were useful for teaching students. Students had access to more than one gigabyte of information about the hypermedia course online. These included class slides, notes, classes, extensive hypertexts, a student response system, a configurable virtual computer, great graphics, sound files, and digital movies. Some students were confused by the availability of such a large number of tools, leading to their inability to make active choices of the most desirable learning material. The importance of unique multimedia resources to students has varied widely. The unique learning style of each student determined the type of material they chose for the course. Because of this issue, an adaptive hypermedia interface was developed that matched each student's lecture material and learning style. To incorporate adaptive hypermedia, standard gateway interfaces were used. The Feld style model has been used for this purpose. When a student logs into the hypermedia course, the course interface is generated dynamically. The code is based on the user's working style. Thus, the material presentation matches the learning style of the student, which may differ from the style of the instructor. The program increased the efficacy and quality of the students ' learning process. The authors reproduce a typical User Media in figure 1.

Also, the virtual computer, the student response system and lesson slides given by the authors is reproduced in Fig 2. The figures are largely self-explanatory as the above-description of the research explain the important points sufficiently well.

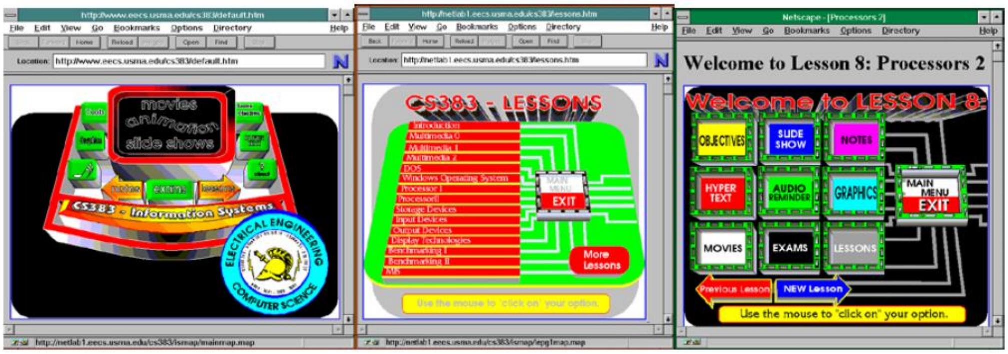

Figure 1. A typical user interface of hypermedia (Carver Jr, Howard, & Lavelle, 1996)

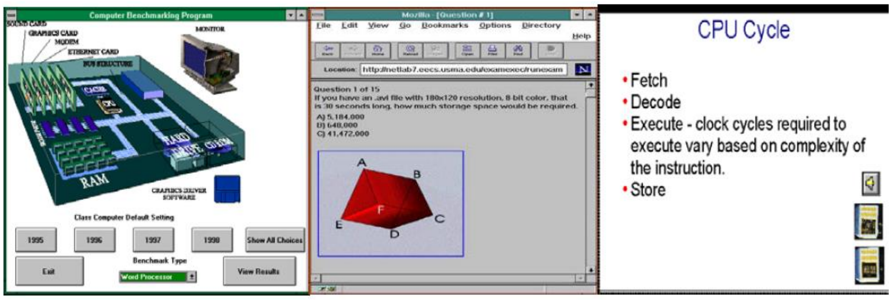

Figure 2. Virtual computer, student response and lesson slides in the system (Carver Jr, Howard, & Lavelle, 1996)

The fact that they have a reduced ability to respond to all needs for enhanced online learning is due to their poor architectural design is reported by Meccawy, Blanchfield, Ashman, Brailsford, and Moore (2008). E-learning 2.0 is now known as web 2.0 learning tools. In the entire learning process, this new generation is a social and collaborative activity. The new Learning Management System (LMS) provides the tools and atmosphere for this type of social education. The authors have proposed a WHURLE 2.0 adaptive LMS framework, which facilitates its integration with all new LMS adaptation functions. The overall architecture of this service is converted into a centralized Web service. The ties with specific methods in Web 2.0 was clarified by an introduction in which Moodle's Web 2.0 social features as an LMS with an adaptation function are integrated.

There are several Massive Open Online Courses (MOOC) built as a video collection in a community of conventional distance learning models. However, they are not sufficiently adaptive to individual learning. In the curriculum environments, both industrialized and developing countries Daniel, Cano, and Cervera (2015) underlined the need for MOOCs to adopt different teaching strategies to promote customized learning. This challenge includes five dimensions: the teaching model for developing country countries, monetization, certification, adaptive learning and the MOOCs.

Developments from a free to an extra fee business model consist of certification (students pay for a badge or certificate); security assessments (students pay for exams to be screened and awarded); recruitment of employees (companies paying access to student records); screening applicants (employers/universities pay for access to screen applicant records). The students should pay four of the eight items listed. This will prevent a large number of students, especially in developing countries, from seeking adequate livelihood qualifications. Therefore, models of these courses must be designed for developing countries rather than requiring students to pay across many components.

Wolf (2002) identified the theoretical and technical aspects of the iWeaver mechanism. This is an adaptive web learning environment. This is interactive. This project aims to create an individualized learning environment that can support individual learning styles (as quoted by the author). It builds on the Dunn and Dunn Learning models. iWeaver uses database-driven Java Server websites, dynamic Flash animations, audio playback, and other learning tools specifically developed for this purpose. The portrayal of the media for each mode of learning is clarified with its explanation. The media allotment of iWeaver is flexible and can change the learner's behavior dynamically. This student-centered approach expects to increase the motivation, knowledge retention, and understanding of iWeaver students. A Java Programming Language teaching prototype was described. Fig 3 reproduces the Dunn & Dunn model for the paper.

The diagram of the iWeaver learning situation flowchart from the perspective of learners is reproduced from the paper in Fig 4. The chart was explained in terms of three stages shown also in the diagram. Nine implemented learning preferences of the model categorised into five perceptual domains and four psychological domains have been tabulated with their prescription, recommended representation and representation type. Some working models of Java programming language learning situation have also bee presented and discussed.

Figure 3. Dunn & Dunn model of learning styles (Wolf, 2002)

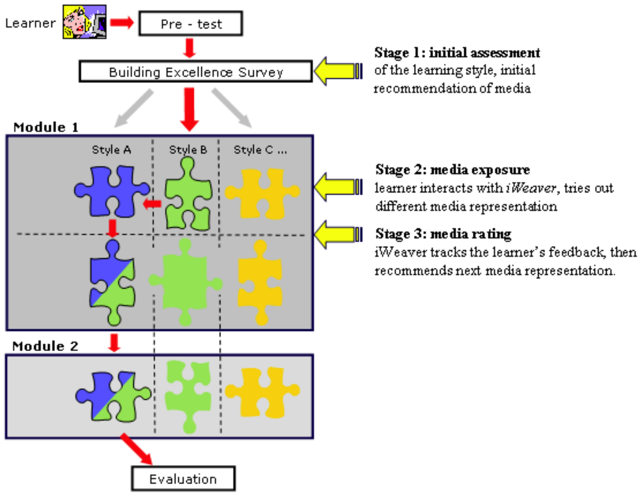

Figure 4. The flowchart of iWeaver learning situation (Wolf, 2002)

Magoulas, Papanikolaou, and Grigoriadou (2003) developed rational design and guidelines to adapt Web-based learning systems using instructional theory and Honey-Mumford learning styles in the context of their adaptation to hypermedia learning systems (Honey & Mumford, 1992). Because of their adaptation, the systems proposed to use individual differences.

For content adaptation and presentation and adaptive navigation, support examples have been provided for instructional manipulations. The overall level of program changes is driven by educational experience that reflects on individual differences. The paper has provided a lot of informative charts, graphs, and computer screenshots.

In their review, Mulwa, Lawless, Sharp, Arnedillo-Sanchez, and Wade (2010) focused on AEHS as a form of Technology Enabled Learning Environments (TELE). AEHS has replaced traditional learning systems with dynamic learning environments. The authors have provided many tables, figures and diagrams and listed information. As the paper deals with many basic aspects of adaptive learning tools, those relevant here are reproduced below.

A TEL model by categorising the pedagogy is reproduced in Fig 5.

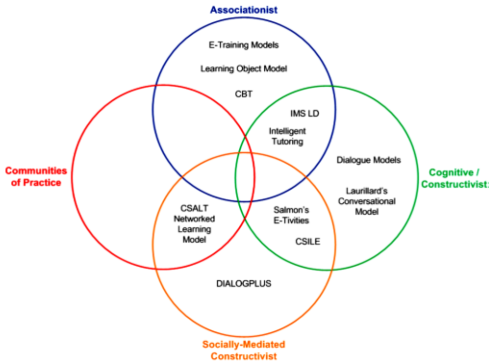

Figure 5. Technology enabled model of adaptive learning by pedagogical categories (Mulwa et al., 2010)

Four categories, viz., practice communities, associationist, cognitive/constructivist and socially mediated constructivist have been recognised in Fig 5. A hierarchical representation of the factors underlying AEHS is reproduced in Fig 6.

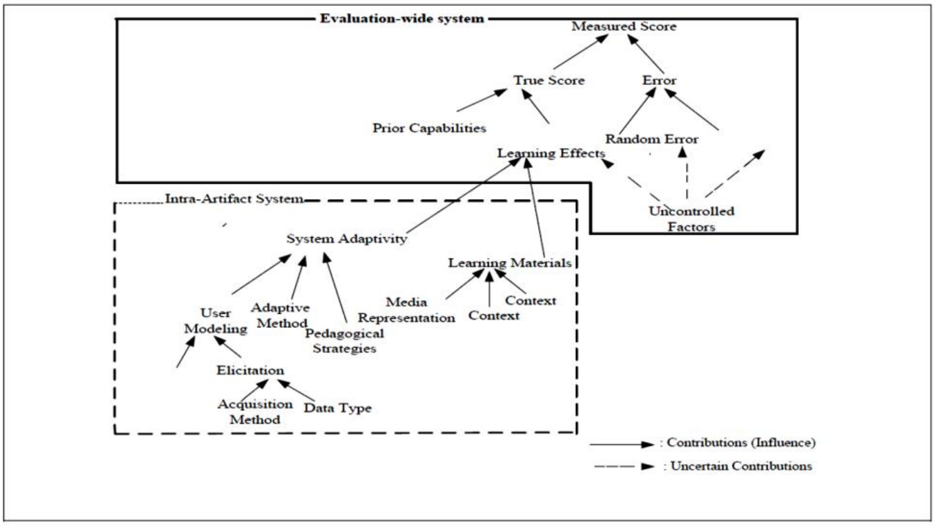

Figure 6. Hierarchy of underlying factors of AEHS (Mulwa et al., 2010)

Figure 6 shows the hierarchical structure of the principal and subcomponents. AEHS of an assessment-wide framework is therefore hierarchically structured for its elements. Dashed arrows are used to identify and connect uncontrolled factors to other system sub-components. The subcomponents within the intra-artifact framework will play the role of uncontrollable variables in the assessment. The order of the appraisal task, on the other hand, is shown by a method of measurement.

