OPCOMITS: Developing an Adaptive and Intelligent Web Based Educational System Based on Concept Map Model

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ABSTRACT: Concept map model is a method that creates domain model by identifying the relationship between concepts in course contents. This study presents an adaptive intelligent web based learning system called OPCOMITS (Object Oriented Programming Tutor using Concept Map Model). OPCOMITS has a free domain model which can be regulated by an expert for any course. It uses concept map model to regulate the topic hierarchy, to measure the student's knowledge about a topic and to stimulate learning. By employing a concept map model, it structures the course and provides an environment in which the lecturer can arrange the chapters, topics, concepts and the prerequisite relationships between the concepts. Thus, it offers an adaptive and effective learning environment by measuring the level of student's knowledge about a topic, offering reinforcing feedback, diagnosing students' weaknesses and directing them to related chapter topic in the domain for revisions. To evaluate the effectiveness of the proposed approach an experiment has been conducted on Computer Programming department in Object Oriented Programming course. From the experimental results, it is found that OPCOMITS has contributed to the academic success of students using it and students have exhibited much better learning than those who have used a conventional e-learning system. Comput Appl Eng Educ 24:676–691, 2016; View this article online at wileyonlinelibrary.com/journal/cae; DOI 10.1002/cae.21740

Keywords: adaptive and intelligent tutoring system; object oriented programming course; concept map; web based learning

INTRODUCTION

The e-learning systems have a particular importance in learning process as they foster the learning process, make the course materials more accessible [1] and provide the learners with the feasibility of accessing learning program [2]. A significant aspect of e-learning system is that they can be effectively used to assess students' learning [3,4].

Until 1995, the use of computer applications in education did not go beyond allowing a static content to be shown to all the students. These e-learning systems were based on presenting the same content to every student without level adaptation and students were given a score based on their answers. There was also no guidance to maximize students' learning performances [5–8]. However, each student's learning rate, level of knowledge, interests, motivation, ability and characteristics differ from each other. With the recent developments in the Internet and computer technology, e-learning has become more adaptive and widespread in use. The purpose of adaptive e-learning systems is directed to increase students' learning performances by providing individual guidance, adapting the content to the students' level of knowledge and goals. An intelligent system such as web-based intelligent tutoring system (ITS) can provide such adaptation in content, feedback and assessment [9]. To support flexible individualized learning, *Adaptive and intelligent Web-based educational systems* (AIWBES) applications have been improved. These systems can be used as an alternative to the traditional e-learning systems which provide the same content to all users regardless of individual learning differences. However, the adaptive systems

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keep data on students' learning performances as well as the previous and current level of knowledge on a topic to customize learning [10]. After the emergence of the first AIWBES, intelligence and adaptation of new techniques have been developed to provide a better quality of learning content to students.

AIWBES combines hypermedia and user modeling for individualization in learning. These systems adapt the content of a hypermedia page to the student's learning history, goals and preferences in the user model with the *adaptive presentation and adaptive navigation support* [11–13]. However, representing the students' level of knowledge on a domain and individualization in learning is a challenging task because the domain model might contain multiple knowledge levels with different degrees of difficulty and prerequisite relationships among concepts. Therefore, using concept map approach in modeling the domain is an effective way of addressing this challenge [5,14]. Concept maps are used for different purpose. For instance, they can be used in design of complicated structures, communication of complex notions and provide support for reading comprehension and information management as well as encouragement for self-understanding [15]. They can also be used in clarifying the ambiguities in a problem. Hence, they allow a critical thinking process and provide alternative solutions to a problem. As shown in numerous studies [16–19], they also have a pivotal role in learning process.

When looked into the particular role that concept maps play in learning process, it can be seen that they maps have the ability to display any hierarchical learning content with a prerequisite relationship in a visual form that can easily be examined and shared, provide a way to organize learning content and identify students' learning problems. Constructing a concept map clarifies the domain model, provides a framework for making knowledge explicit and it can be used to identify student's misconceptions and hence provide feedback. Additionally, the maps can be used to assess student knowledge, however, less clear is how concept maps can be used in e-learning environments to regulate a course content and to customize it according to student's individual needs.

Over the last few years, with the integration of information technologies, the concept maps are used in several research studies on teaching and learning processes to clarify student misconceptions, assess and evaluate a student's understanding of a particular topic and provide proper guidance to improve learning [17,19,20–25]. All of these are difficult to draw from traditional assessment methods.

Concept maps involve systems that can be used to represent information and identify the interrelationships of the topics in ITS' domain model, it can also be used in student modeling to determine how much a student knows in the content knowledge and provide an accurate guidance for learning. Math-ITS [26] PTTD [5], CREKK-ILE [14] can be listed as some of the systems using concept maps in ITS environment.

MathITS is an Intelligent Tutoring System. It is designed with the aim of creating examples, questions and chapters. By using the concept effect table presented in the study, the model determines the extent of learning of the concepts by the students and calculates the level of difficulty of the questions in the system [26]. On the other hand, PTTD (Personalized Tutoring, Testing and Diagnosis Environment) is an extended project of ITES. It has a Java based interface and provides web based access. In this study, the prerequisite relationships among concepts are modeled and implemented to identify poorly-learned and well-learned concepts for individual students [5]. Lastly, the CREEK-ILE system, as a student model, is designed to support students' reasoning with concept maps. It is an intelligent tutoring system that uses concept maps and situation-based queries in combination. In this system, the concept map that the student creates is compared to the concept map prepared by the lecturer to identify student's shortcomings [14].

The above mentioned studies focus on the development of concept maps with no concerns of addressing the advantages of the systems in learning environments. However, it is well argued in the literature that the use of ITS in computer science education has a significant advantage compared to teacher-led classroom instruction and non-ITS computer-based instruction information [27]. Many adaptive tutoring systems for programming languages like PeRSIVA [28], ELM-ART [7], and C-Tutor [29] have implemented a student model that identifies the needs, preferences and knowledge level of each individual learner and interacts with students. However, they do not take into account how the level of a learner's knowledge of a concept can affect the level of her/his knowledge level of another related domain concept. To achieve this, prerequisite relationships between the concepts need to be considered and need to be incorporated into the learning materials' domain concepts. For the modeling domain with prerequisite relationships Bayesian Network networks have potential. For instance, a study similar to our research was conducted by Butz et al. [30]. Their research provides an alternative learning environment for computer programming course. The system, called BITS, was developed by using Bayesian networks. However, unlike our study, Butz et al. [30] propose a very simple directed acyclic graph to from prerequisite concepts in domain modelling. The system does not aspire to cover sophisticated and complicated topics and the dynamic relationships between concepts but it rather aims to address the basic topics of the course. On the other hand, in our study, the concept modeling is complex, establishes a relation and hierarchy between concepts and topics. It models the inner relationships within concepts. By using this structure, it guides students' learning and provides a pedagogical assistance on their level of learning. Aslo, Buzt et al. [30] study developed a framework for only computer programming course and cannot be used as an authoring tool for other courses whereas the system in this paper is user-friendly, flexible and can be adopted to other courses and learning needs.

When previous studies in literature are analyzed, although systems using concept map model detect the weaknesses of student, they do not offer alternative course content to the student or adapt the content according to the needs of student.

To sum up, the system proposed here is superior in terms of presenting navigation support based on the student's detected learning level for each concept, supplying content adaptation, and taking advantage of adaptive technologies via concept map model. Also, unlike previous research, the model we developed in this paper is domain independent, which means anyone not specialized in internet programming can easily use it. In this respect, it can be adapted for different courses. This paper presents OPCOMITS (Object Oriented Programming Tutor using Concept Map Model), an innovative integrated adaptive e-learning environment using concept map modeling to be used in Object Oriented Programming course as a complementary educational tool. Since we conducted this research in formal learning environment, unlike distance learning courses, our aim was to assess students' learning on a specific subject rather than grading. The system also operates on a concept-level of analysis and can assess even the sub-sections and concepts of a related topic. It can provide students with feedback and directs them to the related course material presented in this system.

