CHAPTER 3
AN AUTOMATED ASSESSMENT OF LEARNERS’ LEARNING IN E-LEARNING USING CONCEPT MAP AND ONTOLOGY MAPPING

3.1 INTRODUCTION

Teaching-learning process is the heart of any education system. It is the most powerful instrument that helps in achieving the aims and objectives of education. Teaching and learning are related terms. In the teaching-learning process, the teacher, the learner, the curriculum and the pedagogy are organized systematically, to attain some predetermined goal. Learning refers to what the learner understands from the subject being taught. Teaching is providing proper direction and management of learning path. It is the process of providing opportunities for learners to learn. The teaching-learning process is the backbone of any learning system. Assessment lies at the heart of the teaching-learning process because assessment shapes the learners’ understanding of the curriculum and determines their ability to progress. It is therefore not unsurprising that almost all learning management systems (LMSs) offer support for assessment, e.g., for the creation, execution, and evaluation of multiple choice based tests. The term assessment is often used to summarize all activities that teachers use to help learners learn and to quantify the learning progress and outcomes. The latter, in particular, means that assessment measures and documents the knowledge, skills, and attitudes of an individual learner, a learning community (e.g., class, course, or workshop), or an educational institution. In the traditional system, there will
be face-to-face communication between learners and the teacher. The teacher not only teaches but also monitors and assesses the understanding of all the learners.

In any e-learning system, it is important that both teacher and learner keep track of learner’s progress and to check whether the learner has understood the topic. In traditional education system, the teacher and the learner involve in a face-to-face communication with each other at a particular place and a specific time and so, regular knowledge assessment may be carried out and the teacher can easily check the understanding of the learner. At the same time, teachers may have to evaluate the assessment of hundreds of learners. This may be a biased and time consuming process. In e-learning, it is very important to automatically assess the learner’s learning. One of the main advantages of e-learning is that it can facilitate adaptive learning such that instructors can dynamically revise and deliver instructional materials in accordance with learners’ current progress. In general, adaptive teaching and learning refers to the use of what is known about learners, apriori or through interactions, to alter how a learning experience unfolds, with the aim of improving learners’ success and satisfaction (Kelly 2005; Willoughby 2012). In e-learning, a regular knowledge assessment is required to be carried out using different kinds of tests for many reasons. Effective assessment and feedback can be defined as practice that equips learners to study and perform to their best advantage in the complex disciplinary fields of their choice, and to progress with confidence and skill as lifelong learners, without adding to the assessment burden on academic staff.

3.2 BLOOM’S TAXONOMY

Bloom's taxonomy is a classification of learning objectives within teaching learning process proposed in the year 1956 by a committee of educators chaired by Benjamin Bloom. It refers to a classification of the
different objectives that teacher set for learners (learning objectives). Bloom's taxonomy divides teaching learning objectives into three domains: Cognitive, Affective, and Psychomotor (sometimes loosely described as knowing/head, feeling/heart and doing/hands respectively). Within the domains, learning at the higher levels is dependent on having attained prerequisite knowledge and skills at lower levels. The goal of Bloom's taxonomy is to motivate teachers to focus on all three domains, creating a more holistic form of education. Figure 3.1 shows the levels in Bloom’s taxonomy.

![Bloom's Taxonomy](image)

