



Learning Pattern Discovery: Impact of User-Centric Design Approach towards Enhancement of E-learning Systems

Kingsley Okoye

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LEARNING PATTERN DISCOVERY: IMPACT OF USER-CENTRIC DESIGN APPROACH TOWARDS ENHANCEMENT OF E-LEARNING SYSTEMS*

KINGSLEY OKOYE

School of Architecture Computing and Engineering

University of East London

Docklands Campus, 4-6 University Way, E16 2RD, London, UK

u0926644@uel.ac.uk

Abstract

Purpose: The purpose of this paper is to propose a system for automated learning directed towards discovering and enhancement of the set of recurrent behaviours that can be found within a learning knowledge base and how they can be modelled to enable a more effective reasoning and tactical strategies for personalized adaptation and decision making.

Design/Methodology/Approach: The paper introduces a methodology that makes use of information readily available within a learning process to explore and analyse the data to obtain inference knowledge capable of enhancing individual learning performance. The author evaluated this approach through a user-centric design prototype and a model developed using Business Process Model Notations to corroborate the focus on improving performance of e-learning systems.

Findings: The technological response to satisfying the increasing demand for richer and more precise depiction of e-learning applications capable of providing platforms for pattern exploration where users can browse for knowledge they might consider as interesting; is by providing a personalized adaptive learning system for the users. Adoption of such technological developments will spark a great success for many learners and needed to provide continuous intelligent recommendation, guidance and feedbacks on learner's performance especially in achieving the overall learning objective.

Research limitations/implications: To meet the overall needs of intended users, there is requirement for e-learning systems to embody technologies that support learners in achieving their learning goals and this process don't happen automatically. Such process should take into account the fact that there is an additional task of matching these persons (user profiling) with solutions that best fits their particular learning needs (personalization).

Practical implications: The work in this paper considers the implication of the user centred design approach, and to this end, identify some of the common design problems with e-learning systems as means to revealing the implications for designers to stick to user-centric standards when developing automated learning systems in order to ensure learners satisfaction and reliability.

Originality/value: The approach and prototype described in this paper provides a more enhanced model for learning which is useful towards the development of e-learning systems that are more intelligent, predictive and robotically adaptive, which also aid in discovery of new learning patterns and enhancement of existing learning processes.

Keywords automated learning, pattern discovery, learning data, user profiles, e-learning system.

Paper type - [Research paper](#)

1. Introduction

E-learning systems should dynamically support different adaptive learning paths and contents to fit learner's diverse needs based on the users profile, background, learning styles and goals. This should take into account the fact that there is an additional task of matching these persons (user profiling) with solutions that best fits their particular learning needs (personalization). E-learning systems should enable users to create, share and collaboratively edit contents to suit their individual learning needs and styles. Studies have shown that challenges in current information-rich world is not only to make information available for learners at any time or in any form, but should essentially offer the right content to the right user and in the right format (Huang and Shiu, 2012; Yu *et al*, 2011). Recent challenges in literature shows that contemporary tools for collecting, modelling and analyzing of captured learners data are proving to be more complex in nature due to the increasing demand for systems capable of providing adaptive platform for pattern exploration where users can browse for knowledge they might consider as interesting and useful towards achieving their learning goal (Kriegel *et al*, 2007). This growing complexity is proved by the need for richer and more precise description of real-world objects and depiction of systems that allows for flexible exploration of learning patterns/data types. According to (Kriegel *et al*, 2007) future development will be to find richer patterns by developing systems which derive understandable patterns as well as making the discovered patterns explicable. The current innovations and challenges is what motivates software engineers in recent years to provide personalized adaptive e-learning systems which takes the advantage of the readily available learning data, as well as how to explore and analyse the captured data in order to provide inference knowledge capable of enhancing individual learning performance. With such system, learners can proceed at their own pace, get recommendations about what learning content best fits their learning needs, practice as much as they need on their own, and move ahead to greater challenges when motivated by interest, or data that

demonstrates they have mastered a skill. Personalised adaptive e-learning system is imperative and necessary to provide continuous intelligent recommendations, guidance and feedback on learner's performance.

The work in this paper focus on exploring some of the common design problems with e-learning systems performance and user requirements that needs to be solved in order to provide a user-centred experience, and effective use of such systems. We reveal the implications for developers to stick to certain design standards when developing e-learning applications and then propose an adaptive learning model to help address some of the design problems with present systems in order to improve learners engagement and outcome on performance. This paper further provide road map for future improvements. We look at the determining factors that impacts the development of an enhanced personalized adaptive learning systems based on three probes - Accessibility, Presentation Design, and Standard Compliance - bearing in mind that if e-learning systems developers do not take into consideration these factors along with the user experience, that most developed systems fail desolately and users tend to turn away from the readily available products looking for easier to use and intuitive e-learning platforms.