In the first part of the study, we present the developed system and show how it is applied to the course. In the second part, we present the case study and discuss the pedagogical implication of this system as an educational tool on students' learning and success.

The rest of the paper is organized as follows: section The Structure of OPCOMITS presents OPCOMITS together with its structure, components and use of the system for students and experts; section Empirical Evaluation presents empirical evaluations obtained from the results of students using OPCOMITS and finally section Conclusions and Recommendations presents Conclusions and Recommendations for the future.

THE STRUCTURE OF OPCOMITS

In this section, all content details about web based Intelligent Tutoring System OPCOMITS, which can be used for any course as it benefits from concept maps at stages of subject presentation and detection of knowledge level, and its opportunities for the student are presented.

OPCOMITS was designed on .NET 2013 platform. The system was developed via ASP.NET, C#, SQL Server 2008, HTML-5, CSS-3, and Javascript frameworks (Jquery, JsPlump, etc.). OPCOMITS was available for students on http://www.opcomits.com/ web address. System registration is necessary for students and experts to use the system. There are two kinds of users in the system as shown in Figure 1. The user who logs in the system is directed to his/her own interface according to his/her own authority.

Experts logging into the system create course content and questions by using "Content Management System for Experts" module, add these course contents, questions and concepts in the concept map to the system and create domain model of OPCOMITS by identifying concept-subject, concept-question, concept-prerequisite concept relationships. Experts can also monitor the concept learning level and the achievement that students showed in chapters. In the implemented system, the student model is initiated with the information obtained when the student registers to the system. At this stage, personal information like username, name, surname, password, e-mail address, date of birth, gender and profile picture are gathered at the beginning for student modeling. When the student logs in, the system continues saves the course content and topic that student worked on. All information on student model is used in the decision-making process of the teaching model. Necessary guidance is provided based on learning level and the assessment and evaluation conducted at the end of each chapter.

OPCOMITS Structure can be examined under three segments. These are i) domain model, ii) content management system for experts, and iii) student model and tutoring model.

Domain Model—Content Management System for Experts

Domain maintains the curriculum of the subject, subject titles and necessary subject materials for studying [31]. All subjects in the interface are identified by the teacher. Teachers also specify the relationship or quality of the concept to be uploaded in the system. The system also forms the tutoring model and teachers then will be able to accept default tutoring strategies to form tutoring system [32].

The content management system for experts was designed to be used by experts to create domain model belonging to the OPCOMITS. Operations available for the expert in content management system are shown in Figure 2: Content Transactions, Concept Transactions and Question Transactions.

Content Operations. OPCOMITS web based education could be used for any courses and was designed as a completely dynamic system. First, the content operations are performed by the expert.

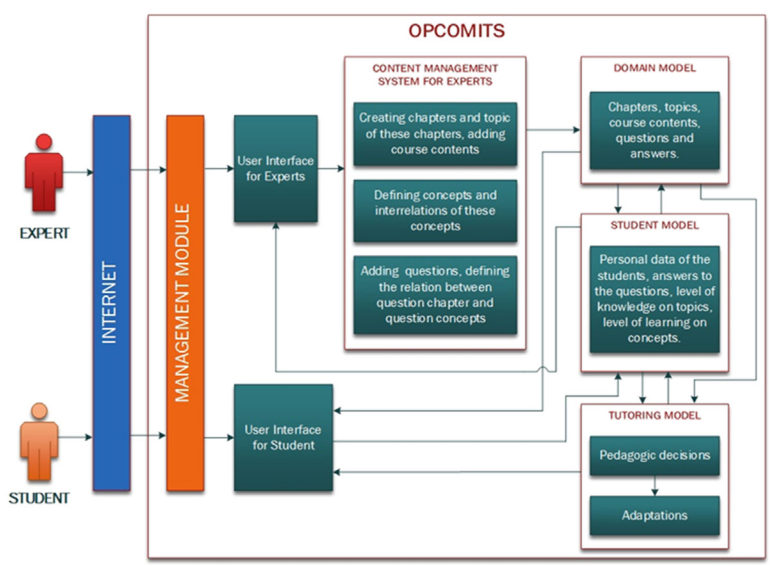

Figure 1 The architecture of OPCOMITS. [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com].

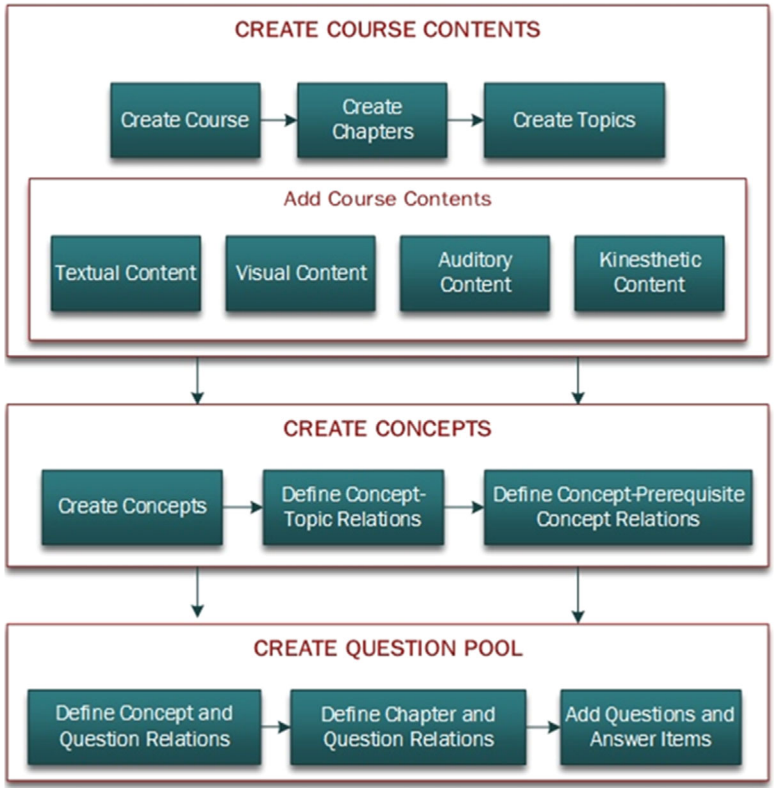

Figure 2 System flowchart of content management system for experts.[Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com].

The expert designs the course, chapters of the course and adds the topics to the chapters. Then different kinds of materials for these topics, such as visual content, textual content, auditory content, and kinesthetic content also can be added to the system by the expert. The expert can carry out these operations with the interfaces shown in Figure 3. In the application simulated for OPCOMITS, course texts, videos belonging to Object Oriented Programming, and flash animations which enable students to perform kinesthetic activities were added by the expert.

Concept Operations. After the content is created expert can start adding concepts with Content Management System for Experts and relates each concept with one or more topics. Concept–topic relation is the expression of what concepts in the system are correlated to which topic in the course content. This information is used to direct students to the topic content based on the result of the student assessment. The expert forms the concept map by identifying concept-prerequisite concept relationships between concepts and definition of the relationship. The concept map of Object Oriented Programming lesson performed as a sample on OPCOMITS by the expert is shown in Figure 4 and 14 concepts were added to the system in addition to those in Table 1. As shown in Figure 5; the expert adds the concepts to the system based on the identified concept map, and defines concept–topic relationships and concept-prerequisite concept relationships with the interface.

A concept can have one or more prerequisite concepts. A concept might also be a prerequisite concept of one or more concepts. This relationship between the concepts is specified on the table defined as Concept Effect Table (CET). For example, if Cj concept is a prerequisite concept for Ci concept, the relationship between them is defined as $Cj \rightarrow Ci$ and valued as $CET\,(Cj,Ci) = 1$. The list of concepts on OPCOMITS which were applied in tutoring for the Object Oriented Programming course is shown in Table 1. The relationship between these concepts is identified in Table 2. According to this table, because it is a prerequisite concept of C1, C2 is valued as $CET(C1,C2) = 1$. According to the table, because it is a prerequisite concept of C10, C12, C13, C14 concepts, C9 concept is valued as $CET(C9,C10) = 1$, $CET(C9, C12) = 1$, $CET(C9,C13) = 1$, $CET(C9,C14) = 1$ [5].