**Figure 3.1 Bloom’s Taxonomy**

### 3.3 CONCEPT MAP AS A KNOWLEDGE ASSESSMENT TOOL

Concept Map (CM) is a pedagogical tool developed by Novak in 1970s (Novak & Cañas 2008). Concept Maps are based on two cognitive theories: Ausubel’s assimilation theory (Ausubel et al 1968) considering conceptual nature of human learning and hierarchical organization of knowledge and Deese’s associationist memory theory (Deese 1965) advocating networked arrangement of concepts. A CM is a semi-formal knowledge representation tool visualized by a graph consisting of finite, non-empty set of nodes, which depicts concepts, and finite, non-empty set of arcs (directed or undirected), which expresses relationships between pairs of concepts. A linking phrase can specify the kind of a relationship
between concepts. As a rule, natural language is used to represent concepts and linking phrases. Moreover, all arcs of the graph can have the same weight, or weights can be different. A proposition, concept-relationship-concept triple – is a semantic unit of CMs. It is a meaningful statement about some object or event in a problem domain (Cañas 2003). According to Novak & Cañas (2008), CMs are represented in a hierarchical fashion with the most general concepts at the top of the map and the more specific concepts below them, but cross-links can be used to indicate relationships between concepts in different domains of a CM by forming some kind of a network. There is a wide variety of CM tasks which allow providing of knowledge assessment, adaptable to learners’ characteristics. However, two main groups of them are:

- ‘fill-in-the-map’ tasks where the structure of a CM is given, and a learner must fill it using the provided set of concepts and/or linking phrases
- ‘construct-the-map’ tasks where a learner must decide on the structure of a CM and its content by him/herself.

The step-by-step construction of a CM and a sequence of CMs constructed by a learner can illustrate the evolution of person’s understanding of the topic (da Rocha & Favero, 2004). According to Cañas (2003), CMs can foster the learning of well-integrated structural knowledge as opposed to the memorization of fragmentary, un-integrated facts and externalize the conceptual knowledge that learners hold in a knowledge domain. The representation of knowledge structure is the topmost quality which substantiates the use of CMs as an alternative tool for knowledge assessment in relation to different form of tests and essays.

According to (Novak & Cañas 2008), CMs are represented in a hierarchical fashion with the most general concepts at the top of the map and
the more specific concepts below them. But cross-links can be used to indicate relationships between concepts in different domains of a CM by forming some kind of a network. Concept Maps have been effectively used in knowledge assessment for many years. This can be used in assessing knowledge at the beginning or during or at the end of teaching-learning process. Concept maps can be used at the beginning of a learning process in order to determine the level of knowledge learners already possess, during the learning process to identify changes in learners’ knowledge and to adjust content and teaching methods of the course, and at the end of the learning process in order to determine the achieved knowledge level. Concept Maps allow evaluation of higher order levels of cognitive development in Bloom’s taxonomy, especially when learners must choose the most prominent and most useful linking phrases and cross-links (Anohina-Naumeca et al 2011).

3.4 EXISTING SYSTEMS FOR AUTOMATIC ASSESSMENT

In this section some existing systems for automatic assessment of learners is reviewed. Table 3.1 illustrates some existing systems available for automatic assessment of learners.

Table 3.1 Existing Systems for automatic assessment

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Existing System</th>
<th>Purpose</th>
<th>Limitations</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>Scheme-robo(Saikkonen et al 2001)</td>
<td>Assessment of programming assignments in scheme</td>
<td>Can assess only programming assignments in scheme</td>
</tr>
<tr>
<td>3</td>
<td>AutoGrader (Helmick 2007)</td>
<td>Assessment of Java programs</td>
<td>Only java programs can be assessed</td>
</tr>
<tr>
<td>4</td>
<td>CodeLab (<a href="http://www.turingscraft.com)">http://www.turingscraft.com)</a></td>
<td>Assessment of Java, C/C++, and Python programs</td>
<td>Only for programming languages</td>
</tr>
</tbody>
</table>
Table 3.1 (Continued)