In this paper, we propose a learning model directed towards discovering and improvement of the set of recurrent behaviours that can be found within a learning executing environment. The proposed model is developed in order to address the problem of determining the presence of different learning patterns within a learning knowledge base and how they can be modelled to enable a more effective reasoning and tactical strategies for personalized learning adaptation and decision making. The standpoint for our approach is based on the following objectives to;

- Show how user data from learning processes can be extracted and transformed into useful harmonization for improved learning performance.
- Provide a more enhanced model for learning which is useful towards the development of e-learning systems that are more intelligent, predictive and robotically adaptive, which also aid in discovering of new and enhancement of existing learning processes/pattern.

The focus is on identifying data about different users within a learning knowledge base and enriching the information values of the resulting model based on the captured user profiles.

The rest of the paper is structured as follows; in the next sections, we identify some of the key design criteria considered necessary towards achieving performance and usability in e-learning systems, and then propose design principles that serves as an effective guide towards the design and development of a user-centric adaptive learning system. Next, we propose an automated learning system that is capable of detecting changing trends in learning behaviours and abilities of users in order to help address some of the design problems with present e-learning systems. In addition, we discuss the importance of the described design methods and stipulation towards the achievement of an enhanced user performance and effectiveness in e-learning systems. The last section discuss and analyse appropriate related works in relation to this area of research, followed by the conclusion and road map for future research.

2. E-Learning Design practice and Criteria.

In this section, we determine some of the key design criteria necessary towards achieving performance and usability in e-learning systems, and then propose some design principles that serves as a working guide towards the design and development of user-centric adaptive e-learning systems.

2.1. Presentation Design

The quality of the components embedded in e-learning system is highly influenced by the way the contents are designed and presented (Leacock and Nesbit, 2007). Design presentation is relevant to all expository media with regard to text, images, sounds, videos, graphics and animations. Presentations that are very high in quality usability standard is expected to incorporates aesthetical design values and development of learning information in formats that are efficient and consistent with the fundamental essence of research and knowledge of educational multimedia products, by demonstrating standards in the development of e-learning applications. The principles about clear and concise expression for data graphics and writing style recommended by Tufte back in 90's represents the significance of the presentation design subject in the design of e-learning products (Tufte, 1997). Further, findings in support of Tufte design presentation results from the provenance of the abstract quality of the

human working memory as expressed by Mayer’s principle for developing educational multimedia products (Mayer and Moreno, 2003).

Mayer & Moreno, described presentation design as being a basic and intrinsic element in the process of learning due to interactions among the components of the systems designed for learning, and that these components cannot be impaired without affecting the purpose of the system. To this end, an effective presentation design is relevant to e-learning systems development and deployment, and is expected to efficiently contribute to intellectual and learning development. E-learning systems that have poor presentation design can result to extraneous information representation, which tends to reduce the quality and amount of information available for learners understanding. The International Standards Organisation (ISO) are engaged in developing a new standard called the ISO/AWI 23973 "Software ergonomics for World Wide Web user interfaces" (Bevan, 2005). The organization has been developing ergonomics standards for over 20 years in the field of human-system interaction. Most of the set standards contain general principles from which appropriate interfaces and procedures can be derived. Their purpose and strategy has been focus on the following aspects of user interface design; high-level design decisions and design strategy, content design, navigation and search as well as content presentation. To this end, we propose some design principles that can serves as an effective guide to minimizing the extraneous information content through;

- Clear and logical principles that suggest the excluding of materials that are irrelevant and are not needed by the intended users.
- Contiguity rule that suggests the presentation of components that the learners can manage and integrate rationally in time and space.
- Modality rules in addition to standard which suggests explanation of graphics or animations with some form of audio narration other than text only (Okoye *et al*, 2014a)

In Fig 1 we propose a design framework which is useful for software developers to guide their design towards an improved performance in e-learning applications.

