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A Framework of Concept Complexity-based Personalized E-learning System

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Authors' contributions

This work was carried out in collaboration between all authors. Authors ATA and OAO designed the study model and carried out all laboratory work, revised and edited the manuscript. Authors OAO, SVO and BBA wrote the first draft of the manuscript and carried out literature review. All authors read and approved the final manuscript.

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ABSTRACT

Personalized learning allows individual learner to be taught and assessed in ways that are appropriate and comfortable for that learner. It allows teaching to be carried out in several ways in order to increase the scope of learning. Personalized learning is an important aspect of e-learning systems because no particular learning path will be adequate for all learners. Hence, this research paper presents a framework of concept complexity-based personalized e-learning system. Some existing works on personalized e-learning have dealt with learner's preference without considering the complexity/difficulty level of the course concepts and the degree of relationship that exist between the various course concepts. Other works also prevented the students from gaining the freedom to rearrange the course concepts in the most individually preferred order. Hence, this affects the learning ability and the overall performance of learners. Therefore, by allowing the learners to know the complexity/difficulty level of each of the course concepts and giving learners the freedom to rearrange the course concepts in the order they will like to learn will not only improve the learning ability of learners but will also give personalized e-learning an edge.

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1. INTRODUCTION

E-learning is commonly referred to as the intentional use of networked information and communications technology in teaching and learning. A number of terms are used to describe this mode of teaching and learning. They include online learning, virtual learning, distributed learning, network and web-based learning. The letter "e" in e-learning stands for the word "electronic", e-learning would incorporate all educational activities that are carried out by individuals or groups working online or offline, and synchronously or asynchronously via networked or standalone computers and other electronic devices [1]. According to the National Educational Technology Plan developed by the US Department of Education, personalized learning is defined as adjusting the pace (individualization), adjusting the approach (differentiation), and connecting to the learner's interests and experiences [1]. Personalization is broader than just individualization or differentiation in that it affords the learner a degree of choice about what is learned, when it is learned and how it is learned. The rhetoric is often phrased in terms of learning 'anytime, anywhere or any place'. This may not indicate unlimited choice since learners will still have targets to be met.

E-Learning exploits interactive technologies and communication systems to improve the learning experience. It has the potential to transform the way we teach and learns across the board. It can raise standards and widen participation in lifelong learning. It cannot replace teachers and lecturers, but alongside existing methods, it can enhance the quality and reach of their teaching [2]. E-Learning is fundamentally about learning and not about technology. Strategic development of e-learning should be based on the needs and demands of learners and the quality of their educational experience [2]. Personalization refers to instruction that is paced to learning needs (i.e. individualized), tailored to learning preferences (i.e. differentiated), and tailored to the specific interests of different learners. In an environment that is fully personalized, the learning objectives and content, as well as the method and pace, may all vary [3].

2. RELATED WORKS

In [4], an Ontology Based Personalization System for e-learning was proposed. The research work was motivated due to the fact that learning is time bound; otherwise, one might learn an aspect of a particular field forever. Hence learning should be guided by time. In [5], a Neurofuzzy-based Model for Active and Collaborative Online Learning was proposed. This paper proposed a new e-learning model that adapts instructional content to individual learning styles and preferences; new assessment parameters into the e-learning model for focused and improved study performance. This would allow for active participation and interaction on the part of learners engaging in the virtual educational community to take control of the learning. In [6], an Ontology Based Recommendation E-learning Management System was proposed. The research was motivated due to the need to develop a system that improves on the limitations of the existing ones. It was also motivated as a result of the omission of prerequisite knowledge of some courses by students in an academic environment and also by the dependence of students solely on the materials given to them by their tutors without considering other useful materials in a course. In [7], a Semantic Web to E-learning Content was proposed. With the development of the information technology and the wide use of the internet in the recent years, web has become an important learning platform. Its accessibility has made it a successful environment particularly for E-Learning education and gives rise to various methods of content delivering. Semantic Web is a web of data that are defined and linked in a way that enables machines to understand the semantics, or meaning, of information on the World Wide Web [7].