The author reproduces a simplified AES architecture in Fig. 7. Three-component elements of this model: the subject model that stipulates the specific adaptation to be made; the consumer and background models that stipulate the conditions to be adjusted for their content; and the models for teaching and adaptation that suggest pedagogical methodology and adaptation types. A diagram has been provided that illustrates possible places of learning, learning methods, and information processing stages. Nevertheless, it is learning as such rather than practical learning or its techniques.

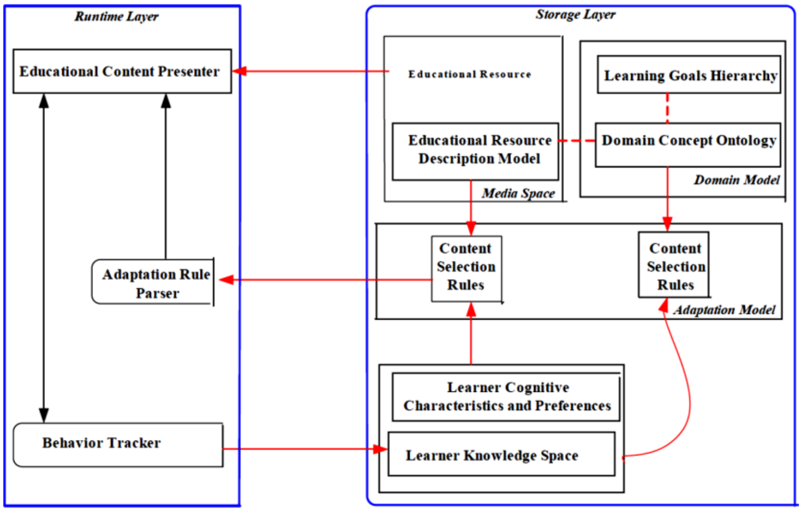

Figure 7. A generalised architecture of Adaptive Education System (Mulwa et al., 2010)

Some systems of AEHS using different models of learning styles proposed by different authors were cited. The iWeaver, discussed above, is one of the 15 systems tabulated with brief descriptions. The variables used in AEHS by many researchers are numerous. Some of them have been listed. Although there are many benefits for adaptive educational games and adaptive learning itself, some limitations have also been identified. These limitations are largely contextual. Hence, when AEHS is considered for implementation in any learning context, benefits need to be balanced against limitations to determine how exactly it can be implemented. On the whole, the paper provides a lot of information on the practical side of AEHS implementation.

Thyagharajan and Nayak (2007) noted that, in a distributed environment, content creation for an individual learner is a serios problem for e-learning systems. There is difficulty in developing learning modules according to e-learning standards and at the same time match it with individual leaner requirements. There are specific problems of structuring and organization of learning materials in conceptual units with added metadata definitions. Some of the problems related to personalisation of learning are finding a method of personalisation capabilities using distributed and also connected repositories; supporting leaner identification and profiles when distributed environment is used; methods to integrate personalisation capabilities with other functionalities as learner supports and provide reusable learning content across different e-learning environments. After discussing some well-known AEHS, including iWeaver, the authors propose a framework of their own. The authors claim that their framework has runtime reconciliation of discrete elements of adaptivity, making extensible personalized e-learning resources possible. It reduces browsing time and thus improves not only the performance of the learner, but also provides more time for learning to reduce the learner's cognitive load. Application of "create once, use often" principle enables its reuse in many other similar learning contexts.

Carchiolo, Longheu, Malgeri, and Mangioni (2007) proposed an architecture consisting of four layers. It consists of a database layer, which stores, shares and reuses courses and teaching materials; an adaption layer allowing generation of personalized courses; a presentation layer, which provides learning paths of personalized courses; and finally an interface layer for the development of several learning interfaces. Each layer is described, and the profile management system is also explained. The proposed architecture is reproduced in Fig 8.

Brusilovsky (2004) offers KnowledgeTree, a framework for integrated online learning based on distributed wise, reusable learning practices. KnowledgeTree had the objective of overcoming the gap in intelligent tutoring and adaptive hypermedia between LMS-centered web-based application and the under-used technology.

This integrated approach, therefore, addresses both the adaptive systems ' component-based assembly and the reusability of teachers.

For around two years, KnowledgeTree was used in several real-world teaching situations. Three different KnowledgeTree course trees and two different Knowledge Sea maps were created over this period. Three main activity servers coordinate more than 200 virtual events. In Nijhavan and Brusilovsky (2002), the details of the KnowledgeTree were also presented. Several KnowledgeTree diagrams are shown in Figure 9 to 11.

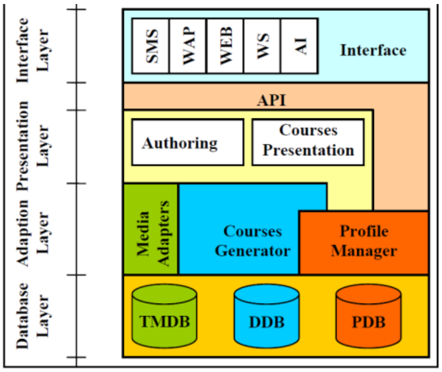

Figure 8. Proposed four layered reusable AEHS architecture (Carchiolo, Longheu, Malgeri, &Mangioni, 2007)

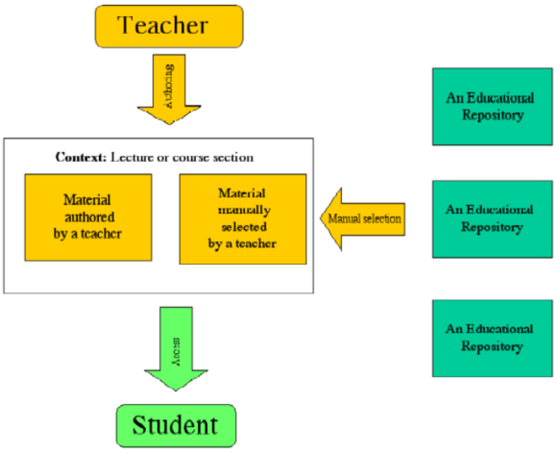

Figure 9. The reuse approach in course design and delivery (Nijhavan & Brusilovsky, 2002)

In Fig 9, the reuse approach consists of enabling teachers to access and include resources for their course materials. This is a dynamic step. Students use static accesses to the course materials.

The architecture of KnowledgeTree is given in Fig 10 reproduced from the authors. Its tree-like structure consists of the portal as the central trunk with students' model and activity servers as the branches of this tree.

The portal of KnowledgeTree is reproduced in Fig 11.

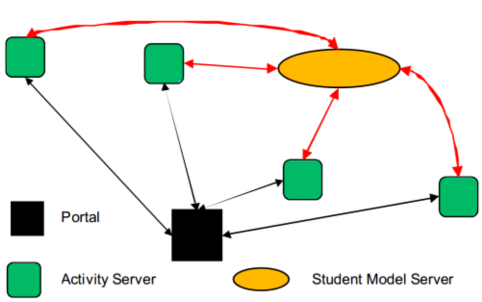

Figure 10. The main components of KnowledgeTree architecture (Nijhavan & Brusilovsky, 2002)

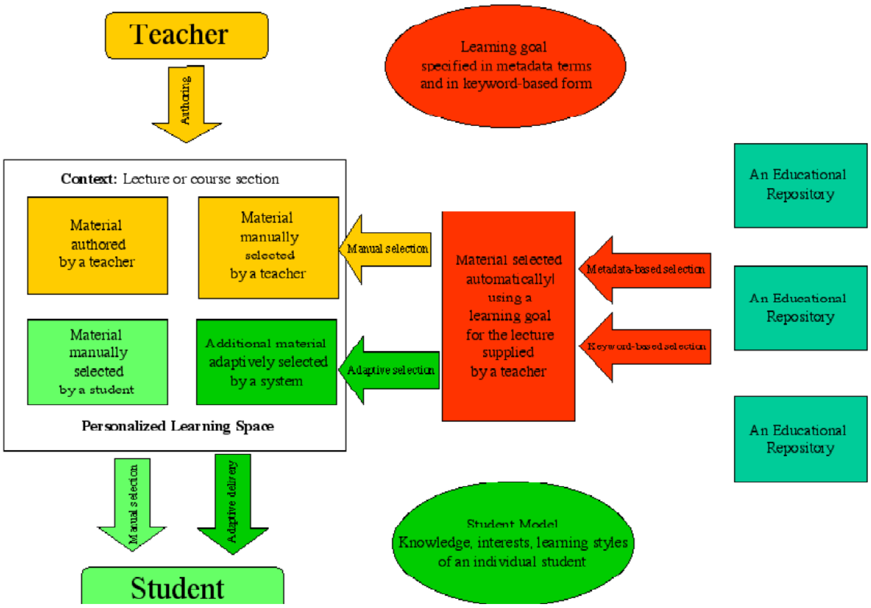

Figure 11. The KnowledgeTree Portal (Nijhavan & Brusilovsky, 2002)

Fig 11 shows a combination of reuse and AEHS systems. Thus, the problems of static e-learning systems are solved. The maximisation of personalised support to the learner can enhance motivation and effectiveness of personalised learning.

In terms of domain modelling of courses, or learning-related activities, the current e-learning standards are inadequate to capture the rich semantic structure of static learning materials or single and multi-participant processes. A variety of ways exist to integrate semantic-level information into the metadata structures which accompany learning materials. The most promising approaches seek to formalise or standardise ways for semantically, in which, there is articulation of relationships and properties of the units from which materials and activities are composed.

It is possible to design alternative adaptation methods and techniques based on the available information. Scope and viability are most restricted when the adaptation "logic" itself in integrated with structural metadata. The potential drawbacks of the latter approaches include the excusive applicability of the logic that is already incorporated in adapting or personalising materials; only procedural logic is incorporated which has no semantic value, making its use as input unfeasible for the application of alternative adaptation methods or techniques. There are many ALE oriented standards, but are still inadequate to model for individual learners. Other modelling standards are still far from this type of standardisation (Paramythis & Loidl-Reisinger, 2004).

Torrente, Moreno-Ger, Fernández-Manjón, and Del Blanco (2009) tackled issues relating to the use of serious video games for education. Three main issues are methods needed to make the most of video games inherent in adapting to maximize the effectiveness of the experience; the design of methods for tracking and evaluating students ' performance in using these tools; the further development of new game-specific learning architectures for delivery and sharing to students. The main questions are The authors have used HCT blood testing for these three issues.