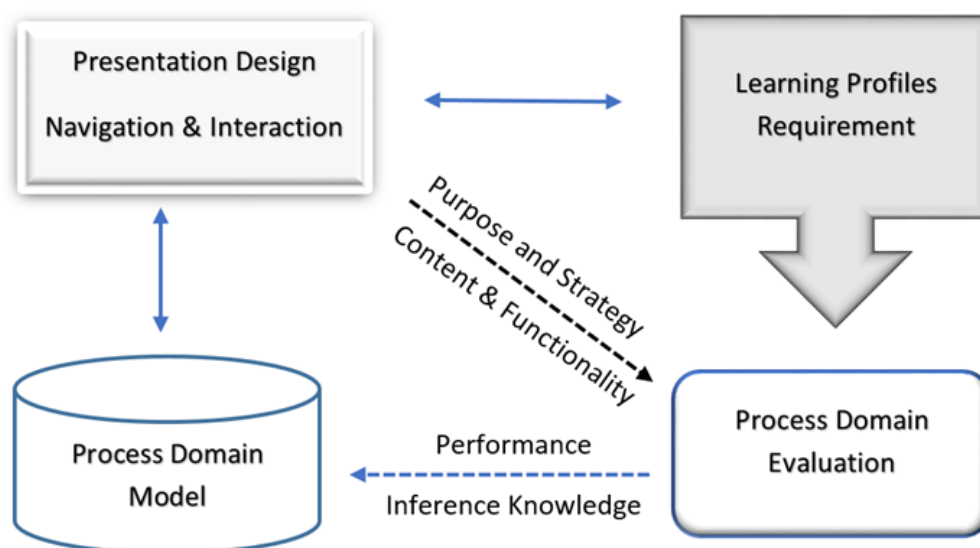


Fig 1. Presentation Design Framework for Human-System Interaction

There is strong evidence that presentations which combine graphics with text, most of the time tends to intuitively ease and improve learning when compared with text only designs (Saldaño *et al*, 2013). Such design approach has been adopted by the software developers community and has proven to be effective towards the design and development of personalized and adaptive e-learning systems. Designers have to understand the implication of graphical representation in presenting speech notions so prominent from their more self-explanatory use in presentation of useful data and informations intellectual maps consisting of nodes, connected by links captioned with relational terms serves as powerful projection or alternatives to presentations with text only. Such systems needs to be designed in a way that makes them intuitive or comprehensive enough to impact knowledge or intellectual, but concise enough as to be able to allow flexibility and consistency in usage. Designers

should put into consideration how the platforms they build make use of text, sounds, conceptual diagrams, videos, animations etc. to effectively communicate their ideas or purpose to the intended users. We concur that presentation design that is flexible and consistent in usage, clear, concise, aesthetically pleasing, and which effectively integrates the various components of multimedia (text, images, graphics, sounds and videos) in formats that are suitable for the learning platforms can profitably provide an exhaustive and efficient application that is convenient for learning. Take for instance, rather than explaining how to clone a computer system by text only, why not have a step by step animation that shows how all the components fit together? and why not enable the user to click on the animated components to find out their part names and components? Similarly, an electronic encyclopedia might use many words to describe the sound that parrots make without really communicating those sounds, but enabling the user to click buttons to hear the sound is a huge benefit.

2.2. Accessibility Design

An indispensable user factor to consider when building e-learning systems is Accessibility. This is an important feature as learners will not be able to interact and complete tasks if they find it difficult to use the learning platform. Studies have shown that many e-learning applications do not provide fully sufficient level of accessibility to the users (Okoye *et al*, 2014a; Saldaño *et al*, 2013; Ali *et al*, 2008). These studies suggest that designing and developing a reasonably accessible e-learning application should be a priority to the designer as most learners are more satisfied with accessible platforms, attracts more users and are more likely to make return visits. The increase in dominance of various computer user interface results in conditions whereby learners with disabilities find it cumbersome to use and access the e-content. This group of learners may unintentionally be kept out from the feasible benefits of e-learning; if designers do not conform or put into consideration the problems with accessibility of design structure and outcome on performance. Take for instance, in a situation whereby users who are hard of hearing or deaf are being provided with e-learning materials that includes sound and does not contain texts or captions, or on the contrary, e-learning platforms that tends to exclude users with visual impairments by presenting the contents only in text or graphical forms without sound. According to Okoye *et al*, 2014a, provision of multiple ways to operate the technology and retrieve information so that users can choose alternatives based on their physical capabilities; is a great way to help ensure users have an improved accessibility and support for the learning technologies they use. For instance, ensuring keyboard accessibility and navigation, and providing accessible user interface control over the font size or page colours. This means that a good design practice should provide various or diverse means of accessing the learning resources.

The IMS Global Learning Consortium, 2006, provided guidelines for developing accessible e-learning platforms. They stated specifically that in dealing with e-learning applications, that these guidelines address accessibility issues in tests, interactive exercise, presentation tools, repositories, schedule organizers, threaded message boards and synchronous collaboration tools such as text chat and video conferencing. They proposed and recommended the use of standard technical formats in providing accessibility for e-learning applications, and that in providing accessibility; e-learning application developers requires a detailed understanding or knowledge about these standards and guidelines.

The International Standards Organisation (ISO) in part of ISO 9241 stated in (Bevan, 2005; Travis, 2009) contains general recommendations to improve the accessibility of learning technologies. The standard advocates a conceptual structure for accessibility that comes in four dimensions.

- Comprehension and specification of context to be used focusing on diversity of the users, the significance of objective, resources and interface features that impacts accessibility.
- Identify the accessibility requirements for users, knowing who the intended users are.
- Designing the model and algorithm for the product considering accessibility.
- Evaluating the accessibility of the user profile and design algorithm of the e-learning product with the intended user group.