3. METHODOLOGY

Course Concept Complexity Level [CCCL] was used for this research work. The model includes two major parameters; Degree of Relationship between Course Concepts [DRCC] and Difficulty Level [DL]

The conditional probability of A given B is,

$$P(A|B) = \frac{P(A \cap B)}{P(B)} \tag{1}$$

Provided $P(B) \neq 0$

Where $P(A|B)$ denotes the probability of a particular Course Concept A having related sub-concepts in Course Concept B of the same Course, $P(A \cap B)$ represents the number of matched sub-concepts in A and B and, $P(B)$ denotes the number of sub-concepts in B.

Let d represents the degree of relationship between concepts of a particular course such that

$$d = \begin{cases} high, P(A|B) \geq 0.4 \\ moderate, P(A|B) \geq 0.1 \wedge P(A|B) < 0.4 \\ low, P(A|B) < 0.1 \end{cases} \quad (2)$$

The difficulty level parameter is associated with two sub-parameters

- Estimated time and
- Performance estimate.

[4] model was adopted for the computation of these two sub-parameters. The estimated time is used to determine the time spent by learners over a course concept c_i as illustrated below:

Let Ω be the actual time spent by a student on concept content such that:

$$\Omega = \mathrm{Q} - \mathrm{S} \quad (3)$$

Where Q is the timestamp when resuming for a concept evaluation and S is the timestamp when resuming for accessing a concept content. Let Y be the student time status for concept content such that,

$$\mathrm{Y} = \frac{\Omega}{\mathrm{T}} \quad (4)$$

where Ω is the actual time spent by a student on a concept content and T is the time given to go through concept content. We denote β be the actual time spent by a student during a concept evaluation, F be the time stamp after finishing a concept evaluation and Q is the time stamp when resuming for a concept evaluation.

$$\beta = \mathrm{F} - \mathrm{Q} \quad (5)$$

Let Z be the student time status for concept evaluation and t be the time given to answer set of questions about a concept, hence:

$$\mathrm{Z} = \frac{\beta}{t} \quad (6)$$

Performance estimate is used to determine the performance of learners in a course concept c_i as illustrated in equation 7.

The performance estimate is expressed as;

$$\gamma = \frac{c_a}{c_a + w_a} \quad (7)$$

where $c_a > 0 \vee w_a > 0$

Such that $c_a \subseteq [0 : N]$ and $w_a \subseteq [0 : N]$
N is the total number of questionnaire, c_a is the correct answer and, w_a is the wrong answer.

The difficulty level D includes average performance estimate θ

$$\theta = \frac{\sum_{i=1}^{n} \gamma_i}{n} \quad (8)$$

Therefore:

$$D = \frac{\sum_{i=1}^{n} \left(\frac{\theta}{Y_i + Z_i} \right)}{n} \quad (9)$$

n is the total number of learners. We denote L as the set of difficulty level D of Concepts in a Course C such that

$$L = \{ D_{C1} < D_{C2} < D_{C3} < \cdots < D_{Cn} \} \quad (10)$$

Function R is the reordering relativity rule between concepts such that the degree of relativity between concepts of a particular course will be; $R \Rightarrow High > Moderate > low$.

Therefore, the Complexity Level of set of Concepts of a particular Course is expressed as:

$$CCCL = \{ D_{C1} < \mathrm{D}_{C2}^{\mathrm{R_{C1}}} < \mathrm{D}_{C3}^{\mathrm{R_{C2}}} < \cdots < \mathrm{D}_{Cn}^{\mathrm{R_{Cn-1}}} \} \quad (11)$$

Therefore, for any D_{C2} its' $R_{C1} > D_{C3}(R_{C1})$ and for any D_{C3} its $R_{C2} > D_{C4}(R_{C2})$. This implies that for any D_{Ci} its' $R_{Ci-1} > D_{Ci+1}(R_{Ci-1})$ where $i > 1$. In order words concept ranked at D_{C2} will have higher degree relationship (R_{C1}) value to D_{C1} than concept ranked at D_{C3} to D_{C1}, likewise D_{C3} has higher degree of relationship to D_{C2} as compared to D_{C4}. In the case where two concepts have equal degree of relationship to a particular concept ahead of them, the concept with lower difficulty level will gain priority over the other.