The advantages of game-based e-learning in terms of adaptation and measurement were explored by Del Blanco, Torrente, Moreno-Ger, and Fernández-Manjón in 2014. However, it is not very easy to combine and integrate the complexity of both fields. In this way, VLE correspondence and norms such as SCORM, IMS, and LD seem to be more complicated. In order to solve this problem, the authors proposed an intermediate architecture. In the student-centered VLEs, the software incorporated interactive sports. The intermediate software consisted of an intermediate two-module to resume existing standards or VLE implementation. The communication among a standard VLE and an adaptive educational video game with this architecture is unrelated to any given game or standard. The new games can, therefore, be created for various learning contexts with no regard for the internal details for student-centered VLEs. The design of pedagogically important aspects can now be concentrated. Unlike the SCORM kit, for every game, the instructor adds during the learning process that only the contact configuration profile must be updated. Due to its scalability to other platforms and games and educational settings, the benefits of the middleware extend the range of teachers to be reused. Flexibility to support new standards and revisions of the plugging adapters will also facilitate interoperability, maintenance, and reuse of the contents. The medium-sized model has been tested and verified in three interactions. The top view of the authors ' middleware architecture is shown in Fig 12.

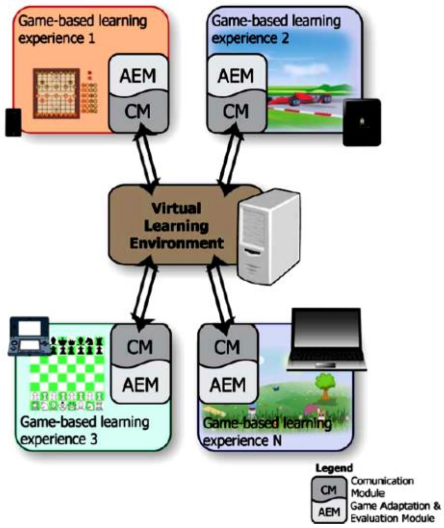

Figure 12. Top view of the proposed middle-ware architecture (Del Blanco et al., 2014)

The communication sequence given by the author is reproduced in Fig 13. This diagram gives clear idea about the mechanism by which the middle-ware functions to enhance the game reusability without the need to change the basic game configurations or standards.

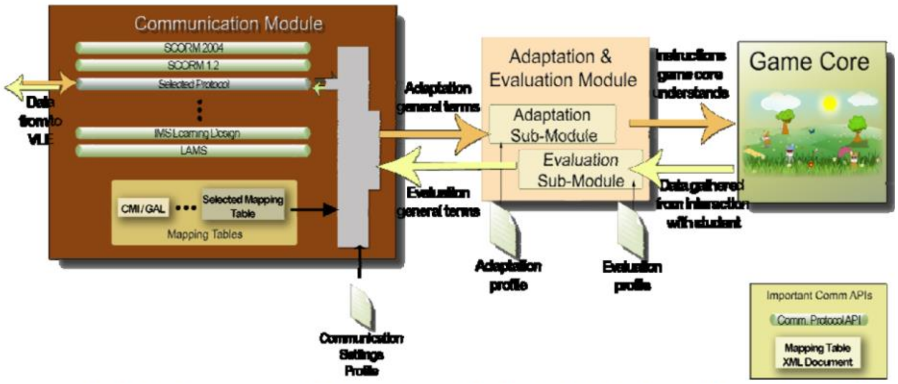

Figure 13. The communication sequence between two middle-ware modules and the game core (Del Blanco et al., 2014)

Educational videogames are best suited to high levels of student engagement and exploratory learning. Videogames, particularly, support this adaptation in a natural manner. Therefore, they act as good vehicles to enrich the adaptive features of VLE. Effective learning models to leverage the potential of games and to integrate them with the available learning materials and VLE.

Developed methods for creating custom learning ideas without implementing any learning methodology, but promoting their reusability and exchangeability is a task. Berlanga and García (2005) proposed that the Adaptive Educational Hypermedia Systems (AEHS) be able to achieve this by using the specifications of IMS Learning Design (IMS LD) as a notational method. Teachers and programmers will then be free to develop custom learning experiences that are interoperable and reusable.

According to the proprietary terminology used to describe the adaptiveness and education elements and the lack of interoperable between different courses and applications, the use of AEHS was minimal. The solution suggested by Berlanga, García, and Carabias was the annotation of adaptive regulations, techniques, and elements of learning using IMS Learning Design (IMS LD). Berlanga and Garcia-Peñalvo (2008) also discussed Moe or less the same points.

In terms of their origin, training, motivation, and learning goals, the highly heterogeneous nature and profile of participants lead to a low finishing rate in MOOCs. Sein-Echaluce, Fidalgo-Blanco, Garcia-Peñalvo, and Conde (2016) proposed a framework with logistics, methodology, and technology models in order to address this issue. This consists of an apprenticeship management system for core technology and increases versatility in course logistics. The model was tested and validated as an iMOOC platform and evaluating the usefulness and extent of its learning needs.

Aroyo et al. (2006) through the integration of learning standards, Semantic Web, and adaptive technologies that meet learners' needs. In most adaptive learning systems, the authors addressed and implemented structured models and standards which play their role as the basis for adaptive hypermedia systems. Five complementary models of adaptive hypermedia systems can be presented as the knowledge driving the adaptation process. In the domain model, the modification is defined. The user and context models. The activity (instruction) specifies the parameters to be used in the models of adaptation, and adaptation indicates how the adaptation should be carried out. In Figure 14, these are clarified.

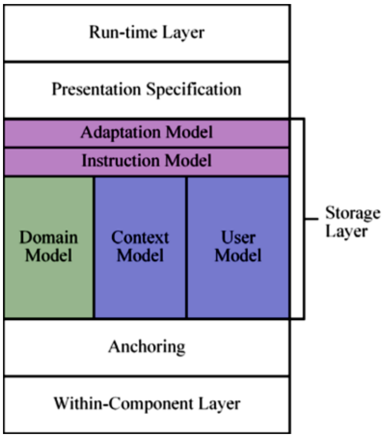

Figure 14. Enhanced Adaptive Hypermedia Application model (Aroyo, et al., 2006)

Brusilovsky's (2003) review of the development of adaptive hypermedia educational schemes from design to production includes detailed descriptions of each step, with diagrams. The descriptions go to fundamental level. Some of the diagrams are reproduced here. In table imaged in Fig 15, the author lists the differences between traditional educational hypermedia and adaptive hypermedia. There are many extra steps both in designing and authoring processes. This is one reason for the complexity of AEHS, as reported often.

Regular educational hypermedia	*Adaptive educational hypermedia*
Design	
	Design and structure the knowledge space
	Design a generic user model
	Design a set of learning goals
Design and structure the hyperspace of educational material	Design and structure the hyperspace of educational material
	Design connections between the knowledge space and the hyperspace of educational material
Authoring	
Create page content	Create page content
Define links between pages	Define links between pages
	Create some description of each knowledge element
	Define links between knowledge elements
	Define links between knowledge elements and pages with educational material

Figure 15. Differences in the steps of designing and authoring between regular educational hypermedia and adaptive hypermedia (Brusilovsky, 2003)

Fig 16 shows the structuring dimensions of AEHS. The distinction between knowledge space and hyperspace both in terms size and number is quite clear.

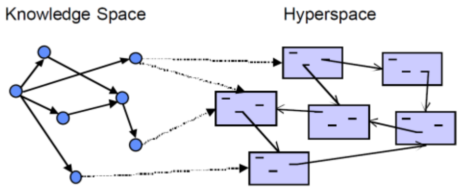

Figure 16. Knowledge and hyperspace (Brusilovsky, 2003)

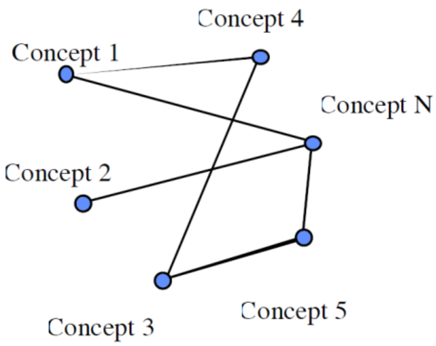

Figure 17. A network domain model (Brusilovsky, 2003)

The student overlay model, as the user is the student, is a paradigm for student information representation. Each student knowledge model stores specific data, based on the user knowledge estimated, for each domain model concept. The simplest and oldest one, as we know–not known for that reason, has a binary value. More frequently, a weighted overlay model is applied to distinguish between several user knowledge levels of a concept with a qualitative value that is good-fair.

A concept-page fragment diagram explains all the processes up to fragment indexing, as given in Fig 18.

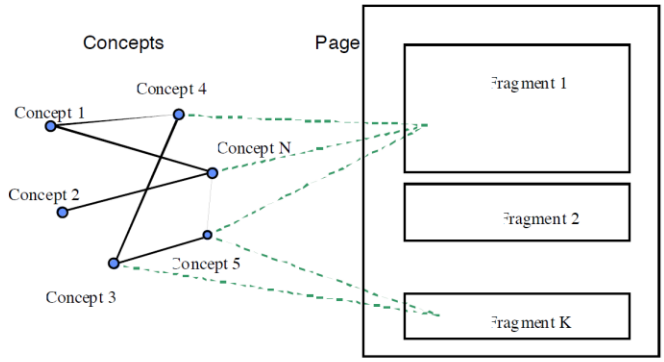

Figure 18. Concept-Page-Fragment indexing (Brusilovsky, 2003)

Various tools used in authorising stage by different authors have been listed. Some tools like KnowledgeTree and iWeaver were developed after 2003 and hence not included.

Using the theory of asynchronous learning, Own (2010) designed and experimentally tested an adaptive web-based learning system for students to learn oxidation-reduction reactions. The tests showed good student outcomes.

Armani (2004) noted that the LMS (learning management systems), which facilitates the organization of existing materials into web-based e-learning courses, was made famous among professors due to its friendly interface.

Hauger and Köck (2007) compared among and between e-learning platforms and adaptive e-learning platforms for variables related to learning, cooperation, collaboration, learning management, adaptivity and standards. Only very few of either group possess all the components of these variables. Between the groups, adaptivity was one variable absent in the case of e-learning platforms, as can be guessed. On the other hand, provision for chats did not exist in most adaptive platforms and much less standards were used in them.