From all standard arrangement, we see without doubt that e-learning application developers should bear in mind the need and requirements of the learners in their context goal when designing new learning products. The process involves putting into consideration the requirements and purpose for various users together; including users with diverse educational background, capabilities and disabilities. For instance, stipulating list of terms and definitions or summary of the necessary knowledge the learner must have already as to be able to accomplish their

learning purpose will make the e-learning product more accessible especially for first time users. Consideration of accessibility factors is a great way of increasing performance and usability of e-learning systems.

2.3. Standard and Compliance Design

In e-learning application design, standard promotes best practice and attitude. This is important especially for system performance and usability. Standards compliance is an essential prerequisite in the development stages of many software applications including e-learning applications. With the rapid advancement in learning technologies, it is appealing to state that there is a lot more to proper and ethical design than simply making use of standard. In spite of all ideas, usability standard is still critical and plays an essential role in the development of an intuitive e-learning system because the idea of compliance to standard;

- Makes sure consistency is achieved in automated learning systems. The approach provides measures that assist educational multimedia designers in avoiding noise and inconsistencies in user interfaces.
- Determines and make clear good design practice and routine.
- Helps the designers put into consideration the user profiles/requirements and the issues with design of graphical user interface.

Standards compliance is essential in solving some of the technical problems that affect the usability of e-learning products. According to (Travis, 2009), the International Standard Organization revealed comprehensive design principles that e-learning application developers must put into consideration to ensure the design of a usable learning platform. The standard consists of five scopes of concept;

- *Design decisions in addition to strategic designs* - what are the objectives of the e-learning system? how does it meet the need and requirement of its intended users? who are the intended learners and what are their objectives?
- *Design of content* - how is the content arranged, how would the system handle other issues like offering user-specific customization and privacy? what is the conceptual model of the system?
- *Search and navigation* - how would the content of the e-learning application be arranged so that learners can navigate the pages with ease? how can the learners search for information and contents of the e-learning product?
- *Presentation of the content* - how will the individual pages of the system be designed to enable learners in accessing and in making use of the content or information in the system? how will the links be designed?
- *General design view* - how will the developers design for an international audience? how will the system provide help? what is the download time? and is it acceptable?

To accomplish a high level of standard compliance towards solving these common problems; designers of e-learning applications should stick to all applicable standard and should make resources available for the intended users. The quality of how information is described and how it closely conform to the learning objective is critical in assisting learners advance from searching to discovering (Duval and Hodgins, 2006; Okoye et al, 2014b).

As the prevalence of e-learning applications continue to increase, the significance of a utilitarian, consistent and distributive information system continue to increase as well. The compliance to/and consistent use of standardized means of information representation will significantly increase the interactivity of e-learning depositories. With consistency of data and information, searching tends to be more precise and broad, organization of work becomes uniform and simple and there is also efficiency and accuracy in sharing of information. Compliance to standards is a good way of assessing the quality of e-learning systems, and designers must make sure that the combination of resources associated with the systems complies to the international standards and ascertain whether they have completed them with the applicable details and exactness; to allow others make use of the content in evaluating pertinence of the resulting systems.

To achieve effectiveness in design and development of e-learning systems, designers must stick to all relevant standards and specifications and should make available to the intended users the adequate and specific information required. Considering a situation whereby different caption is being provided for the same element eg. "goal" vs "objective" the points being raised is that these factors are critical and should be put into consideration by e-learning system developers during the development and evaluation of the system. When the determining factors (accessibility, presentation design and standard compliance) are narrowed down and put into consideration, it is

perceived to assist e-learning system designers to procure a fit for purpose user-centered planning and instructional design. We opine that designers must understand who their targeted audience are before moving into their design because many learners tends to turn away from some e-learning system if they find it difficult to intuitively use the platform. Undoubtedly, it may be seen that without clear standards by which usability in e-learning system is evaluated or measured, it will be difficult for designers to have knowledge on how to ensure the system will be comprehensively usable. We show that the adoption of clear, concise and visible guidelines will help both learners and designers in achieving an exhaustive, intuitive and effective use of e-learning technologies. Confidently, with the wide spread of the rate at which these evaluation standards would be adopted for design, we believe a large scale in proportionate of e-learning systems will exhibit rich usability and prove effective for learning.

3. User-Centric Design Model towards Enhancement of E-learning Systems and Application.

In this section of the paper, we propose a personalised adaptive learning system that is expected to collect routines and monitor changes in user's behaviour during a learning process. This is to determine which adaptations technique is suitable or may be required progressively through time. The learning model is expected to take into account users profile i.e. prior knowledge of learners background, learning behaviour and actions when using the system. The system should also be capable to dynamically update the representation of users performance taking into account the changing state of the learners and the variations in information that is relevant to each user considering the fact that there is an additional task of matching such learners (user profiles) with solutions that best fits their particular learning needs/requirement (Nganji *et al*, 2013). According to (Huang and Shiu, 2012; Nganji *et al*, 2011) the key challenge in developing automated system for learning is to build effectively represented user profile, learning styles and goal to help support reasoning about each learner. Our proposed model is an automated learning system that is capable of detecting changing trends in learning behaviours and abilities of individual users. The goal is to discover user interaction patterns, and respond by making decisions based on adaptive rules centred on captured user profiles.