Question Operations. The last stage in the OPCOMITS Content Management System for Experts is adding questions and answer options to the system. This is carried out by the expert with the interface shown in Figure 6.

While creating questions, concept–question relation represents the level of correlation between the concepts and the questions prepared by the expert to determine the extent of learning the concepts. The expert, while preparing the questions, utilizes the table of Range of Relationships between the Concept and Question, indicated in Table 3. The value of relation of this relationship can be between 0.00 and 1.00 as shown in Table 3.

Based on the values in Table 3 as seen in Figure 7, if Question-1 has a B level relationship with C_1(Concept1), then the weight of this relationship has a numerical value of 0.75. In other words, Question-1 has a "strong" relationship with C_1 and this question tests the level of knowledge about concept C_1 only. It is not necessary to round up the level of relationship between the question and the concept to a weight of 1 because the weight is attained

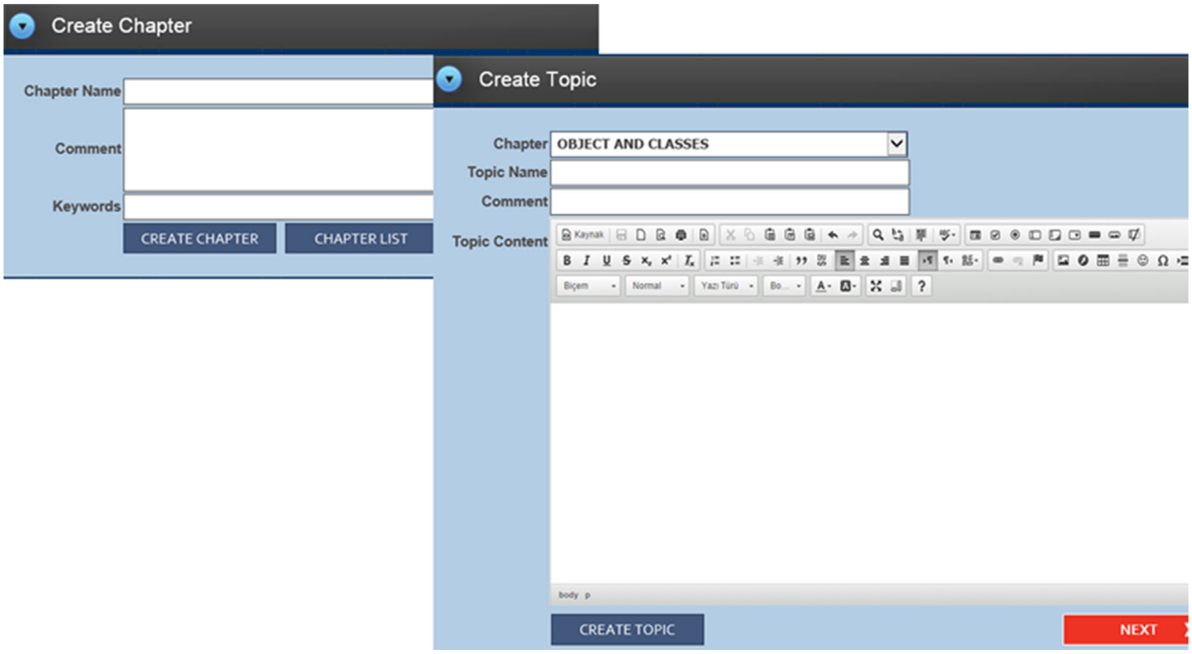

Figure 3 Creating chapters and topic screens for experts. [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com].

according to the difficulty level of the questions. '1' stands for the most difficult question whereas '0.25' stands for the easiest.

A question can measure learning level of more than one concept. Therefore, when a question is added, it could be related to more than one concept. However, while the question is related with one or more concepts, total relation value could be 1.00 at maximum. As seen in Figure 8, while Question-2 has a B level relationship to C_1 (Concept1), it has a D level relationship to C_2

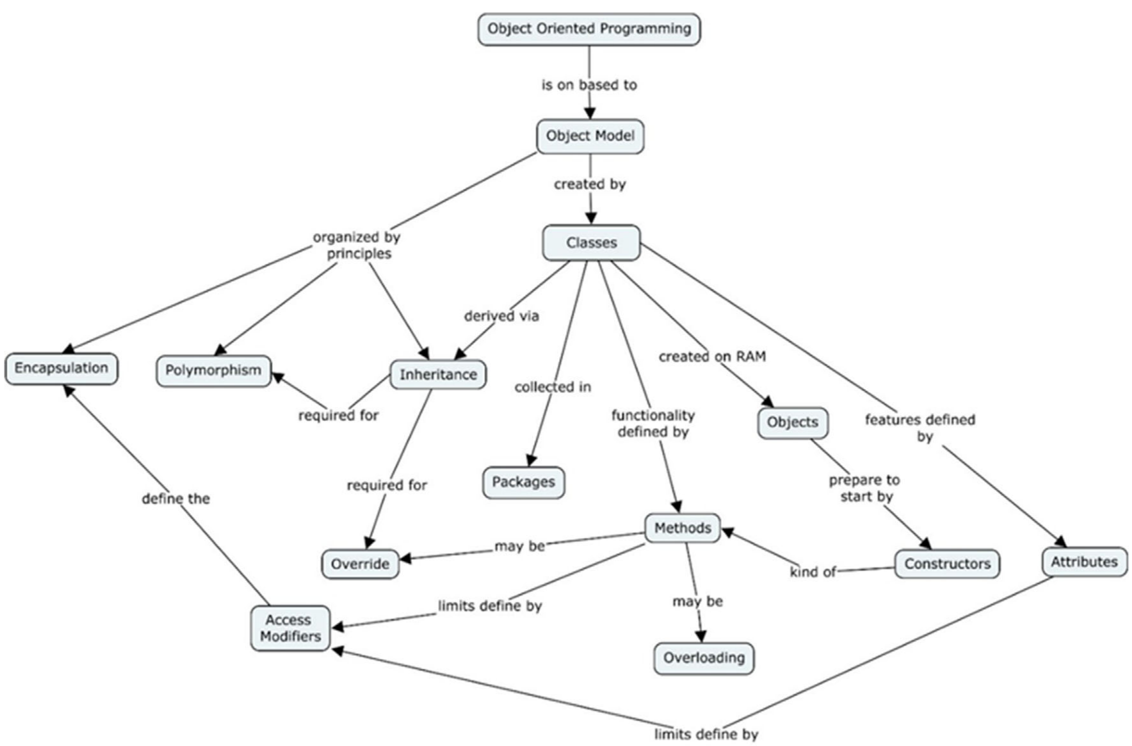

Figure 4 Concept map for object oriented programming course. [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com].

Table 1 List of Object Oriented Programming Tutoring Concepts

C1	Object oriented programming	C6	Inheritance	C11	Attributes
C2	Object model	C7	Polymorphism	C12	Overloading
C3	Classes	C8	Packages	C13	Overriding
C4	Objects	C9	Methods	C14	Access modifiers
C5	Encapsulation	C10	Constructors		

(Concept2). In this case, Question-2 has a "Strong" relationship to C_1 and a "Low Level" of relationship to C_2.

When the data in Table 4 is analyzed, we can see that the weight of the relationship of Q_1(Question-1) to C_1 (Concept1), is 0.75, and the other areas in the table are 0 since it has no relationship to other concepts. We can also see that Q_2(Question-2) has a relationship of 0.25 to Concept1, has a weight of relationship of 0.75 to C_2 (Concept2), and no relationship to other concepts. Lastly, the relationship level of Q3 (Question-3) with C1 (Concept-1) is valued as 1.00 and no relationship with other concepts is observed.