Only automated connections in a corporation of educational material are possible for cost-effective implementation of technology-based learning. The WHURLE coordination method (Moore, Stewart, Zakaria, & Brailsford, 2003) suggested in Moore, Martin, Brailsford, and Ashman (2004) was to be used by WHURLE. The WHURLE design and model given in figures 19 and 20 are reproduced.

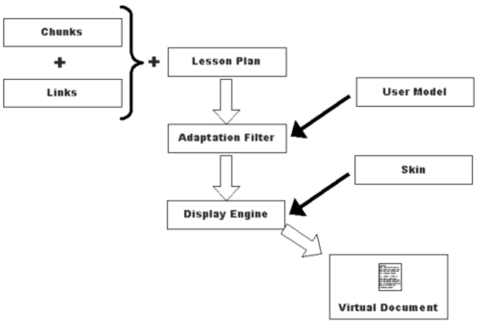

Figure 19. System diagram of WHURLE (Moore et al., 2003)

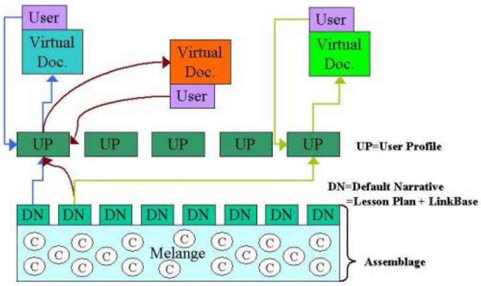

Figure 20. The conceptual system of model of WHURLE (Moore et al., 2003)

An automated navigation system is used to create structural links from the lessons automatically. Teachers or students provide authored ties consist of two-way connections from various content points or between WHURLE and other web sites. For written connections, a link-base is used. This link is also attached to a lesson created by teachers to a user profile created by students. Such relations can be one-to-more. These are carried out by Goate, a proxy system that modifies its content. This is illustrated from their work in Fig 21. GHURLE was the connected system.

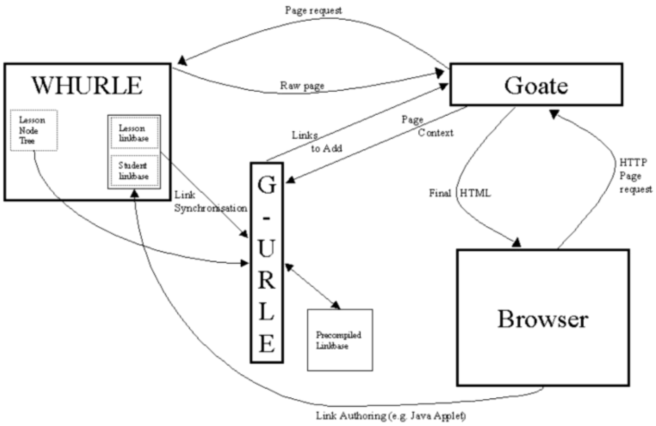

Figure 21. Ghurle System Diagram

The Goat proxy provides access to WHURLE. The browser transmits a request to the proxy, which then passes to WHURLE, a request that gives Goate a' raw' page. Concerning the current node tree, the Ghurle language module attaches the raw page links of the precompiled directory base. The links are made using the corresponding (not shown) module and are then transferred back to the browser. For instance, a java applet tool provided by the WHURLE interface can add authored links to the student connection. (Brailsford, Martin, & Ashman, 2004).

Weber, Kuhl, and Weibelzahl (2001) described the Netcoach authorship system. For NetCoach to develop adaptive learning courses, they did not require programming knowledge. Writers and tutors assist the creation and maintenance of courses in various ways through an online interface. Nevertheless, the article does not include a complete diagram.

Chatti, Dyckhoff, Schroeder, and Thüs (2013) proposed a learning analytics model using the four dimensions: data and environments, what?, stakeholders, who?; objectives why?; and methods (how?). Then the published literatures were mapped against these dimensions to evaluate the extent of work done on each dimensions. The reference model is reproduced in Fig 22.

Chang, Lin, and Wu (2010) have built and tested an integrated video education system to incorporate the virtual email associate in the videos. The e-partner may comply and animate with the student's learning style and the pupil's teaching behavior. With this enhanced system, the focus is increasingly on the content of lectures, and the study is simultaneously self-paced. The test results showed that the learning experience of the students was improved when compared to the original lecture video. The enlarged video was more attractive than to watch class lectures.

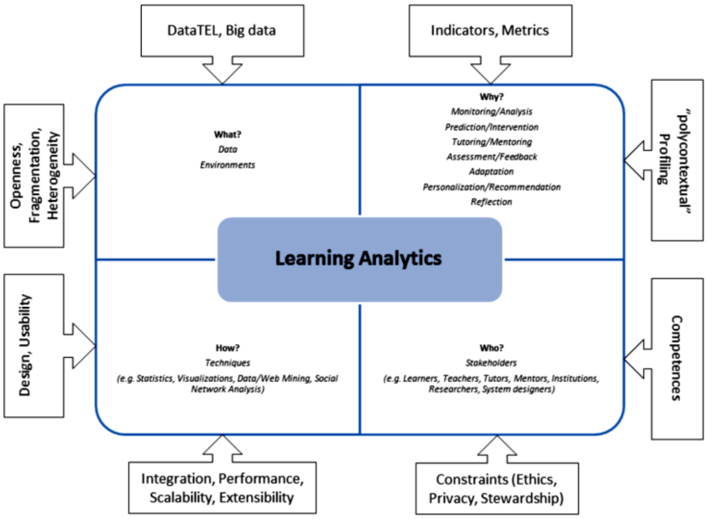

Figure 22. Learning Analytics reference model (Chatti et al., 2013)

El Bakry, Saleh, Asfour, and Mastorakis (2011) and (Saleh, El-Bakry, Asfour & Mastorakis, 2010) suggested and validated integrated learning environment for logic programming, condensed functions in Boolean language and related fields. The model produced dynamically and adaptively suitable courses for each student, based on the learning profile of current database and workflow technologies. The model used explicit and implicit feedback to meet the needs of the learner. In order to adapt to different skills of learners and improve critical skills, the learner's temperament was used to assess each individual style.

This enhanced the model's strength, ease of use, and simplicity. It could also suggest a learning strategy and suitable electronic media suit the needs of the learner. The strategies have been designed to encourage students to observe, analyze, express their opinions, search for a solution, and understand the information deeper. The model has been created through the integration of visual basics, flash, Microsoft access, and other appropriate tools.

IMS Learning Design (IMS-LD) is one of the requirements for creating study units (UoLs). This is used to describe a certain pedagogical style or technique, such as interactive game learning. However, the process of creating a UoL is difficult due to its lack of topics such as education eGames and high-level authoring tools for IMS-LD. However, even if they are not specifically IMS-LD-oriented, external tools can be used. The main challenge here, as technological differences may be between them, is the combination of these external resources with the personalized learning experience of an LD UoL. Burgos et al. (2008) solved this problem with the use of conversational games built into IMS-LD UoLs to enhance personalized learning. The key features of this system are the incorporation of both materials and communication, which allows for the effect of integrated learning.

ECSAIWEb was a smart tutoring system design environment introduced by Sanrach and Grandbastien (2000). The tutorial knowledge in this system is contained in a tutor. It was originally planned for non-networked service and was renamed ECSAI. It is reused and revised for the World Wide Web in this updated version. Two adaptations have been added now to present adaptive presentations and adaptive navigation to the students to present their domain knowledge.

Two major problems in the AEHS are the inconsistency and insufficiency of the set of rules in the adaptation model. This can lead to the creation of logical gaps in sequences of learning resources or routes. Karampiperis and Sampson (2005) proposed an alternative method of sequencing to solve this problem. In general a concept sequence with available learning resources is created by integrating the paths of learning based on pre-defined adaptation rules. All potential paths that suit the learning goal are generated first in the proposed design. It then selects the one you want. Such collection can be based on the use of a judicial process by assessing a specific learner's relative suitability of learning resources. The newly designed system was compared to the ideal system produced through simulations by simulating a perfect regulatory AEHS. The methodology proposed has been found to produce nearly precise learning pathways, which prevent the need to define complex rules in the AEHS adaptation model.

An extended ant-colony optimization approach was suggested by Wang, Wang, and Huang (2008). This was based on a new process of metaheuristic exploration of group patterns. The model has been designed to help students move on an inclusive path during their online learning journey. The focus of this program was on the relation of educational content to the research style of integrated learning of each individual. An adaptive analysis rule was built for this purpose. It showed how people in various learning styles could link content that is more likely to be useful in order to create an optimal learning path. This identification was overlaid with a style based ant colony system that optimized its algorithm parameters for actual use during the pedagogical process.

An easily accessible framework to develop adaptive learning systems for improved learning performance is one of the challenges. Tseng et al. (2008) suggested a modular framework facilitating the division into modular learning objects to make teaching materials more modular. The regular SCORM has been added. The subject content can be dynamically matched to each individual student's profile and portfolio. The development of an adaptive learning system using this innovative approach. Experiments on a college computer course have shown its utility in designing integrated learning systems for enhancing student learning performance. In this article we presented the necessary explanatory diagrams and algorithms.

Squires (2014) addressed the effect of mobile technology on modern instruction improvements. This starts with m-learning and leads to active learning through m-learning capabilities by the uninitiated learner. The models for this principle were developed using references from contemporary literature, m-learning and feedback, m-learning methods, expanded realities and the final impact of m-learning on long-term applications. The future of mobile technology and education to enhance the potential of adaptive learning is investigated on the basis of these discussions.

El Bachari, Abdelwahed, and El Adnani (2010) proposed an adaptive e-learning model based on the individuality of the learners, Personalized LearnFit Education System Framework. To understand the personality of the student, they used the personality dimensions of the Myers-Briggs (MBTI) type indicator. The environment therefore suits the expectation of the learner.

Raiyn (2017) explored use of digital game based adaptive learning to develop hot skills among students. The authors proposed a method involving a visual learning environment in which, the Bloom’s taxonomy of ordering, selection, evaluation, contrasting and comparing were used. Problem-based approach was used. The tool was tested among primary school children for a computer programming course. Its usefulness was validated through pre and post survey among the users.

In China, a system of adaptive learning, "Yixue," has been developed and implemented. It diagnostically evaluated students ' mastery of excellent grained skills. This gave them educational material that suited their characteristics and skills on the basis of this diagnosis. The Yixue system used 12 secondary school topics in 2017 by more than 10,000 students in 17 Chinese towns and cities. In assessing its usefulness, encouraging results were obtained. The effectiveness of the 8th and ninth graded mathematics programme, Feng, Cui, & Wang 2018, has also been evaluated separately.