The approach described in this paper focuses on the personalization of learning contents for the users which makes it possible to efficiently generate learning patterns based on the sequence or control-flow of each individual learning patterns/behaviours. The proposed approach uses process adaptation and discovery technique (Okoye *et al*, 2014b; Van der Aalst, 2011) to allow for traces not present in an existing learning path to be discovered, by using adaptive rules to generalise and allow for behaviours unrelated to the ones in the learning knowledge-base to be observed. According to (Han *et al*, 2008), Decision Tree Learning (DTL) is one of the scientifically proven technique that focuses on the classification of activities within a learning knowledge-base to predict patterns based on discoverable variables. The technique uses uncompromising response variable by classifying the learning activities and arranging the resulting value in form of a tree. The process consist of nodes that correspond to the possible values (leaf nodes) and the predictive variables (non-leaf nodes). Each learning concept (class) within the tree splits a given set of node into two or more subsets (sub-class). In essence, all instances within the tree are represented as a sub-class of a domain class referred to as *root node*. Based on the attribute of the activities within the domain class of the learning model tree, the learning concepts splits into ones that are leaf nodes and ones that are non-leaf node. Activities within the learning model are classified according to their corresponding attributes by ontologically describing the domain concepts, subclasses and the associated instances of the various learning concept class. Attributes may appear multiple times within the tree but not twice on the same path. This is aimed to handle values based on supposed semantics and to ensure that no class can have the same instances, as we show using the Knowledge Interchange Format (KIF) syntax below;

```
( forall ( ?X ?Y )
  ( => ( Class ?X ?Y )
    ( not ( Instance1 ?X ?Y )
      ( Instance2 ?X ?Y ) ) ) )
```

Decision tree learning uses a recursive top-down algorithm expressed in terms of the root node, r , and all associated instances to the root node. Where $x = \{r\}$, the set of nodes to be traversed (Van der Aalst, 2011; Han et al, 2008). Thus

```

IF  $x = \emptyset$  THEN END
Else
// Select and extract all the subset of  $x$  based on Entropy

 $X = X/\{x\}$ , where  $x \in X$  ( $x$  is a subset of  $X$  based on entropy)

// Check if splitting is possible?

IF  $X = \emptyset$  THEN END
Else
// create a set of Child nodes  $Y$  and Add  $Y$  to  $X$ 
 $Y = X \cup Y$ 
// and Connect  $x$  to all Child nodes in  $Y$ 
End
    
```

Fig 2(a). Decision Tree Learning Algorithm.

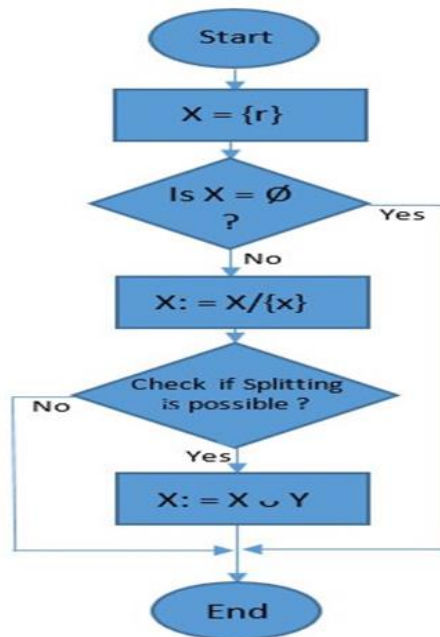


Fig 2(b). Top-down Flowchart of the Decision Tree Learning Algorithm

As shown in Fig 2(a) and 2(b), one of the basic function of the Decision Tree Learning algorithm is to help designers to define how the sequence flow of the learning activities split and also decide when to stop adding nodes.

This function is achieved by using the //Check if splitting is possible? IF $X: = \emptyset$ THEN END, Otherwise, the nodes continues to split through the enabling function; Else //create a set of Child nodes Y and Add Y to X , ($Y: = X \cup Y$), until the value of $X: = \emptyset$.

The algorithm is beneficial in improving the resulting nodes or to restrict the learning tree to a certain level. It is necessary in order to determine the variation of the smallest unit (*node*) within the learning activity sets by splitting the set of activities into subsets using the idea of *Entropy*

$$(E = \sum_{i=1}^k P_i \log_2 P_i). \quad (1)$$

The more we split a node the lower the entropy until the overall root node reaches a definition value equals to zero. Entropy (*eqn. 1*) provides itself as a measure that is used to define and quantify the diversity in a leaf node to determine if splitting is possible or needed. The decision tree learning algorithm is useful for Learning Pattern Discovery to help locate all decision points in the process model, paths taken, and the attributes of learning activity sets known at (or prior) the decision point. The observations are further enhanced by revealing the most likely underlying learning activity that is not invalidated by the next set of observations. The important aspect of such approach as described in this paper, is that we aim to analyse the sequence of activities to produce the behaviour of a particular learner (user profile) and can be used to extract, transform and load new and more enhanced system for learning capable of increasing learners performance or goal in an unswerving path as shown in Fig 3.