The definition of the values which will be in Concept-Pre Request Concept Effect Table and Concept-Question Relation Table on OPCOMITS via content management system by the expert constitutes the basic building blocks of OPCOMITS Tutoring model.

Tutoring Model

Tutoring model is the focal point of Intelligent Tutoring Systems to perform organized tutoring activities. To guide students during the learning process, it accepts effective tutoring strategies based on the student. It is the structure which decides how to continue tutoring by using the information in the information field and student model. It is the module which takes decisions such as starting subject for tutoring, continuing range, questions to be asked, error messages to be given, and whether any clues will be shown or not [31,33]. In this section, we first discuss, Concept Error Rate, which has a very important role on working OPCOMITS Tutoring Model, followed by Assessment and Guidance operations in the tutoring model, concluding with observations about OPCOMITS Adaptation.

Concept Error Rate. When a student completes the topics within a chapter, s/he answers the end-of-chapter questions. Based on the student's answers, an assessment is made by calculating the Concept Error Rate (CER) for each concept contained in the chapter. CER expresses the student's faulty learning level on a concept. It is calculated individually for each concept in the chapter according to Eq. (1) and it can be any value between 0–100. In the equation, the values of the relationship between question and concept are used. These values are defined by the experts and can be seen in Concept-Question Relationship Table 4. These values are used to form Concept – Question and Answer Table shown in Table 5. This table is utilized to identify CER value and to assess each student's answers. The purpose of this procedure is to monitor correct and/or incorrect answers for each student and to see which concepts' level of knowledge are tested with these questions.

In Eq. (1); TWCQ (the Total Weight value of Concept-Question relationship) is the total weight of relationship values of all questions related to concepts. On the other hand, TWEQ (the Total Weight of the Error of the concept-Question relationship) is the total weight of relationship values of the questions (related with any concept) answered incorrectly by student. An example with three questions which illustrates this calculation is shown in Table 5.

Table 5 contains the "Concept-Question and Answer Table" with three questions completed for a sample student assumed to answer Q_1(Question-1) Correctly, Q_2(Question-2) Incorrectly and Q_3(Question-3) Correctly. It could be seen in Table 5 that C1 (Concept-1) respectively has value of 0.75 with Q1(Question-1),0.25 with Q2(Question-2) and 1 with Q3(Question-3). According to these three questions, *TWCQ is calculated as 2* and *TWEQ is calculated as 0.25*.When these values are written in equation 1,value of CER for C1 is expressed as CER_{C1} is calculated as *12.5%*. The corresponding value of this figure in Table 6 means the Concept 1 is well learned.

$$\mathrm{CER}_{Cj} = \frac{\sum_{i=1}^{m} \mathrm{TWEQ}(C_j,Q_i)*100}{\sum_{i=1}^{m} \mathrm{TWCQ}(C_j,Q_i)} j = 1,2,3 \ldots n \quad (1)$$

Evaluation and Guidance. After CER values of concepts in OPCOMITS Tutoring Model are calculated, level of learning of

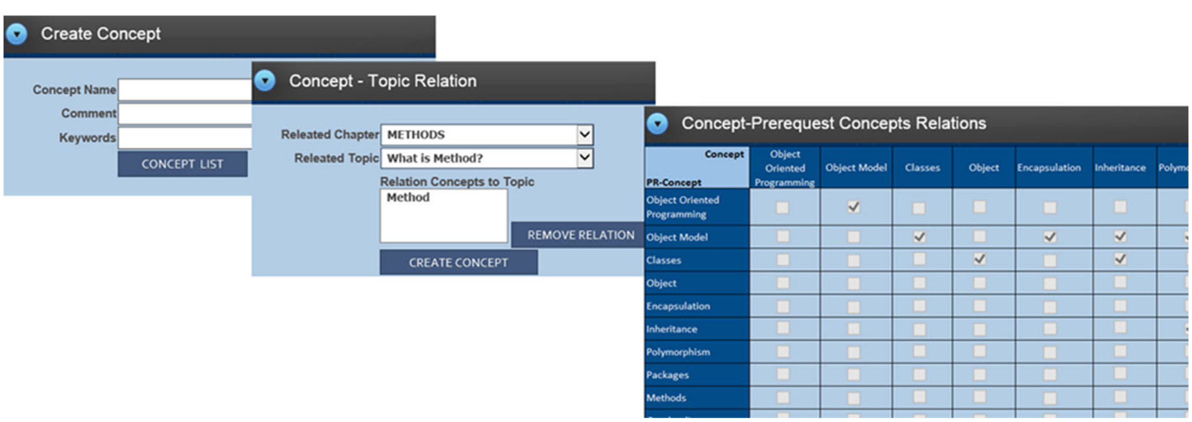

Figure 5 Creating concept and concept relations defining screens for experts. [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com].

Table 2 Concept Effect Table

	C													
PRC	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14
C1	0	1	0	0	0	0	0	0	0	0	0	0	0	0
C2	0	0	1	0	1	1	1	0	0	0	0	0	0	0
C3	0	0	0	1	0	1	0	1	1	0	1	0	0	0
C4	0	0	0	0	0	0	0	0	0	1	0	0	0	0
C5	0	0	0	0	0	0	0	0	0	0	0	0	0	1
C6	0	0	0	0	0	0	1	0	0	0	0	0	0	0
C7	0	0	0	0	0	0	0	0	0	0	0	0	1	0
C8	0	0	0	0	0	0	0	0	0	0	0	0	0	0
C9	0	0	0	0	0	0	0	0	0	1	0	1	1	1
C10	0	0	0	0	0	0	0	0	0	0	0	0	0	0
C11	0	0	0	0	0	0	0	0	0	0	0	0	0	1
C12	0	0	0	0	0	0	0	0	0	0	0	0	0	0
C13	0	0	0	0	0	0	0	0	0	0	0	0	0	0
C14	0	0	0	0	1	0	0	0	0	0	0	0	0	0

C, Concept; PRC, Pre-request concept.

each concept is identified and necessary guidance is provided. If the error rate of any concept is close to 0, then the level of learning of the topics on that concept is that much greater. Conversely, if the error rate of any concept is close to 100, then the level of learning of the topics on that concept is that much poorer. Four different stages defining concepts learning level over this value are shown in Table 6. As seen table, if CER value is between 0–25, the learning level of concept is defined as "Well learned", between 26 and 50 as "Learned", between 51 and 75 as "Poor," and between 76 and 100 as "Very Poor."

The student is accepted as unsuccessful in the concepts scored as "Poor" and "Very Poor" whereas for scores of "Learned" and "Well Learned" the students is recognized as successful. For example, in Table 5, when the data of student evaluated according to Eq. (1), findings are $CER_{C1} = 20\%$, $CER_{C2} = 75\%$, $CER_{C3} = 0\%$ and learning level is accepted as "Well Learned" for C1,"Poor" for C2, "Learned Well" for C3. After identifying concepts which the student failed, guidance is provided as shown in Figure 12. This guidance is provided beginning from the concept located at the top according to the concept-prerequisite concept relationship in the concept map. The student is asked to revise the topics related to concepts she has been unsuccessful. Students are not allowed to proceed with the next chapter unless they complete all concepts successfully. The topics students are asked to revise are presented with more visuals and examples.

Adaptation in OPCOMITS. OPCOMITS supports student-driven learning in a hyperspace of an educational material and provides adaptive presentation and adaptive navigation support.