In order to resolve the problems of MOOCs, Fidalgo-Blanco, Sein-Echaluce, García-Peñalvo and Conde-González (2016) proposed logistic, methodological and technological models of an adaptive framework. The framework used a learning management system as its core technology to provide the basic elements of adaptive learning. The logistics of the courses have been used to expand the adaptive options. In an adaptive network composed of four adaptive MOOCs, the planned models were introduced. The feedback survey revealed positive results from students regarding their perceived usefulness and needs for adaptive processes.

Dividing data into natural groups gives a good summary of the progress and performance levels achieved by students facilitates targeting of teaching and tutoring. This is particularly important in the case of online adaptive learning systems as there are larger number of students with high diversity. Clustering also helps to design predictive models to facilitate intelligent tutoring systems. Hämäläinen, Kumpulainen, and Mozgovoy (2015) evaluated the currently available clustering methods and suggested the most desirable clustering tool.

A case of using adaptive learning to enhance reading skills was investigated by Villesseche, et al. (2019). A platform TACIT was used for measuring inferential skills of reading in a blended teaching environment. A large sample of primary level students were tested. The results revealed the usefulness of adaptive e-learning as an effective method of enhancing reading comprehension for primary-school learners. Teachers found this blending easily into the lessons with enhanced the game aspect.

In developing gamified chatbots for adaptive training, user-related factors, such as age and gender become important. For the right target market level, these considerations must be successfully combined in the chatbot with the game elements. The development of the educational chat game "CiboPoli" was debated by Fadhil and Villafiorita (2017). This was a special program to teach children healthy lifestyles through the interactive environment of social games. The game was based on a paper prototype designed to teach students in elementary schools about healthy diets and managing food waste.

The chatbot approach is more active and possesses IA skills. External modules such as the dialog module, user-specific information module and the machine learning module are included in the future development plans. This proved to be better than the paper version at first evaluation of the prototype.

Interactive textbooks is a current adaptive learning tool being popularised by book publishers. They claim that their products help maximize the effectiveness of the time spent by students with course textbooks as it tests key concepts and the points of focus for students further. Positive student outcomes in terms of improved preparedness and grades are also claimed. Phillips and Trainor (2019) undertook a study on the student side of whether these benefits. In the early research with students in business class, it was discovered that students grasped the content of their courses more clearly than conventional e-books, which the emphasis was on the more important content of their allocated reads. While, Jiang, et al. (2016), conceptually discussed the 5G applications in machine learning and radio (wireless) learning with the help of diagrams. Various methods of measuring supervised, and unsupervised learning were also discussed.

Kumar, Singh and Ahuja (2017) found in a review of adaptive adaptive intelligent tutoring (AITS) styles that most studies defined a learning-based framework or architecture for adaptable intelligent teaching (AITS). Some concentrated on the AITS effect on the motivation of learners and academic results. Also, algorithms from rule and bayesian networks have been used more often to automatically predict learning styles.

Chen, Chiang, Jiang and Yu (2017) developed and tested a context-specific teacher training model in an all-round learning environment. The model offers teachers adaptive and personalized content in a U-learning environment for various subjects. The platform included intra-and inter-group knowledge building and in-depth research collaborations and facilities to reflect the review and summarization facilitated by the supervising teacher. The model was used for general teacher training to check the effect. The study of the teachers found that teachers trained easily and had a positive approach to the pattern.

TheProTuS programming tutoring system (Vesin, Mangaroska, and Giannakos, 2018), proposed to provide smart and interactive content, customisation options, adaptive features, and learning analytics in order to provide users involved in learning complex cognitive abilities. The results of an empirical study showed that students found it useful to monitor progress, promote reflection and get feedback to assess the understanding of their actions and the learning strategies they needed.

Dlamini and Leung (2018) examined whether incremental machine learning techniques can be incorporated and assessed for adaptive pedagogy. Their performance. The goal was to determine the most appropriate incremental machine learning technology for smart tutor system implementation. The Vector Machines Support (SVMs), k-Nearest Neighbour (k-NNN) and the algorithm from Naïve Bayes were tested using the same datasets in practice. Of these three, the naive Bayes was the best. Thus it seems that Naïve Bayes is most suited for pedagogical ITS decisions.

The two specific obstacles for adaptive education technologies include the successful integration of e-learning programs into the continuous development of the curriculum and the recognition of integrated personalization based on the learner's improvement in his learning behavior. Rani, Nayak and Vyas (2015) used the following methods. For extracting information from the content contained in ontology, DL Query has been used. The Silverman Field model was used to assess student learning types. For integrated learning, JADE agents have been hired to track learner behavior. Cloud storage was used to expand the ontological content.

For the next generation of adaptive learning systems, seven characteristics were identified by Essa (2016) as follows:

1. It is cost-effective to develop, maintain and support.

2. The academic attributes and information status of the subject can be reliably measured.

3. Decisions and recommendations are implemented effectively and efficiently. These include defining each learner's optimum education opportunities and practices at all times.

4. It can support multiple simultaneous users.

5. It is scalable to be implemented by open standards for client programs.

6. Science, science, engineering and mathematics (STEM) areas and many other subjects are generally applicable.

7. It can upkeep clear open learner models, in which learners can control better with ownership of their own learning.

These were discussed in detail under teaching machines, formal framework, deep learner models, learning objects, advanced learning analytics.

Al-Othman, Cole, Zoltowski and Peroulis (2017) have developed a new interactive cloud instructional framework for engineering students. The ADEPT program focused on customizing research in major university lessons. The result was the proactive and ongoing involvement of students. The author described in an early version of ADEPT in a sophomore course at Purdue University the principles, implementing strategies and initial results. The initial findings showed that ADEPT did not easily identify student engagement practices and study patterns through other methods, including the reporting process.

Laforcade, Loiseau and Kacem (2018) suggested a model-driven architecture system in their work to make it easier to develop and test adaptive learning scenarios. The question of personalization will be dealt with directly and then test the domain elements and the rules for adaptation by the domain experts and computer scientists. A method of metamodeling was also advised that the domain elements be defined both for the 3-incremental perspective and for the domain elements to be used and generated. The description of the game and student profile were then also proposed as input models for the generator in order to produce an adapted scenario as output model. The system was used to assist young children with autism in comprehension and universal visual output in the context of the Escapeit initiative.

Akhavan, Teimuri, Rajabion, and Philsoophian (2018) explored the role of knowledge management in adaptive e-learning and proposed a model to enhance teaching. Strong relationships were obtained between the main components of knowledge management such as creation, application and sharing; and adaptive e-learning components including management; evaluation and system security; Culture and human resources; learning paths and scenarios; learning objects and educational contents.

The adaptive learning method model for foreign language skills for adult, independent learning has been proposed by Liu, Ruan and Zhou (2018). A thorough analysis of and application of adaptive learning technology showed its involvement in a wide range of areas. However, their fields of application are limited to certain areas. The improvement of the learning model and use of Big Data and Adaptive Engine education provides personalized and more accurate learning.

Learning mathematics is ever a major issue due to the failure of students to understand the basic concepts and inability to apply them. One reasons for this problem may be the use of standardized teaching methods which do not align with the individual characteristics of each student. Oliveira, et al. (2018) proposed the OPERA learning adaptive system to provide the basics for further mathematics learning according to the diversity of the users/learners. OPERA does this by collecting learner interaction data for active and contextualized monitoring the learning process and to identify achieved knowledge and difficulties of the learner in each stage. OPERA uses the analysis results of these data to reorganize the sequence of contents. The precise information needed to progress is also given for making learning much more efficient.

A model that integrates Moodle with its optimized content network with knowledge and skill was developed by Louhab, et al. (2019). The teachers would also be able to manage their students ' learning processes by applying flipped instruction. To validate the model, a Flipped Learning Adaptive Management (SAM-FL) plugin has been implemented. As basis of the model, many hierarchical agents are used which allow modularity in the creation of content and test thresholds. The model was evaluated in order to compare the output level of the learner with the entry level. The quality of the experience with the students was analyzed for the subjective evaluation.

In order to increase the listening understanding of 11-year students, Hsu (2015) was to provide adaptive support. Three levels of subtitle filtering according to student needs were used to develop a video-based language learning system for handheld devices. The first (elementary) sub-tale excluded 220 visual words in English and provided the remaining words with sub-titles and Chinese translations. The second level excluded 1000 English words at high frequency and provided the remaining words with sous-titles. 2200 high frequency English words were omitted in the third (high intermediate) subtitles stage.

A new agent-based ecosystem model has been proposed by Rodríguez, Palomino, Chamoso, Silveira and Corchado (2018). The objective of this model was to use Virtual Organizations (VO) in the field of LMS. The aim was for students and teachers to cooperate and work. The model was developed to adjust an agent's VO to participants ' characteristics in terms of tasks and resources available in the LMS. Observational research on the increase in learning efficiency with mobile adapters during graduate studies was conducted by Garcia-Cabot, de-Marcos, and Garcia-Lopez (2015). In contrast with an e-learning approach, smartphone implementation has had a small impact on the performance of functional skills. Information was also collected and compared to traditional computer accesses about the context for using the mobile system. In a similar context, students learned irrespective of how they viewed content.

Silent readership was improved in children exposed to adaptive learning methods under the TERENCE program for primary school children, according to Vincenza, Rosita, Daniele, Rosella and Pierpaolo (2016). The TERENCE curriculum featured quiet reading, insightful games related to reading stories and reviews, which were assisted by technology. The differences between silent readers and spoken readers have been raising. The method was a useful tool for the instructors. In favor of silent lecture, the TERENCE program improved understanding ability.

Lack of visualization is a problem in learning chemistry. There is also a need for enriching the learning method. Blended learning, as a method of adaptive learning, helps to integrate the classes with better visualisation of topics in chemistry. Blended learning consists of combining methods of teaching like online and face-to-face learning. Thus, misconceptions could be suppressed, the understanding of chemistry could be improved, and greater time efficiency could be achieved. Space and time limitations will cease to exist. Technological or school infrastructure limitations as learners can use their own devices like smartphone for learning. The restrictions on the use of portable devices like mobile phones in schools will have to be removed. Various alternative uses of blended learning in chemistry classes were discussed by Nadii and Adi (2018).

The possible effect of adaptive mobile learning on learning performance; perceive usefulness, and willingness to use of undergraduate students were evaluated by El Said (2019) in a learning environment of using the adaptive m-learning tool personalising the learning material format to the user and device contexts. Implicit measure (dwell time), explicit measure (satisfaction questionnaire) and learning assessment (post- test) were done in an experimental approach. The traditional school e-learning system was used as control. Results revealed significant improvement in perceived usefulness of learning materials and the learners' willing to use the tools in the case of adaptive mobile learning compared to the traditional e-learning.