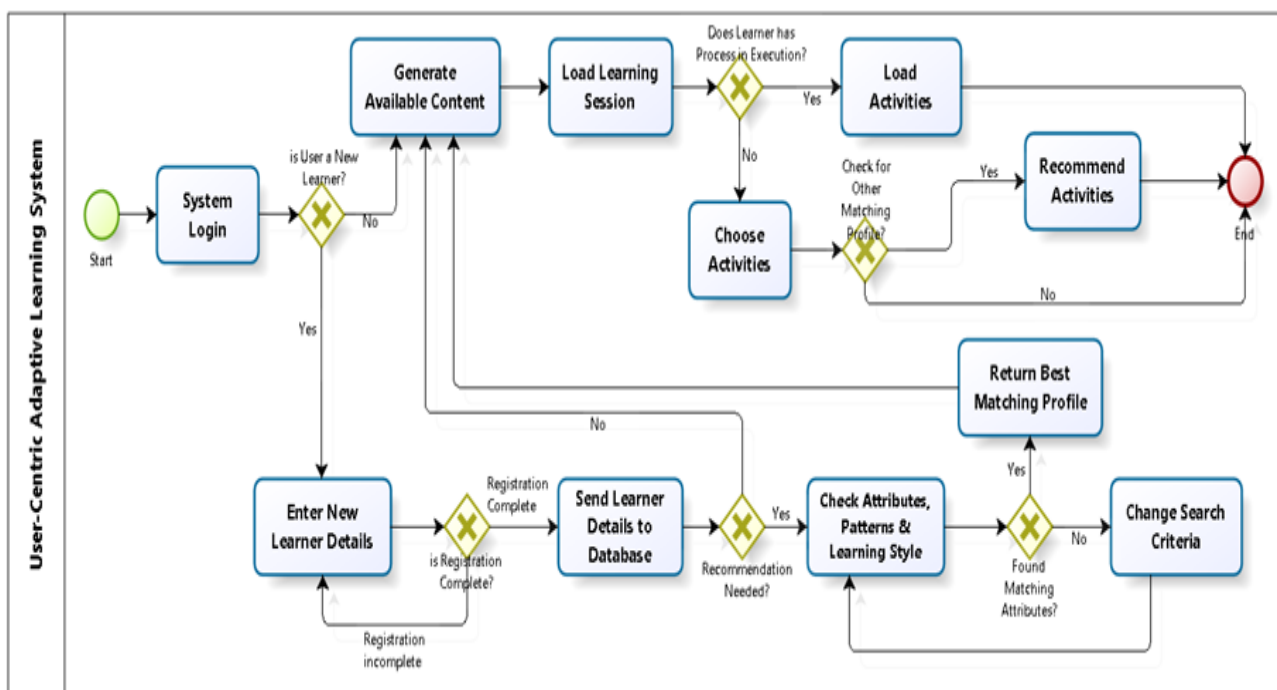


Fig. 3 Architectural Diagram of proposed Personalised Adaptive e-Learning System

In Fig. 3 we show that modelling of data about the learning process is an important tool towards unlocking the information value of the various activities within the learning knowledge-base, by way of finding useful and previously unknown links between the activity concepts. The motivational perspective is the search for explanatory and predictive patterns within the learning process especially with regards to the large volume of users that are involved. Martin and Majidian, 2013, refers to this tactics as Creative Knowledge Discovery which is concerned with the creation of new and effective patterns either by generalization of existing patterns or by analogy to patterns embedded in other domains. According to (Martin and Majidian, 2013) an important prerequisite for the approach is that we understand the relations within the learning data, thereby allowing us to

find paths that are hidden in the knowledge base and to extract novel patterns that can be utilized for subsequent modelling and enhancement of the learning system.

The ability to analyse the learning information and create concepts is fundamental to representation and modelling of the various learning activities and paths that users follow. This techniques can be applied towards automation of learning processes and the extraction of useful models, as we describe below:

- Create the Learning concepts that will be harmonized within the Learning Model.
- Provide Process Descriptions and pathways to accommodate all user Object and Data Types.
- Create the gateways and conditions for activity sequence flows to map the user objects with the Learning concepts.
- Check for Consistency of prediction, monitoring and recommendations for all defined Learners within the Model.