In adaptive presentation, knowledge and skills of students at different levels require different ways of explanation of the same concept. For example expert level students can be provided more

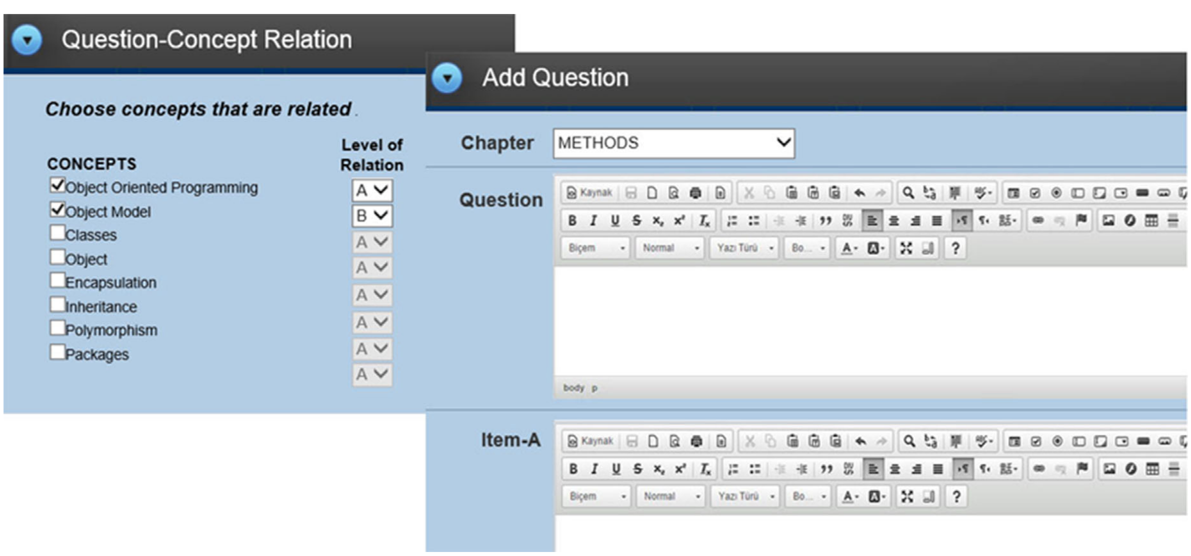

Figure 6 Adding question and question-concept relation screen for experts. [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com].

Table 3 Range of Relationship Between the Concept and Question

Level of relation	Value of relation	Description of relation
A	1.00	Direct relation
B	0.75	High-level
C	0.50	Mid-level
D	0.25	Low-level
E	0.00	No relation

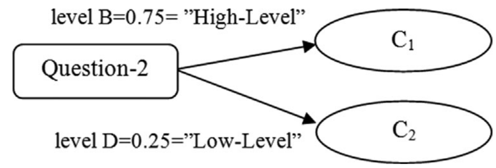

Figure 8 The relationship between question-2 with C1 and C2.

detailed information while a novice can get a simpler explanation. The name of the adaptation technique is named depending on the instructional content type. Text based instructional materials in hypermedia are presented to the student with adaptive text presentation, while multimedia based ones are presented by multimedia adaptation [34–36]. *Adaptive navigation support* helps students to find their paths in the system by adapting link presentation and supports the student in hyperspace by changing the appearance of visible links. The most popular technologies to adapt the links *are direct guidance, link sorting, link hiding, link annotation, and map adaptatio*n [12,13].

The important part of intelligent behavior in OPCOMITS is knowledge about the subject and the student represented in a form of domain model and student model. The domain model represents the knowledge as a conceptual map model. The domain is divided into elementary concepts and structured as a concept map where the several kinds of relationships between the concepts including prerequisite relationship.

Direct Guidance. Direct guidance is implemented in OPCOMITS in a form of curriculum sequencing with links representing the relationship between concepts, which include prerequisite when the student first connects to OPCOMITS. Next best node for the student is suggested to the student. As the student progresses through the OPCOMITS, other adaptation techniques can be used with the help of the student model.

Adaptive Annotation. The student model is the system's representation of the learner's current educational status for each concept.

The knowledge level of the student for a certain concept is assigned one of the characterizations [Well Learned, Learned, Poor, and Very Poor].

This assignment is based on students' answers to assessment questions. The student has demonstrated knowledge about the concept by solving the required number of problems for the concept. The expert module uses the approach described in "Tutoring Model" for decision-making in order to assess the student's knowledge level on each particular concept in the domain.

OPCOMITS supports learner's navigation in the lesson contents by annotating the links that appear at the end of each assessment and navigation area. Links to concepts with different educational status are made visible to the student using different colors and a special icon image at the end of each assessment. In our system, the use of icons and different colors next to the names of the links (which are related to one or more concepts) provides additional information to the student. In the navigation area, we used colored links according to learning level of concepts. The same coloring technique is used in the assessment and navigation.

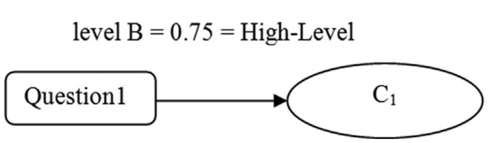

Figure 7 The relationship between question-1 with C1.

OPCOMITS assessment screen, navigations and status screens of students for each concept, colors, visual icons and their definitions are shown in Table 7. Subject links belonging to not-ready-to-be-learned in OPCOMITS are defined with icon 3, as seen in table. Figure 10 (Student Course Content Screen) presents how to use this icon. Image 5 in Table 7 is the icon which expresses concept learning level of students. This icon defines learning level for each concept as shown in Figure 12. Red is used for "very poor", orange for "poor", blue for "learned" concepts and green for "well learned" concepts in guiding students and defining concept learning level.

Adaptive Hiding. The idea of adaptive hiding in OPCOMITS is to restrict the navigation area by hiding or disabling links of irrelevant pages. Adaptive hiding reduces the cognitive load by hiding pages which are not suitable for learning. If the student is not ready to understand a page content or if page content is outside the students' current learning goal, such pages are assumed irrelevant and they are removed from the navigation area.

Adaptive Presentation. Adaptive presentation is the second step of the adaptation process in OPCOMITS. After determining what concept should be delivered, optimal presentation of concept proceeds.

OPCOMITS implements content level adaptation based on the calculated learning level of concepts in the domain. Illustration of concept includes appropriate selection of learning materials.

Basic explanation and simpler examples are provided for concepts of topics in which learning level is scored as "Poor" and "Very poor". New concepts are explained with the concepts that the students knows well and are presented in examples thus recently learned knowledge is associated with the previous knowledge of student to foster learning.

Student Model

The student model diagnoses the needs, misconceptions and cognitive abilities of each individual student. It is a key factor in

Table 4 Concept–Question Relationship Table

	Concept				
Question	C_1	C_2	C_3	...	C_n
Q_1	0.75	0	0	...	0
Q_2	0.25	0.75	0	...	0
Q_3	1	0	0		0
...	...	...	...	...	...
Q_m	0	0	0	...	0

Table 5 Concept–Question and Answer Table for Student-1

	Concept					
Question	C_1	C_2	C_3	...	C_n	Answer
Q_1	0.75	0	0	...	0	Correct
Q_2	0.25	0.75	0	...	0	Incorrect
Q_3	1	0	0	...	0	Correct
...	...	...	...	...	...	
Q_m	0	0	0	...	0	
Total	2	0.75	0.25	...	0	

making instructional decisions and allows understanding and identification of student needs [37,38].

The user model that represents and maintains essential information about each user is a core component of any intelligent or adaptive tutoring system [10,28]. In the developed intelligent tutoring system, while modeling the student knowledge, "Overlay Student Model" is used together with concept map approach. The aim of this model is to make the knowledge of the student closer to the knowledge of expert. The pre-requisite of overlay student model is that content knowledge, rules, concepts and cases should be separable under main headings. Value spaced determined by the system designer is used for level of learning for each topic. Each heading for student level stars with a certain value and this value changes dynamically according to student behavior [39–41]. In overlay student model, the student knowledge is regarded as a subset of expert knowledge. In this study firstly; domain model is divided into concepts that could cover the entire field and student knowledge is modeled at the level concepts and based on to what extent student knows a concept. Identifying the level of learned concepts can be realized via Content Management System for Experts of the domain model and built according to the concepts.

In OPCOMITS, the student model is created with the obtained information when a student registers in the system. In this stage, personal information like user name, name, surname, password, e-mail address, date of birth, gender and profile picture are taken to activate student modeling transaction. Upon registering to the system, the student begins the course by clicking on "Start Course" button.