Murray and Pérez (2015) did not obtain significant difference in student scores between adaptive learning and the traditional objective-based approach. Based on this finding, the authors argue that pedagogy, and not technology, must drive the development of advanced learning systems.

2.2 Some common trends

The selected papers are categorised according to the type of study and tabulated in Table 1 with the citations concerned. Out of 68 papers in the list of references, two had had been cited and discussed in the Introduction chapter and two are cross-references for some concepts presented in the frameworks. Out of the balance 64 papers, 15 were in the nature of reviews and general discussions. However, some topics like future of adaptive learning with 5G facilities and use of mobile phones for learning chemistry enabled with videogames were interesting. There was also suggestion for reconsideration of ban on mobile phones in campuses. Considering that two other papers also dealt with mobile e-learning (m-learning) with adaptive technology, this point needs serious thoughts.

Table 1. Categorisation of selected papers for this review

Type of study	No.	References
Review/Discussions	15	(Mulwa, Lawless, Sharp, Arnedillo-Sanchez, & Wade, 2010), (Paramythis&Loidl-Reisinger, 2004), (Torrente, Moreno-Ger, & Fernandez-Manjon, 2008), (Magoulas, Papanikolaou, &Grigoriadou, 2003), (Berlanga&García, 2005), (Berlanga, García, &Carabias, 2006), (Berlanga&García-Peñalvo, 2008), (Brusilovsky, 2003), (Squires, 2014), (Hämäläinen, Kumpulainen, &Mozgovoy, 2015), (Jiang, et al., 2016)- 5G, (Kumar, Singh, & Ahuja, 2017), (Essa, 2016), (Akhavan, Teimuri, Rajabion, &Philsoophian, 2018), (Nadii&Adi, 2018).- mobile-based blended learning for chemistry,
Framework/Model	26	(Carver Jr, Howard, & Lavelle, 1996), (Meccawy, Blanchfield, Ashman, Brailsford, & Moore, 2008)-WHURLE 2.0, (Wolf, 2002)- iWeaver, (Thyagharajan&Nayak, 2007), (Carchiolo, Longheu, Malgeri, &Mangioni, 2007), (Brusilovsky, 2004), (Nijhavan&Brusilovsky, 2002) - KnowledgeTree, (Torrente, Moreno-Ger, Fernández-Manjón, & Del Blanco, 2009), (Del Blanco, Torrente, Moreno-Ger, &Fernández-Manjón, 2014)- middle-ware architecture, (Sein-Echaluce, Fidalgo-Blanco, García-Peñalvo, & Conde, 2016), (Aroyo, et al., 2006), (Own, 2010), (Armani, 2004), (Moore, Stewart, Zakaria, &Brailsford, 2003) and (Moore, Martin, Brailsford, & Ashman, 2004)-WHURLE, (Weber, Kuhl, &Weibelzahl, 2001) Netcoach, (Chatti, Dyckhoff, Schroeder, &Thüs, 2013), (Burgos, et al., 2008), (Sanrach&Grandbastien, 2000) ECSAIWEB, (El Bachari, Abdelwahed, & El Adnani, 2010)- LearnFit, (Fadhil &Villafiorita, 2017)-chatbotCiboPoli, (Al-Othman, Cole, Zoltowski, &Peroulis, 2017)- ADEPT, (Laforcade, Loiseau, &Kacem, 2018)-Escapeit, autism, (Liu, Ruan, & Zhou, 2018)-foreign language learning, (Oliveira, et al., 2018)- OPERA for maths, (Rodríguez, Palomino, Chamoso, Silveira, &Corchado, 2018)-agent-based environment,
Evaluation with or without development of model	23	(Daniel, Cano, &Cervera, 2015), (Hauger&Köck, 2007), (Chang, Lin, & Wu, 2010), (El-Bakry, Saleh, Asfour, &Mastorakis, 2011), (Saleh, El-Bakry, Asfour, &Mastorakis, 2010), (Karampiperis& Sampson, 2005), (Wang, Wang, & Huang, 2008) Ant colony, (Tseng, et al., 2008) Modular, (Raiyn, 2017) digital game and PBL, (Feng, Cui, & Wang, 2018)-Yixue, (Fidalgo-Blanco, Sein-Echaluce, García-Peñalvo, & Conde-González, 2016)- iMOOC, (Villesseche, et al., 2019)-TACIT, (Phillips & Trainor, 2019)- interactive textbook, (Chen, Chiang, Jiang, & Yu, 2017)- U-learning in teacher training, (Vesin, Mangaroska, & Giannakos, 2018)- ProTus, (Dlamini& Leung, 2018), (Rani, Nayak, & Vyas, 2015), (Louhab, et al., 2019)- SAM-FL for flipped learning, (Hsu, 2015)- m-learning with video games for listening comprehension, (Garcia-Cabot, de-Marcos, & Garcia-Lopez, 2015)- m-learning evaluation, (Vincenza, Rosita, Daniela, Rosella, &Pierpaolo, 2016)- TERRENCE for reading skills, (El Said, 2019)- significant improvement, (Murray & Pérez, 2015)- no difference

A large majority of papers dealt with frameworks or models to solve certain perceived problems in using adaptive learning technology. A total of 49 papers out of 64 were on this aspect. Out of these, 26 papers confined to the discussion of the frameworks they proposed and did not include any evaluation studies. On the other hand, out of 23 papers evaluated a framework or model they proposed and some others did just a general evaluation of certain aspects related to adaptive learning frameworks and models. Most studies were from USA, UK, Germany, China and Indonesia and India. There was a notable deficiency of papers from the Middle East.

3. Discussion

Except one paper of Murray & Pérez (2015), who did not find any significant difference between the non-adaptive and adaptive technology, all other papers found at least some advantage of adaptive learning technology. There was no paper which claimed superiority for non-adaptive technology. Most papers supported development of tools for adaptive learning styles, preferences and needs of learners. The methods to determine them differed with the frameworks and models.

Many different theories and approaches were used to determine learning styles. Almost all papers perceived the existence of a problem and suggested solutions in the form of frameworks or models. Very few papers reported some studies to identify the problem properly. Some of them contained implementation algorithms, but not many.

However, the exact effects of the tools developed in frameworks or models depended on the contextualised tools. This is where the many different frameworks and models are relevant. For example, a video game approach was good for visualisation of configurations in chemistry and improve listening comprehensions of children with autism. Use of video games may not be advisable everywhere.

Ultimately, many frameworks are now available for comparable contexts. There should be some serious research comparing these frameworks in different learning environments. This will provide a precise picture of which specific method is suitable when.

4. Conclusions

This review identified numerous papers dealing with adaptive and non-adaptive learning technology. Most of them were in the nature of proposing frameworks or models based on a generally identified need to match method of learning with the learning styles of students. The superiority of these frameworks over non-adaptive tools was proved in many studies. Overall, it has been found that the adaptive learning tools offer numerous advantages and have a superior quality over non-adaptive learning tools.

This research has implications on the quality of learning capability of the students and also on the quality of delivery of teaching. Infrastructural limitations in schools are possible but can be overcome through smartphones / other technologies. For future research, it would be worthwhile to compare the adaptive learning tools with non-adaptive learning tools using a quantitative methodology.

References:

Akhavan, P., Teimuri, Z., Rajabion, L., & Philsoophian, M. (2018). Knowledge management and adaptive e-learning: Iranian schools case study. In P. Akhavan, M. Z. Teimori, L. Rajabion, & P. Maryam (Ed.), *Knowledge Management and Adaptive E-Learning: Iranian Schools Case Study. The 19th European Conference on Knowledge Management, (ECKM 2018), 6-7 September, Italy,* (p. 10 pp). Retrieved December 22, 2019, from https://www.researchgate.net/profile/Peyman_Akhavan/publication/327981712_Knowledge_management_and_adaptive_e-learning_Iranian_Schools_Case_Study/links/5bb1f20f45851574f7f3a96c/Knowledge-management-and-adaptive-e-learning-Iranian-Schools-Case-Study.pdf

Al-Othman, M. A., Cole, J. H., Zoltowski, C. B., & Peroulis, D. (2017). An adaptive educational web application for engineering students. *IEEE Access, 5*, 359-365. doi:10.1109/ACCESS.2016.2643164

Armani, J. (2004). Shaping learning adaptive technologies for teachers: A proposal for an adaptive learning management system. *Proceedings of IEEE International Conference on Advanced Learning Technologies, 30 Aug.-1 Sept. 2004, Joensuu, Finland* (pp. 783-785). IEEE. doi:10.1109/ICALT.2004.1357656

Aroyo, L., Dolog, P., Houben, G.-J., Kravcik, M., Naeve, A., Nilsson, M., & Wild, F. (2006). Interoperability in personalized adaptive learning. *Journal of Educational Technology & Society, 9*(2), 4-18. Retrieved December 20, 2019, from https://core.ac.uk/download/pdf/15476522.pdf

Berlanga, A. J., & García, F. J. (2005). Authoring tools for adaptive learning designs in computer-based education. *Proceedings of the 2005 Latin American conference on Human-computer interaction, Cuernavaca, Mexico — October 23 - 26, 2005* (pp. 190-201). ACM. doi:10.1145/1111360.1111380

Berlanga, A. J., & García-Peñalvo, F. J. (2008). Learning Design in Adaptive Educational Hypermedia Systems. *Journal of Universal Computer Science, 14*(22), 3627-3647. Retrieved December 20, 2019, from http://www.jucs.org/jucs_14_22/learning_design_in_adaptive/jucs_14_22_3627_3647_berlanga.pdf

Berlanga, A. J., García, F. J., & Carabias, J. (2006). Authoring Adaptive Learning Designs Using IMS LD. In V. P. Wade, H. Ashman, & B. Smyth (Ed.), *International Conference on Adaptive Hypermedia and Adaptive Web-Based Systems AH 2006.Lecture Notes in Computer Science, vol 4018*, pp. 31-40. Springer, Berlin, Heidelberg. doi:10.1007/11768012_5

Brusilovsky, P. (2003). Developing adaptive educational hypermedia systems: From design models to authoring tools. In T. Murray, S. Blessing, & S. Ainsworth (Eds.), *Authoring tools for advanced technology Learning Environments* (pp. 377-409). Springer, Dordrecht. doi:10.1007/978-94-017-0819-7_13

Brusilovsky, P. (2004). KnowledgeTree: A distributed architecture for adaptive e-learning. *Proceedings of the 13th international World Wide Web conference on Alternate track papers & posters, New York, NY, USA — May 19 - 21, 2004* (pp. 104-113). ACM. doi:10.1145/1013367.1013386