4. Related Work

There has been a combination of factors that affect learners experience with e-learning systems in recent years which includes the level of efficiency in use and effortlessness learning, lack of satisfaction with the system, confusing navigation, slow in loading and download time, frequency of errors and difficulty for first time users in learning the interface quickly. There has been remunerations both in theory and in practice towards developing standardized and strategic means of evaluation of e-learning applications to accord with the changes in demand for users. Accordingly, Okoye *et al*, 2014a proposed a theoretical method towards a rich and enhanced usability in e-contents and validated the technological impact by suggesting two types of methodology; one that suggests the removal of unnecessary and non-essential contents, new materials to be added to a content repository and/or re-use of already existing contents (the no-frills methodology) - and another which identifies the potential users as well as the content type, creates prototypes fitting the expected user's need and finally evaluates the developed product with test/heuristics to analyse its impact on the users (the Agile methodology).

There is evidence, that in the design of e-learning platforms that it is essential to define usability goals, and to specify the intended context of users and that the adoption of clear, visible and concise guidelines for assessing usability in e-learning products will help both learners and designers in achieving an intuitive, in-depth and effective use of learning technologies. The work in (Okoye *et al*, 2014a) put forward a novel framework for practice that enables a deeper understanding of accessibility requirements for dynamic web applications centred around a particular user group. Through evaluation of collected facts and analysis; the authors propose and implement solutions to the dynamic web accessibility issues by designing and deploying a software application, and its implementation for best practice that informs developers on how best to significantly and effectively approach the design of e-contents and applications with accessibility issues in mind as well as considering the user groups.

Niu and Kay, 2010, mentions that an important pragmatic concern is that it must be inexpensive to create e-learning systems and its presentations for different learners. The authors argue that e-learning platforms should dynamically update the representation of knowledge to take into account the changing state of the learners and changes in the information that is relevant to each user over time. They further suggest that such system is applicable and effective especially for users with learning difficulty; to manage their learning progress and also help improve their activity of daily life, thereby bridging the gap between such users and other learners seen as non-disabled.

In (Okoye *et al*, 2014b, 2015, 2016) the authors used the idea of process mining augmented with semantic reasoning and concepts to discover, monitor and improve the set of recurrent behaviours that can be found within learning processes. The authors utilised the technique in order to address the problem of determining the presence of different learning patterns within a learning knowledge-base. The study constructs a semantic learning process model; a User-Oriented Learning Knowledge-Base system(UOLKBs) that is of great impact and significance in this area to drive learning using process mining techniques to discover new rules through semantic reasoning, and adopting web languages such as Ontology Web Language and Semantic Web Rule Language. The result of the research shows that learning is the flow of activities within a Learning process Knowledge-Base (workflow), and being able to use Description Logics and programming languages to automatically compute the class hierarchy of learning activities is one of the major benefits of building personalized adaptive e-learning systems. Annotation properties are used to add information (Metadata – data about data) to the classes, individuals and object/data

properties within the learning knowledge base. The outcome is relevant in bridging the gap between the levels of learning for different users by providing them with the same learning opportunity; through a system that adaptively support the personalisation of contents based on data regarding the users learning behaviour or actions.

According to (Huang and Shiu, 2012) searching for suitable learning paths and content for achieving a learning goal is time consuming and troublesome especially on dynamic learning platforms. To tackle these problems, the authors propose a User-Centric Adaptive Learning System (UALS) that uses sequential pattern mining to construct adaptive learning paths based on users' collective intelligence and recorded events, and then employs Item Response Theory (IRT) with collaborative voting approach to estimate learners' abilities for recommending adaptive materials.

Process discovery, which lately has been seen as the most important and most visible intellectual challenge related to semantic mining of processes e.g learning process, aims to automatically construct useful models like Petri net or a BPMN model and describes causal dependencies between learning activities (Van der Aalst, 2011; Fahland and Van der Aalst, 2012). In principle, one could use process discovery to obtain a model that describes learning in reality. The second type of process mining is conformance checking where, an existing learning process model is compared with an event log of the same process to check if in reality it conforms to the resulting learning model (Adriansyah et al, 2011; Calders et al, 2009; Munoz-Gama and Carmona, 2011; Rozinat and Van der Aalst, 2008). Conformance check could imply that the model does not describe the executed learning process as observed in reality or is being executed in a different order. It could also mean that activities in the model are skipped in the log or that the log contains events not described by the learning model. Given this drawback, the last type of process mining; model enhancement comes into play. Van der Aalst et al, 2011, used the idea of an enhanced existing model to maintain compliance and to quantify deviations using information about the actual process recorded in the event logs from a given process.