4. CONCEPTUAL FRAMEWORK

The conceptual framework of the proposed personalized e-learning system is shown in

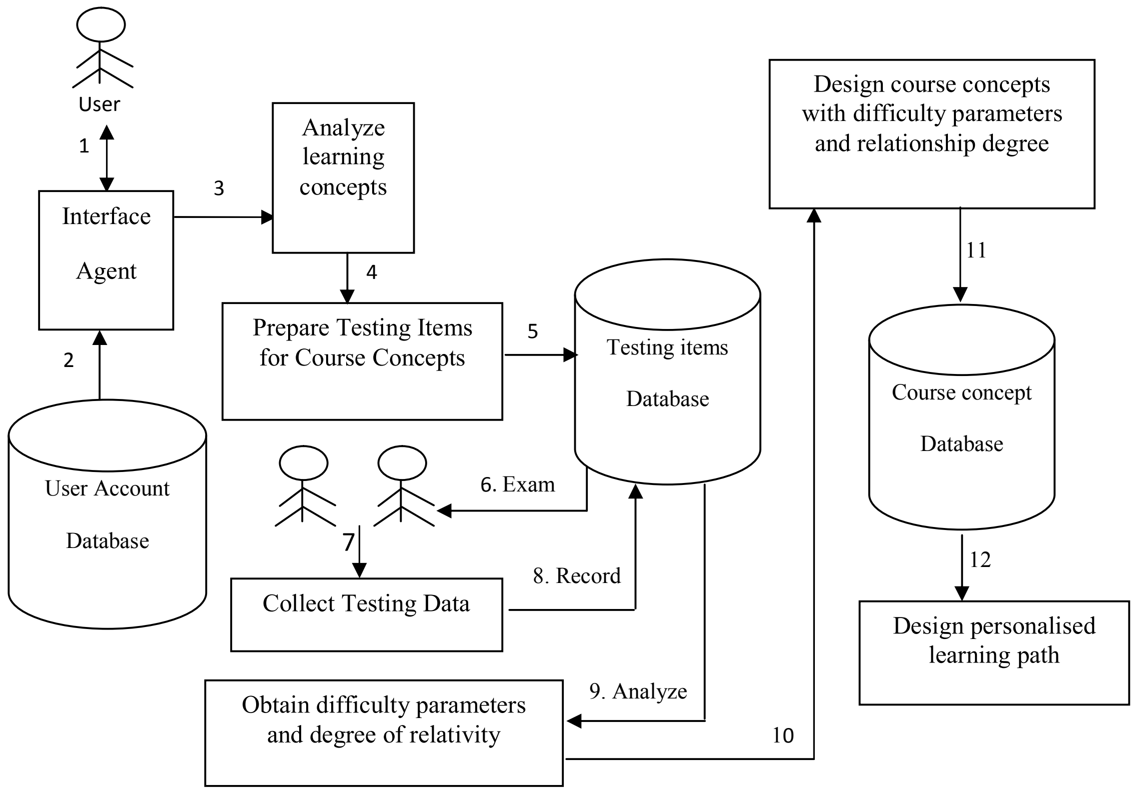

Fig. 1. Conceptual framework of the personalized E-learning system

Fig. 1. It consists of various components which interact together to present personalized course concepts to meet the learning ability of individual learners. The interface agent provides a friendly interactive medium for interacting with the users and it serves as an information channel for communicating with the system. It provides the functions of account management, authorization and query searching. The user account database stores the users profile such as the names, sex, age, and status. The testing items database records all the questions contained in the questionnaires, the objective questions that are used for evaluating the performance of the system and users responses to questionnaires. The course concept database contains the different course concepts and their respective complexity/difficulty parameters and the degree of relationships that exist between the various course concepts.

5. SAMPLE APPROACH TO CONCEPT LEARNING PATH

The Course Concept Complexity Level [CCCL] modeling process is a detailed course concept design procedure to establish the difficulty parameters of course concepts, the degrees of relationship between course concepts and to generate the personalized learning path for individual learners. The first step is to choose a particular learning material/course, for this purpose we chose computer networks as the course to be studied by the learners. After which we identified some concepts/topics in computer networks. The learning concepts are the various topics in computer networks with detailed note on each of the topics that the individual learners are expected to study very well during the learning process and these concepts include: introduction to computer networks (I), networks physical topology (N), switching (S), OSI reference model (O) and, transmission media (T). The next step is for the course concept experts/lecturers to prepare detailed note and the corresponding testing items/ questions on each of the course concepts. Test questions are drawn by the course concept experts based on the learning concepts. These test questions are administered to the individual learners, their respective responses are collected and analyzed in order to determine the difficulty parameters of the course concepts and the degree of relationships that exist between various course concepts.