Burgos, D., Moreno-Ger, P., Sierra, J. L., Fernández-Manjón, B., Specht, M., & Koper., R. (2008). Building adaptive game-based learning resources: The integration of IMS Learning Design and. *Simulation & Gaming, 39*(3), 414-431. doi:10.1177/1046878108319595

Carchiolo, V., Longheu, A., Malgeri, M., & Mangioni, G. (2007). An Architecture to Support Adaptive E-Learning. *IJCSNS International Journal of Computer Science and Network Security, 7*(1), 166-178. Retrieved December 20, 2019, from http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.96.6811&rep=rep1&type=pdf

Carver Jr, M. C., Howard, R. A., & Lavelle, E. (1996). Enhancing student learning by incorporating learning styles into adaptive hypermedia. *Proceedings of World Conference on Educational Multimedia and Hypermedia & World Conference on Educational Telecommunications, EdMedia + Innovate Learning, Jun 17 1996, Boston MA* (pp. 28-32). Association for the Advancement of Computing in Education (AACE). doi:10.1109/13.746332

Chang, C.-H., Lin, Y.-T., & Wu, J.-L. (2010). Adaptive video learning by the interactive e-partner. *Third IEEE International Conference on Digital Game and Intelligent Toy Enhanced Learning, 12-16 April 2010, Kaohsiung, Taiwan* (pp. 207-209). IEEE. doi:10.1109/DIGITEL.2010.54

Chatti, M. A., Dyckhoff, A. L., Schroeder, U., & Thüs, H. (2013). A reference model for learning analytics. *International Journal of Technology Enhanced Learning, 4*(5-6), 318-331. Retrieved December 21, 2019, from https://pdfs.semanticscholar.org/63f9/71de987f6659cb9b6906ae3b8d21b030d69f.pdf

Chen, M., Chiang, F. K., Jiang, Y. N., & Yu, S. Q. (2017). A context-adaptive teacher training model in a ubiquitous learning environment. *Interactive Learning Environments, 25*(1), 113-126. doi:10.1080/10494820.2016.1143845

Daniel, J., Cano, E. V., & Cervera, M. G. (2015). The future of MOOCs: Adaptive learning or business model? *International Journal of Educational Technology in Higher Education, 12*(1), 64-73. doi:10.7238/rusc.v12i1.2475

Del Blanco, Á., Torrente, J., Moreno-Ger, P., & Fernández-Manjón, B. (2014). Enhancing Adaptive Learning and Assessment in Virtual Learning Environments with Educational Games. In *K-12 Education: Concepts, Methodologies, Tools, and Applications* (pp. 578-597). IGI Global. doi:10.4018/978-1-4666-4502-8.ch034

Dlamini, M., & Leung, W. S. (2018). Evaluating Machine Learning Techniques for Improved Adaptive Pedagogy. *2018 IST-Africa Week Conference (IST-Africa), 9-11 May 2018, Gaborone, Botswana* (p. 1). IEEE. Retrieved December 22, 2019, from https://ieeexplore.ieee.org/abstract/document/8417291

Dunn, R. S., & Dunn, K. J. (1994). *Teaching young children through their individual learning styles: Practical approaches for grades K-2.* Pearson College Division.

El Bachari, E., Abdelwahed, E., & El Adnani, M. (2010). Design of an adaptive e-learning model based on learner's personality. *Ubiquitous Computing and Communication Journal, 5*(3), 1-8. Retrieved December 21, 2019, from https://s3.amazonaws.com/academia.edu.documents/46326747/DESIGN_OF_AN_ADAPTIVE_E-LEARNING_MODEL_B20160607-13171-1jbbpcw.pdf?response-content-disposition=inline%3B%20filename%3DDESIGN_OF_AN_ADAPTIVE_E-LEARNING_MODEL_B.pdf&X-Amz-Algorithm=AWS4-HMAC-SHA256&X

El Said, G. R. (2019). Context-Aware Adaptive M-Learning: Implicit Indicators of Learning Performance, Perceived Usefulness, and Willingness to Use. *The ASEE Computers in Education (CoED) Journal*, *10*(3), 1-14. Retrieved December 22, 2019, from http://asee-coed.org/index.php/coed/article/view/417/El_Said_pdf

El-Bakry, H. M., Saleh, A. A., Asfour, T. T., & Mastorakis, N. (2011). A new adaptive e-learning model based on learner's styles. *Mathematical Methods & Techniques in Engineering and Environmental Science, Proceedings of the 13th WSEAS International Conference on Mathematical and Computational Methods in Science and Engineering (MACMESE'II)*, (pp. 440-448). Retrieved December 21, 2019, from https://s3.amazonaws.com/academia.edu.documents/45381510/A_new_adaptive_e-learning_model_based_on20160505-77349-1hy18gp.pdf?response-content-disposition=inline%3B%20filename%3DAdaptive_E-Learning_Based_on_Learners_St.pdf&X-Amz-Algorithm=AWS4-HMAC-SHA256&X

Essa, A. (2016). A possible future for next generation adaptive learning systems. *Smart Learning Environments, 3*(1), 16. Retrieved December 22, 2019, from https://slejournal.springeropen.com/articles/10.1186/s40561-016-0038-y

Fadhil, A., & Villafiorita, A. (2017). An adaptive learning with gamification & conversational UIs: The rise of CiboPoliBot. *Adjunct publication of the 25th conference on user modeling, adaptation and personalization, Bratislava, Slovakia, July 9 - 12, 2017* (pp. 408-412). ACM. doi:10.1145/3099023.3099112

Feng, M., Cui, W., & Wang, S. (2018). Adaptive learning goes to China. In R. C. Penstein (Ed.), *International Conference on Artificial Intelligence in Education, AIED 2018.Lecture Notes in Computer Science, vol 10948*, pp. 89-93. Springer, Cham. doi:10.1007/978-3-319-93846-2_17

Fidalgo-Blanco, Á., Sein-Echaluce, M. L., García-Peñalvo, F. J., & Conde-González, M. Á. (2016). iMOOC Platform: Adaptive MOOCs. *Third International Conference, LCT 2016, Held as Part of HCI International 2016, Toronto, ON, Canada, July 17-22, 2016* (pp. 380–390). Switzerland: Springer International Publishing. Retrieved December 22, 2019, from https://repositorio.grial.eu/bitstream/grial/650/1/amooc%20hci.pdf

Garcia-Cabot, A., de-Marcos, L., & Garcia-Lopez, E. (2015). An empirical study on m-learning adaptation: Learning performance and learning contexts. *Computers & Education, 82*(March), 450-459. doi:10.1016/j.compedu.2014.12.007

Hämäläinen, W., Kumpulainen, V., & Mozgovoy, M. (2015). Evaluation of clustering methods for adaptive learning systems. In I. E. Group (Ed.), *Artificial Intelligence Applications in Distance Education* (pp. 237-260). IGI Global. doi:10.4018/978-1-4666-6276-6.ch014

Hauger, D., & Köck, M. (2007). State of the Art of Adaptivity in E-Learning Platforms. *15th Workshop on Adaptivity and User Modeling in Interactive Systems, LWA*, (pp. 355-360). Retrieved December 21, 2019, from http://users.informatik.uni-halle.de/~lwa07/abis07/Hauger.pdf

Honey, P., & Mumford, A. (1992). *The manual of learning styles.* Peter Honey, Maidenhead.

Hsu, C.-K. (2015). Learning motivation and adaptive video caption filtering for EFL learners using handheld devices. *ReCALL, 27*(1), 84-103. doi:10.1017/S0958344014000214

Jiang, C., Zhang, H., Ren, Y., Han, Z., Chen, K.-C., & Hanzo, L. (2016). Machine learning paradigms for next-generation wireless networks. *IEEE Wireless Communications, 24*(2), 98-105. doi:10.1109/MWC.2016.1500356WC

Karampiperis, P., & Sampson, D. (2005). Adaptive learning resources sequencing in educational hypermedia systems. *Journal of Educational Technology & Society, 8*(4), 128-147. Retrieved December 21, 2019, from http://elibrary.lt/resursai/ Uzsienio%20leidiniai/IEEE/English/2006/Volume%208/Issue%204/Jets_v8i4_13.pdf

Kumar, A., Singh, N., & Ahuja, N. J. (2017). Learning styles based adaptive intelligent tutoring systems: Document analysis of articles published between 2001. and 2016. *International Journal of Cognitive Research in Science, Engineering and Education, 5*(2), 83-98. doi:10.5937/IJCRSEE1702083K

Laforcade, P., Loiseau, E., & Kacem, R. (2018). A Model-Driven Engineering Process to Support the Adaptive Generation of Learning Game Scenarios. *Proceedings of the 10th International Conference on Computer Supported Education CSEDU2018, 1*, pp. 67-77. doi:10.5220/0006686100670077

Liu, J.-H., Ruan, L.-X., & Zhou, Y.-Y. (2018). Application of Big Data on Self-adaptive Learning System for Foreign Language Writing. In N. Xiong, Z. Xiao, Z. Tong, J. Du, L. Wang, & M. Li (Ed.), *International Symposium on Computational Science and Computing, Advances in Computational Science and Computing. ISCSC 2018.Advances in Intelligent Systems and Computing, vol 877*, pp. 86-93. Springer, Cham. doi:10.1007/978-3-030-02116-0_11

Louhab, F. E., Bahnasse, A., Bensalah, F., Khiat, A., Khiat, Y., & Talea, M. (2019). Novel approach for adaptive flipped classroom based on learning management system. *Education and Information Technologies*, 1-19. doi:10.1007/s10639-019-09994-0

Magoulas, G., Papanikolaou, K., & Grigoriadou, M. (2003). Adaptive web-based learning: accommodating individual differences through system’s adaptation. *British Journal of Educational Technology, 34*(4), 511-527. doi:10.1111/1467-8535.00347

Meccawy, M., Blanchfield, P., Ashman, H., Brailsford, T., & Moore, A. (2008). Whurle 2.0: Adaptive learning meets web 2.0. In P. Dillenbourg, & M. Specht (Ed.), *European Conference on Technology Enhanced Learning (Times of Convergence. Technologies Across Learning Contexts. EC-TEL 2008).Lecture Notes in Computer Science, vol 5192*, pp. 274-279. Springer, Berlin, Heidelberg. doi:10.1007/978-3-540-87605-2_30

Moore, A. S., Martin, D., Brailsford, T., & Ashman, H. (2004). Links for learning: linking for an adaptive learning environment. *IASTED International Conference on Web-Based Education.* (p. 6 pp). IASTED. Retrieved December 21, 2019, from http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.581.9261&rep=rep1&type=pdf