According to Miani and Junior, 2015, most of the existing techniques for analysing large growing knowledge bases such as Learning process base focus on building algorithms to help the knowledge-base automatically or semi-automatically extend. The authors note that the use of an association rule mining algorithm to populate knowledge base and to improve the relations between the various users within the knowledge base is a useful approach considering the fact that most systems constructing large knowledge bases continuously grow, they do not contain all facts for each category, resulting in missing value dataset. To resolve this challenge, the authors developed a new parameter called Modified Support Calculation Measure which generates new and significant rules. They also developed a structure, based on pruning obvious item sets and generalized association rules which decreases the amount of discovered rules in order to help maintain the large growing knowledge base and rules. In Okoye et al, 2016, we mention that Association Rule Learning aims at finding rules that can be used to predict the value of some response variables that has been identified as being important but without focusing on a particular response variable. This association aims at creating rules of the form: If X Then Y, where X is often called the *antecedent* and Y the *consequent*. Thus, $X \Rightarrow Y$. According to the work in (Okoye et al, 2016) we show that this rule is similar and can be related to the Semantic Web Rule Language, SWRL, which is a useful language designed for process description especially to provide an improved learning ontology and enhancement of the learning process model. The SWRL rule has the form; $atom \wedge atom \text{ (antecedent)} \dots \rightarrow atom \wedge atom \text{ (consequent)}$. Association rule learning strongly supports the use of such metrics frequently expressed in the form of *support* and *confidence*. These expressions help in measurement of the strength of the association between learning objects. *Support* determines how often a rule is applicable to a given data set which means the fraction of instances for which both antecedent and consequent hold. Hence, a rule with high support is more useful than a rule with low support. A rule that has low support may occur simply by chance and is likely to be irrelevant from a learning perspective because it may not be profitable to monitor, recommend and promote learning activities or patterns.

Elhebir and Abraham, 2015, notes that pattern discovery algorithms uses statistical and machine-learning techniques to build models that predicts behaviour of captured data. According to the authors, one of the most pattern discovery techniques used to extract knowledge from pre-processed data is Classification. They observe that most of the existing classification algorithms attains good performance for specific problems but are not robust enough for all kinds of discovery problems. The authors (Elhebir and Abraham, 2015) propose that combination of multiple classifiers can be considered as a general solution for pattern discovery because they obtain better results compared to a single classifier as long as the components are independent or have diverse outputs. The approach compares the accuracy of ensemble models, which take advantage of groups of learners to

yield better results using the Meta Classifier (Staking and Voting) alongside other Base classifiers: Decision Tree algorithm, k-Nearest Neighbour, Naive Bayesian and BayesNet. Explicitly, the problems of modelling learning processes can be solved by transforming ontology population problem to a classification problem where, for each entity within the ontology, the concepts (classes) to which the entities belongs to have to be determined i.e, classified (d'Amato et al, 2008; Okoye et al, 2014b, 2016).

The approach described in this paper builds from the related works in several aspects. First, we provide an automated learning system that ensures performance through user-centric design. We focus on personalizing learning based on user's profile or learning behaviour as opposed to most existing systems that provide guidance based on views of designers or experts. Second, the paper also support e-learning process bearing in mind the determining design factors that allows for usability and performance from three perspectives; presentation design, accessibility and standard compliance. Third, this work is not only intended to ensure learner's ability to learn or meet their learning needs but is expected to be useful in providing learning path and guidance based on individual differences. This is achieved by collecting user's initial capabilities and preferences on interaction and then determine which adaptations or further assistive measures are best suited or may be required through time. We achieve this by proposing a User-centered learning model which is useful in design, discovering and enhancement of the set of recurrent behaviours that can be found within a learning knowledge base and how they can be modelled to enable a more effective reasoning and tactical strategies for personalized adaptation and decision making.

5. Conclusion and Future Work

The work in this paper reveals some of the key design criteria necessary towards achieving a user-centered experience in e-learning systems and provide measures that are of relative importance when considering the performance and usability of e-learning systems. The work shows that the technological response to satisfying the increasing learning demands is by providing a personalized adaptive learning system for the users. To this effect, adoption of the new technological developments will spark a great success for many learners. It is therefore, of great significance for e-learning system developers to maintain a higher degree of performance and usability design standards that is centered around the intended users, when developing their systems in order to ensure learners satisfaction and reliability. To prove the mentioned practice, we propose an adaptive e-learning model to help address some of the design problems with present e-learning systems in order to improve learners engagement and outcome on performance. This is required and necessary to provide continuous intelligent recommendation, guidance and feedbacks on learner's performance as well as in achieving the overall learning objective.

Future work could focus on extending the approach described in this paper by applying the technique to a different process domain. This will help in analyzing the streams of activities that are involved in the process in order to produce inference knowledge, which can then be used to load a more enhanced model within the process domain area.

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About the author



KINGSLEY OKOYE, received his Bachelors degree in Computer Science from Nnamdi Azikiwe University, Nigeria in 2007, a Masters in Technology Management at the University of East London, UK in 2011. He is currently a PhD candidate in Software Engineering at the School of Architecture Computing and Engineering, University of East London. He is MIET member at the Institution of Engineering and Technology, UK. Graduate Member at the Institute of Electrical and Electronics Engineers, IEEE. His Research interests includes Learning Process Automation, Process Mining, Semantic Technologies, Process Modelling, Internet Applications and Ontology. Kingsley can be contacted via his e-mail; u0926644@uel.ac.uk.