Learning History. Learning History screen shown in Figure 9 is the first screen that student sees when s/he logs in. This screen shows when and which topic student started to study, the last visit of student, and the time for completing a chapter and proceeding to a next chapter. At the same time, how student proceeds with the topic and the time student started a new topic is also shown.

Start Course. In Figure 10, the learning interface of a student is shown. Subject titles of the course takes place on the left side of the screen. When the student clicks on the subject s/he wants to study, textual, visual, auditory and kinesthetic applications of course contents appear on the right side of the screen. Visuals on the left side of the topic headings express status of the student about the topic. These visuals and their explanations are shown in Table 7.

Table 6 Table for Learning Level Assessment Ranges

	Decrease←Concept Error Rate→*Increase*		
$0 \leq CER \leq 25$	$25 < CER \leq 50$	$50 < CER \leq 75$	$75 < CER \leq 100$
Well learned	Learned	Poor	Very poor
	Increase←Learning Level→*Decrease*		

Chapter Questions. As shown in Figure 11, the student who completes all topics in the chapter starts to answer the questions. These questions are chosen from the question pool and are added to the system by an expert. The system does not allow student to proceed to the next questions without answering.

Students who answer all chapter questions see a screen showing their concept success status, as shown in Figure 12. This screen presents learning level of the student for each concept and CER value. If there are concepts in which the learning level of the student is "Poor" or "Very Poor", links guiding students to revise the topics related to these concepts appear. As shown in Figure 13, topics that need to be revised are presented with red colored links presented under "course content" menu and a different icon is also used to show that the topic needs to be revised. The student can see these topics guided by tutoring model along with previous topics, if there is any, under "Recommended Topics" option. After studying the recommended topics, students guided to re-answer questions at the end of the chapter. Chapter questions are chosen from the question pool of the chapter and from questions related to concepts which are recognized as unsuccessful. After students answer these questions, concept learning level and CER rate are re-calculated by the tutoring model. The process repeats until the student becomes achieves successful in all concepts. When all concepts of the student are at "Learned" or "Well Learned" levels, the student is guided to proceed with the next chapter.

My Concept Map. This map consists of dynamic relationships between concepts identified by the expert in Content Management System for Experts and information about definitions of these relationships as shown in Figure 14. It is also the application which shows concept learning level of the students based on their chapter assessment performance. Expert is able to follow student's learning level in terms of concepts and student is able to follow his/her own learning level in terms of concepts through this map. Concepts with learning levels are indicated as "Well Learned" with green, "Learned" with blue, "Poor" with orange, "Very Poor" with red and the ones that have not started yet (Not Formed) is expressed with gray.

Concept Learning Levels. Student can see his or her learning level of a concept, CER value and his or her status on a table with via the screen presented in Figure 15.

Recommended Topics. In Figure 16; Recommended Topics screen is presented. This screen shows the last recommended topics, last time of student visit and the concepts related to these topics.

EMPIRICAL EVALUATION

An evaluation study was conducted at **İstanbul Arel University** in İstanbul, Turkey with students enrolled in an object oriented programming lesson that lasted approximately twelve weeks during the spring semester of 2014, (from February to July 2014). The experiment was conducted with two groups, control and

Table 7 The Guiding Icons and Colors in OPCOMITS

Image	Definition of Image
1	Defines activated and studied topics
2	Menu visual shows topic the student is studying at that moment.
3	Defines that topic has not been activated, yet. The subject will be activated after the current topic has been finished.
4	Visual of the topic headline defining the topic student is studying at that moment.
5	Figure in the left expresses concept learning level. Green rate expresses well learned, Blue rate expresses learned, Orange rate expresses poor, Red rate expresses very-poor learning level of the concept.
6	Topics that tutoring model asks to revise

experimental, through comparing pre-test and post-test results of these two. Two classes taught by the same teacher participated in the experiment and each class contained 20 students.

This study was designed to explore the effect of adaptation using concept map model and to determine the impact on learning achievement. Learners from both groups took the traditional course in the classroom, used the e-learning system in laboratory applications and their own time through the Internet. OPCOMITS was implemented as an experimental system with personalized functions, while the prototype of a traditional, non-personalized e-learning system was implemented as the control system. By design, when the personalized functions of OPCOMITS were disabled, the system became a traditional, non-personalized e-learning system. In the traditional version of OPCOMITS students read course materials freely with a one-size-fits-all content presentation and they did not receive any recommendations, adaptation or guidance through the course.

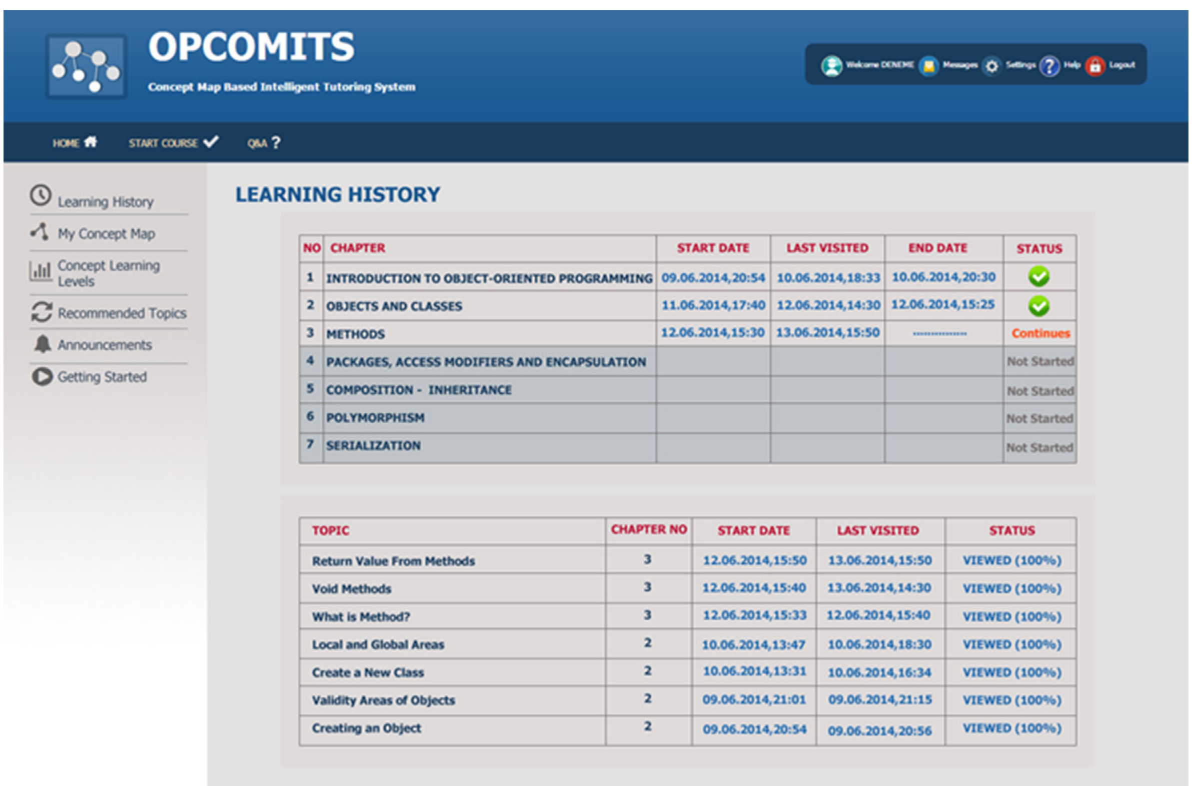

Figure 9 Student learning history screen. [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com].