Table 1. Overview of course concept complexity/difficulty level

Course concept and total sub concept	$\theta = \frac{\sum_{i=1}^{n} \Upsilon_i}{n}$	$D = \frac{\sum_{i=1}^{n}\left(\frac{\theta}{Y_{i+Z_i}}\right)}{n}$
$I: C_1\ (subC_1 = 5)$	3.3684	0.0259
$N: C_2\ (subC_2 = 4)$	2.7368	0.0269
$O: C_3\ (subC_3 = 6)$	3.3684	0.0274
$T: C_4\ (subC_4 = 7)$	3.0000	0.0287
$S: C_5\ (subC_5 = 5)$	2.8947	0.0416

Table 2. Sample approach for degree of relationship between course concepts

Concept	C_1	C_2	C_3	C_4	C_5	Total sub-concept
$\boldsymbol{C_1}$	1	0.4	0.2	0	0	**5**
$\boldsymbol{C_2}$	0.5	1	0.25	0	0.25	**4**
$\boldsymbol{C_3}$	0.16	0.16	1	0.3	0.16	**6**
$\boldsymbol{C_4}$	0	0	0.28	1	0.14	**7**
$\boldsymbol{C_5}$	0	0.2	0.2	0.2	1	**5**

Furthermore, an optimal personalized learning path for each individual learner is constructed. There are various assessments questions drawn on each of the course concepts to determine the learner' understanding after individual learner would have gainfully engaged in the learning process through successful authentication and verification log-in process. An experiment was carried out on 19 learners, Table 1 summarizes the outcome of the complexity/ difficulty levels during the learning process. The next step is to construct the degree of relationship between concepts based on their sub-concepts as shown in Table 2.

For example to determine the degree of how related (relationship) the sub-concept of $\boldsymbol{C_2}$ to C_1 sub-concept we consider numbers of related sub-concept in $\boldsymbol{C_2}$ that are close to $\boldsymbol{C_1}$. This was considered to be 2 out of 5 hence: $P(\boldsymbol{C_1}|\boldsymbol{C_2}) = \frac{P(\boldsymbol{C_1} \cap \boldsymbol{C_2})}{P(\boldsymbol{C_1})} = \frac{2}{5} = 0.4$. On the contrary the $P(\boldsymbol{C_2}|\boldsymbol{C_1}) = \frac{P(\boldsymbol{C_2} \cap \boldsymbol{C_1})}{P(\boldsymbol{C_2})} = \frac{2}{4} = 0.5$. Note that zero (0) value shows negligible relationship. From Table 1 we can deduce that the least difficulty level is I:$\boldsymbol{C_1}$ (Introduction to computer networks), thus it is ranked first. Other concepts will be ordered according to how high (close) their degree of relationship to C_1. According to Table 2, $N: C_2$ is the closest to C_1, C_3 and C_4 are both closer to C_2, however, C_3 will gain priority over C_4 because its difficulty level is lower. Consequently, the complexity level of the concept set will be ordered as: $CCCL = \{I < N < O < T < S\}$ which in turn represent a learning path presented to learners with the privilege of modification by the learners.

6. CONCLUSION

Personalized e-learning system is characterized by adapting learners learning preferences, styles, strategy and approach to meet appropriate instructional content in order to enable learners to actively engage in an online learning process. In this paper, a conceptual framework of concept complexity-based personalized e-learning system was presented, that takes into consideration the complexity/difficulty parameter and the degree of relationships that exist among the various course concepts of a particular course. These parameters are strategically used in the concept complexity based personalized e-learning system to construct an optimal individual learning path. In our future work we plan to evaluate the proposed framework with larger courseware and lager number of students in other to estimate the impact of the framework on learners' performance.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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