Moore, A., Stewart, C. D., Zakaria, M. R., & Brailsford, T. J. (2003). WHURLE-an adaptive remote learning framework. *International conference on Engineering Education (ICEE-2003), July 21–25, 2003, Valencia, Spain* (pp. 22-26). CEE. Retrieved December 21, 2019, https://www.researchgate.net/profile/Adam_Moore/publication/200053112_WHURLE_-_an_adaptive_remote_learning_framework/links/0912f50cf153d80d36000000/WHURLE-an-adaptive-remote-learning-framework.pdf

Mulwa, C., Lawless, S., Sharp, M., Arnedillo-Sanchez, I., & Wade, V. (2010). Adaptive educational hypermedia systems in technology enhanced learning: a literature review. *Proceedings of the 2010 ACM conference on Information technology education, Midland, Michigan, USA — October 07 - 09, 2010* (pp. 73-84). ACM. doi:10.1145/1867651.1867672

Murray, M. C., & Pérez, J. (2015). Informing and Performing: A Study ComparingAdaptive Learning to Traditional Learning. *Informing Science: The International Journal of an Emerging Transdicipline, 18*, 111-125. Retrieved December 22, 2019, from https://digitalcommons.kennesaw.edu/cgi/viewcontent.cgi?article=4443&=&context=facpubs&=&sei-redir=1&referer=https%253A%252F%252Fscholar.google.com%252Fscholar%253Fas_ylo%253D2015%2526q%253Dadaptive%252Blearning%252Btools%2526hl%253Den%2526as_sdt%253D0%25

Nadii, C. Y., & Adi, B. T. (2018). Blended Learning: An Adaptive Learning Method of the New Age. *The Proceedings Book of The 8th Annual Basic Science International Conference 2018,* (pp. 451-457). Retrieved December 22, 2019, from https://www.researchgate.net/profile/Welayaturromadhona/publication/331471801_Identification_of_Groundwater_Potential_Zone_Using_VES_Geoelectrical_Method_A_Case_Study_in_Driyorejo_SubDistrict_Gresik_Regency/links/5c7aaa9b458515831f7de106/Identification-of

Nijhavan, H., & Brusilovsky, P. (2002). A Framework for Adaptive E-Learning Based on Distributed Re-usable Learning Activities. In M. Driscoll, & T. Reeves (Ed.), *Proceedings of E-Learn 2002--World Conference on E-Learning in Corporate, Government, Healthcare, and Higher Education, Montreal, Canada* (pp. 154-161). Association for the Advancement of Computing in Education (AACE). Retrieved December 20, 2019, from http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.445.1998&rep=rep1&type=pdf

Oliveira, M., Barreiras, A., Marcos, G., Ferreira, H., Azevedo, A., & de Carvalho, C. V. (2018). Collecting and Analysing Learners Data to Support the Adaptive Engine of OPERA, a Learning System for Mathematics. *Proceedings of the 9th International Conference on Computer Supported Education (CSEDU 2017).1*, pp. 631-638. SCITEPRESS – Science and Technology Publications. doi:10.5220/0006389806310638

Own, Z. (2010). The Application of an adaptive, web-based learning environment on Oxidation-reduction Reactions. *International Journal of Science and Mathematics Education, 8*(1), 1-23. doi:10.1007/s10763-004-8129-6

Paramythis, A., & Loidl-Reisinger, S. (2004). Adaptive Learning Environments and e-Learning Standards. *Electronic Journal on e-Learning, 2*(1), 181-194. Retrieved December 20, 2019, from https://files.eric.ed.gov/fulltext/EJ1099144.pdf

Pearson. (2016, May 16). *New Insights About 'Adaptive Learning': What It Is And How It Works.* Retrieved December 18, 2019, from Pearson: https://www.pearsonlearned.com/new-insights-about-adaptive-learning-what-it-is-and-how-it-works

Phillips, C. R., & Trainor, J. E. (2019). Accounting students' perceptions of adaptive learning applications. *ASBBS Proceedings, 26*, 425-425. Retrieved December 22, 2019, from https://search.proquest.com/openview/f3e4e8b00c408aa8ea404ce0ad536859/1?pq-origsite=gscholar&cbl=2030636

Raiyn, J. (2017). Toward Development Game-Based Adaptive Learning. *Journal of Education and Practice, 8*(28), 104-112. Retrieved December 22, 2019, from https://pdfs.semanticscholar.org/baa5/a3a0a045c7c08b0daf6f59ec178afba8d2aa.pdf

Rani, M., Nayak, R., & Vyas, O. P. (2015). An ontology-based adaptive personalized e-learning system, assisted by software agents on cloud storage. *Knowledge-Based Systems, 90*(December), 33-48. doi:10.1016/j.knosys.2015.10.002

Rodríguez, S., Palomino, C. G., Chamoso, P., Silveira, R. A., & Corchado, J. M. (2018). How to create an adaptive learning environment by means of virtual organizations. In L. Uden, D. Liberona, & J. Ristvej (Ed.), *International Workshop on Learning Technology for Education in Cloud, LTEC 2018.Communications in Computer and Information Science, vol 870*, pp. 199-212. Springer, Cham. doi:10.1007/978-3-319-95522-3_17

Saleh, A. A., El-Bakry, H. M., Asfour, T. T., & Mastorakis, N. (2010). Adaptive e-learning framework for digital design. *Proceedings of 9th WSEAS International Conference on Telecommunications and Informatics, Italy, 31*, pp. 176-182. Retrieved December 21, 2019, from http://www.wseas.us/e-library/conferences/2010/Catania/TELE-INFO/TELE-INFO-30.pdf

Sanrach, C., & Grandbastien, M. (2000). A Web-based authoring system to create adaptive learning systems. In P. Brusilovsky, O. Stock, & C. Strapparava (Ed.), *International Conference on Adaptive Hypermedia and Adaptive Web-Based Systems, AH 2000.Lecture Notes in Computer Science, vol 1892*, pp. 214-226. Springer, Berlin, Heidelberg. doi:10.1007/3-540-44595-1_20

Sein-Echaluce, M. L., Fidalgo-Blanco, Á., García-Peñalvo, F. J., & Conde, M. Á. (2016). iMOOC Platform: Adaptive MOOCs. In P. Zaphiris, & A. Ioannou (Ed.), *International Conference on Learning and Collaboration Technologies LCT 2016, .Lecture Notes in Computer Science, vol 9753, Part of HCI International 2016, Toronto, ON, Canada, July 17-22, 2016*, pp. 380-390. Springer, Cham. doi:10.1007/978-3-319-39483-1_35

Smartsparrow. (2018). *What is adaptive learning?* Retrieved December 18, 2019, from Smartsparrow: https://www.smartsparrow.com/what-is-adaptive-learning/

Squires, D. R. (2014). M-Learning: Implications in Learning Domain Specificities, Adaptive Learning, Feedback, Augmented Reality, and the Future of Online Learning. *Journal of Educational Technology, 11*(3), 1-8. Retrieved December 21, 2019, from https://files.eric.ed.gov/fulltext/EJ1098557.pdf

Thyagharajan, K. K., & Nayak, R. (2007). Adaptive content creation for personalized e-learning using web services. *Journal of Applied Sciences Research, 3*(9), 828-836. Retrieved December 20, 2019, from https://pdfs.semanticscholar.org/63dd/38c8f7794e6da3594b16503196dab626ebbe.pdf

Torrente, J., Moreno-Ger, P., & Fernandez-Manjon, B. (2008). Learning models for the integration of adaptive educational games in virtual learning environments. In Z. Pan, X. Zhang, A. El Rhalibi, W. Woo, & Y. Li (Ed.), *International Conference on Technologies for E-Learning and Digital Entertainment, Edutainment 2008.Lecture Notes in Computer Science, vol 5093*, pp. 463-474. Springer, Berlin, Heidelberg. doi:10.1007/978-3-540-69736-7_50

Torrente, J., Moreno-Ger, P., Fernández-Manjón, B., & Del Blanco, Á. (2009). Game-like simulations for online adaptive learning: A case study. In M. Chang, R. Kuo, C. G. Kinshuk, & M. Hirose (Ed.), *International Conference on Technologies for E-Learning and Digital Entertainment, Learning by Playing. Game-based Education System Design and Development. Edutainment 2009.Lecture Notes in Computer Science, vol 5670*, pp. 162-173. Springer, Berlin, Heidelberg. doi:10.1007/978-3-642-03364-3_21

Tseng, S.-S., Su, J.-M., Hwang, G.-J., Hwang, G.-H., Tsai, C.-C., & Tsai, C.-J. (2008). An Object-Oriented Course Framework for Developing Adaptive Learning Systems. *Journal of Educational Technology & Society, 11*(3), 171-191. Retrieved December 21, 2019, from https://pdfs.semanticscholar.org/63d6/c7118531b29fb67f7bebd6a6840c9d214d0c.pdf

Vesin, B., Mangaroska, K., & Giannakos, M. (2018). Learning in smart environments: user-centered design and analytics of an adaptive learning system. *Smart Learning Environments, 5*(1), 24. doi:10.1186/s40561-018-0071-0

Villesseche, J., Le Bohec, O., Quaireau, C., Nogues, J., Besnard, A.-L., Oriez, S., . . . Lavandier, K. (2019). Enhancing reading skills through adaptive e-learning. *Interactive Technology and Smart Education, 16*(1), 2-17. doi:10.1108/ITSE-07-2018-0047

Vincenza, C., Rosita, C. M., Daniela, F., Rosella, G., & Pierpaolo, V. (2016). The silent reading supported by adaptive learning technology: influence in the children outcomes. *Computers in Human Behavior, 55 Part B*(February), 1125-1130. doi:10.1016/j.chb.2014.09.053

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. doi:10.1016/j.eswa.2007.04.014

Weber, G., Kuhl, H.-C., & Weibelzahl, S. (2001). Developing adaptive internet based courses with the authoring system NetCoach. In S. Reich, M. M. Tzagarakis, & P. M. De Bra (Ed.), *Workshop on Adaptive Hypermedia, Hypermedia: Openness, Structural Awareness, and Adaptivity. AH 2001.Lecture Notes in Computer Science, vol 2266*, pp. 226-238. Springer, Berlin, Heidelberg. doi:10.1007/3-540-45844-1_22

Wolf, C. (2002). iWeaver: towards an interactive web-based adaptive learning environment to address individual learning styles. *European Journal of Open, Distance and E-Learning, 5*(2), 14 pp. Retrieved December 19, 2019, from https://www.eurodl.org/materials/contrib/2002/2HTML/iWeaver.pdf

Rabee Alqahtani
University of Wollongong
rabee3_1983@hotmail.com

Narentheren Kaliappen
Universiti Utara Malaysia
narentheren@uum.edu.my

Mohammed Alqahtani
University of Bisha