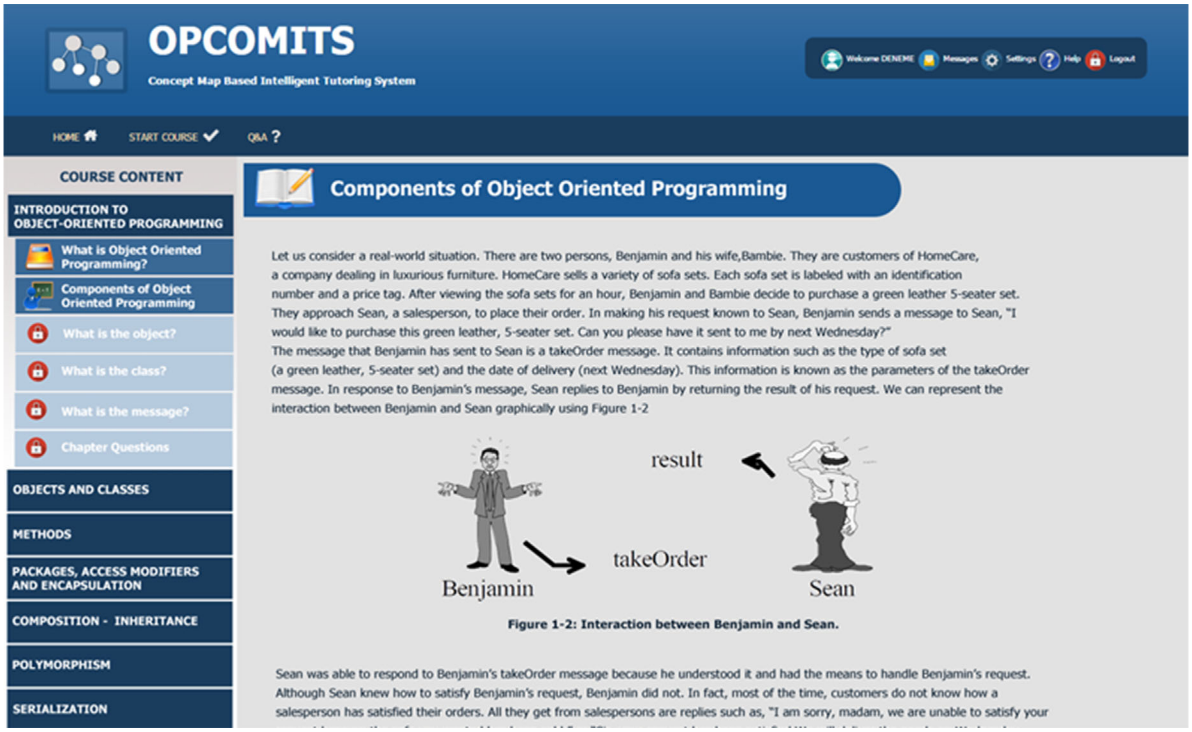

Figure 10 Student course content screen. [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com].

The participants in both groups logged into OPCOMITS for the first time during scheduled class time but could use the system later at any time before the end of the course. Throughout the semester, students in the experimental group and control group learned exclusively with the different versions of OPCOMITS as described above.

Our aim in undertaking such an empirical case was to identify the use of OPCOMITS in students' academic

Figure 11 Chapter questions screen. [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com].

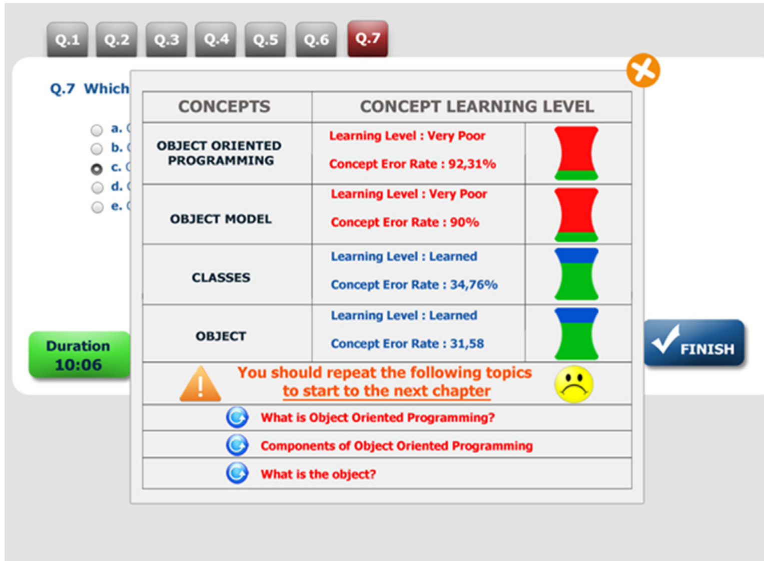

Figure 12 Concept learning level screen of chapter. [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com].

achievement and to find out the extent it creates a difference in their learning. When Studies [42,43] using adaptive learning systems and the way they employed their system to learning contexts are analyzed, it could be seen that they also took pre-test and post-test designs to explore the effect of their system on learning achievement. We acknowledge that the test scores between the control and experiment group do not necessarily imply the adaptiveness of the system or do not mean that students learn better because other variables such as prior knowledge, the time allocated for studying and the time spent in the system may play a role in learning. However, the test scores at least tell us the extent of whether use of OPCOMITS as an alternative space supporting learning environment has had its impact on students' achievement.

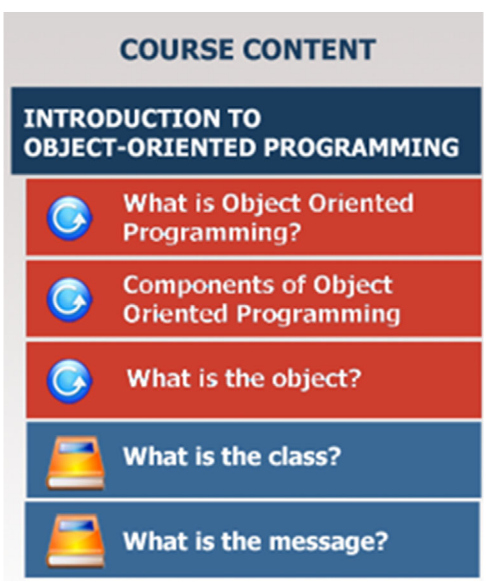

Figure 13 Screening topics needed to be repeated. [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com].

Findings About Academic Success of Experimental and Control Groups

Experimental and control groups are equalized by using crosstab and chi-square test in terms of gender factor and from findings specified that both experimental and control groups were composed of 20% female and 80% male students. In both groups, there is no meaningful difference in terms of gender factor ($X^2 = 1.00$, sd = 1, $P = 0.65$).

A Table 8 shows, a meaningful difference cannot be found in the result of Independent Samples t-test which show the difference between pre-test scores of experimental and control groups-($t_{(38)} = 1.47$, $P > 0.05$). This finding also can be interpreted as there is no difference between score averages of the students in experimental and control groups; in other words, both groups have the same knowledge level.

When Table 9 is assessed, a meaningful difference cannot be found in the result of Paired Sample t-test which shows the difference between pre-test and post-test scores of experimental group ($t_{(19)} = -9.91$, $P < 0.05$). According to this finding, post-test score average ($X = 62.38$) of experimental group using adaptive OPCOMITS is higher than pre-test score average ($X = 35.38$). This suggests that adaptive OPCOMITS application has an important influence on increasing the academic success of students.

When Table 10 is reviewed, a meaningful difference is found in the result of Independent Samples t-test which shows the difference between post-test scores of experimental and control groups($t_{(38)} = 3{,}532$, $P < 0.05$). According to this finding, post-test score average ($X = 62{,}38$) of experimental group which used the improved tutoring system is significantly higher than post-test average of control group ($X = 46.38$). This suggests that adaptive

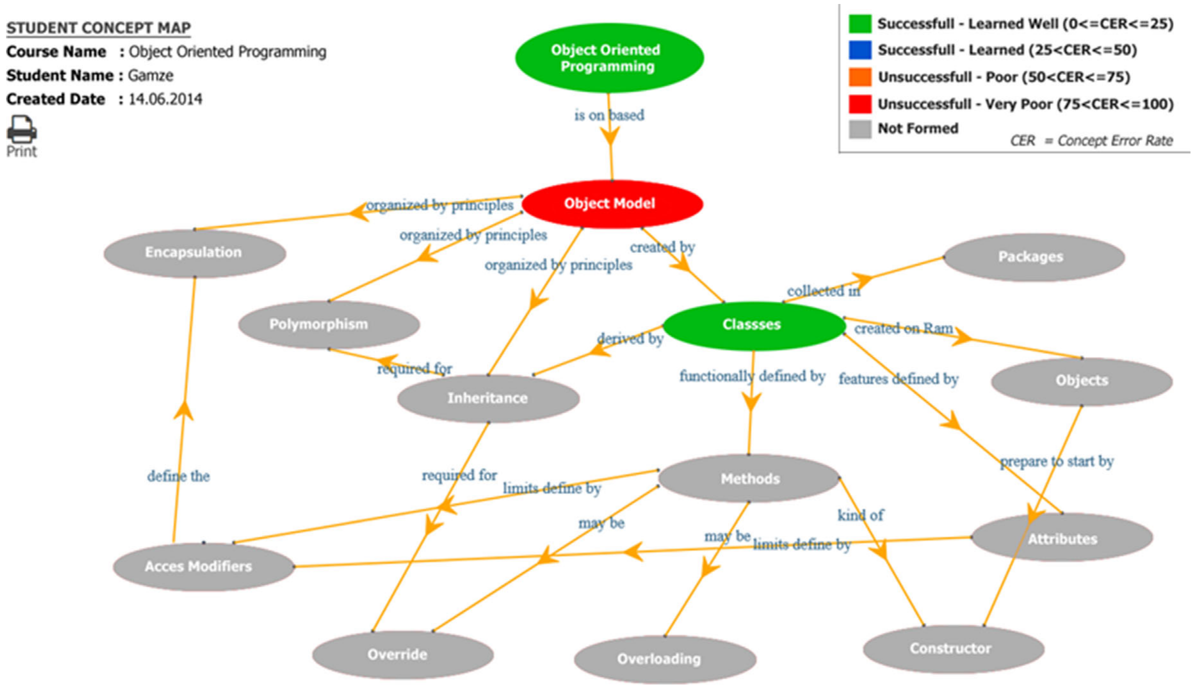

Figure 14 Student concept map screen. [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com].

OPCOMITS system promotes the success of students more than traditional e-learning method does.

Therefore, it can be concluded that the experimental group achieved a significant improvement compared to the control group using the Adaptive version of OPCOMITS developed here.

CONCLUSIONS AND RECOMMENDATIONS

In the domain model, concept map approach is used to represent knowledge, identify the topic hierarchy and interrelations of the topics, and demonstrate the relationship of questions to the topics. An intelligent tutoring system is developed by handling the processes like assessment of how much a student knows the subject field and guiding the student to the correct content for repetition, again in a concept level. The developed system performs the task of personalization of learning which has a significant place in learning systems through concept maps.

By means of Content Management System for Experts, a web based intelligent tutoring system is developed with a structure adaptable to any course. The progressive order of processes in the content management system for experts facilitates the creation of chapter contents, concepts and prerequisite relationships between

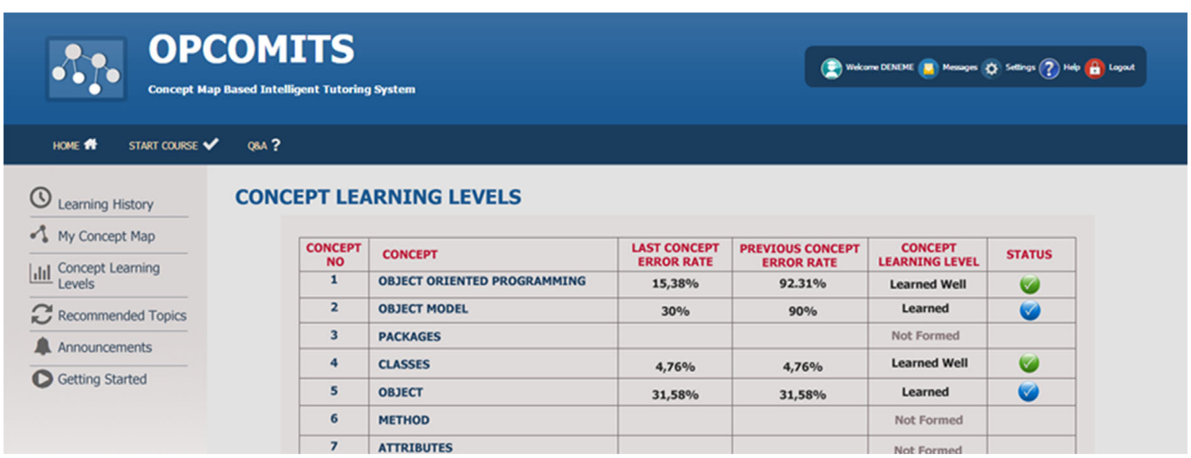

Figure 15 Student concept learning levels screen. [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com].

Figure 16 Student recommended topics screen. [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com].

Table 8 T-Test Findings Belonging to Experimental and Control Groups Pre-Test Score Averages

Groups	*N*	Arithmetic average	Standard deviation	Degree of freedom	*t*	*P*
Experimental group	20	35.38	13.035	38	1.47	0.15
Control group	20	29.62	11.649			

Table 9 T-Test Findings Belonging to Experimental Group Pre-Test/Post-Test Score Averages

Measurement	*N*	Arithmetic average	Standard deviation	Degree of freedom	*t*	*P*
Pre-test	20	35.38	13.03	19	−9.91	0.00
Post-test	20	62.38	15.61			

Table 10 T-Test Findings Belonging to Experimental and Control Groups Post-Test Score Averages

Groups	*N*	Arithmetic average	Standard deviation	Degree of freedom	*t*	*P*
Experimental group	20	62.38	15.612	38	3,532	.001
Control group	20	46.38	12.914			

the concepts and the questions. OPCOMITS additionally makes it possible to regulate content and questions by considering relationships between concepts in topics differently from similar systems using concept map modeling. While an opportunity to regulate the field more flexibly is provided, created concept map is also used at the evaluation stage and individualizing the content and feedback on the level of concept are provided.

To be able to determine the level of learning of the student, a system is developed in which expert-formulated questions can be prepared in a fashion that can check the level of learning for various concepts. With end-of-chapter assessments, students can be directed to repeat topics in which learning is poor. The developed system is not only a tool that helps learning. It also allows reinforcement, topic repetition and practice for the student. During these processes, students do not face any limitations in repetition phase.

To test the learning effectiveness of OPCOMITS, we used t-test and compared the pre-test and post-test results of experimental and control groups. The statistical analysis showed that the change from the pre-test to the post-test results was greater for the experimental group than the control group. These findings indicate that students who learned using OPCOMITS performed significantly better than students who learned with traditional e-learning.

Our experiment achieved positive results for a computer programming course, but it would be interesting to know whether the same approach would work for various other kinds of courses, such as mathematics courses, engineering courses, and foreign languages courses. Consequently, further investigations have been planned to apply the novel approach to on-line tutoring for different courses.

It is also possible to develop a structure in the system in which expert can include verbal, auditory and visual etc. learning styles to the presentation of the content. We believe that incorporating different learning styles will improve the student's learning performance. Further implementations of such system can take the time spent in the system into consideration by using eye tracker system.

In the study conducted, it is possible to implement improvements based on the outcomes obtained from analyzing the data collected from the students by using data mining techniques and reviewing the prerequisite relationship between the concepts prepared by the expert. In this way, it is possible to present the content to the student in a more appropriate and educative manner by identifying the concepts and the relationships between the concepts more accurately.

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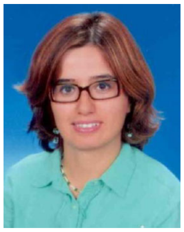
BIOGRAPHIES



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