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Existing System</th>
<th>Purpose</th>
<th>Limitations</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>MyCodeMate (<a href="http://www.mycodemate.com">http://www.mycodemate.com</a>)</td>
<td>Program Code assessment</td>
<td>Only for programming languages</td>
</tr>
<tr>
<td>6</td>
<td>Course Marker (Higgins et al 2005)</td>
<td>Summative assessment</td>
<td>Only for uploading assignments, and MCQ, No descriptive answer assessment</td>
</tr>
<tr>
<td>7</td>
<td>BOSS (Joy et al 2005)</td>
<td>Summative assessment</td>
<td>Not for formative assessments</td>
</tr>
<tr>
<td>8</td>
<td>AT(x) (Beierle et al 2003)</td>
<td>Summative assessment</td>
<td>Not for formative assessments</td>
</tr>
<tr>
<td>9</td>
<td>Moodle (<a href="http://moodle.org">http://moodle.org</a>.)</td>
<td>questionnaires, multiple-choice tests, file uploads</td>
<td>No descriptive answer assessment and not for formative assessments</td>
</tr>
<tr>
<td>10</td>
<td>Blackboard (<a href="http://www.blackboard.com/">http://www.blackboard.com/</a>)</td>
<td>questionnaires, multiple-choice tests, file uploads</td>
<td>No descriptive answer assessment and not for formative assessments</td>
</tr>
<tr>
<td>11</td>
<td>OLAT (<a href="http://olat.org">http://olat.org</a>)</td>
<td>questionnaires, multiple-choice tests, file uploads</td>
<td>No descriptive answer assessment and not for formative assessments</td>
</tr>
</tbody>
</table>

Almost all of these systems have the common property of providing (along with the actual testing of programming assignments) functionality for managing users, courses, assignments, and submissions. Furthermore, these systems are difficult to extend and to adapt to one’s own requirements. They are built for the purpose of testing programs in a certain language or employ a certain test method. This results in rather inflexible, monolithic systems not created for possible extension by additional functionality. The result of the assessment provided by these systems can be used only for grading the learners. All these systems perform only summative assessment not formative assessment. Most of these systems are used to assess only the programming exercises which cannot be extended for other context.

3.5 MOTIVATION

Assessment is a very important part in the teaching-learning process of any learning system. An important aspect of effective teaching-
learning process is careful assessment of the extent to which learners have assimilated the material they were taught. The role of assessment in teaching-learning process is not only for assigning grades to learners, but can also be used to direct them to achieve the objectives of the course. But providing flexible and adaptable knowledge assessment, as provided by human teacher in classroom teaching is a key challenge for e-learning designers. There are five levels of assessment approaches suggested in Bloom’s taxonomy, in order to provide efficient teaching-learning both cognitive and non-cognitive. Unfortunately, assessing learners’ learning by tests, quizzes or assignments assess the learners only at the first three levels of Bloom’s taxonomy (Huitt 2011; Wu et al 2011). It fails to assess the learners in the higher levels of the taxonomy. Learners need more understanding and need to give more elaboration when they are assessed at the higher levels of the taxonomy (Ghauth & Abdullah 2010; Razzouk & Razzouk 2010). Several researches have been performed to assess the learners at the first three levels of Bloom’s taxonomy. One of the main advantages of e-learning technology is that it can facilitate adaptive learning such that instructors can dynamically revise and deliver instructional materials in accordance with learners’ current status. Assessing learners at the last two levels of Bloom’s taxonomy is required to provide efficient teaching-learning process. This motivated us to propose a model using concept map and ontology mapping to assess the learners’ learning at the higher level of the Bloom’s taxonomy.

In this chapter, a model using concept map and ontology mapping to assess the learner’s learning at the higher level of Bloom’s taxonomy is proposed.

3.6 LITERATURE SURVEY

Assessment is very important in the teaching-learning process of any learning system to make sure that the learners are progressing towards the course objectives and to adjust teaching-learning process accordingly. The
role of assessment in teaching-learning is not always used for assigning grades. They are used to improve the quality of instruction in the teaching-learning process (Lauer 2012). There are two types of assessment: summative and formative assessment. Summative assessment is a periodic assessment used to determine at a particular point in time what learners’ know and do not know. Formative assessment is a part of the teaching-learning process that provides information needed to adjust teaching and learning while they are happening (Garrison & Ehringhaus 2007). Classroom Assessment Techniques (CATs) are teaching strategies that provide formative assessments of learner learning. It has been argued that the use of CATs enhances and improves learner learning (Simpson-Beck 2011). Formative assessment can have a powerful impact on learner motivation and achievement (Marzano 2009). Cauley & McMillan (2010) discusses the key practices that teachers can use to gather important information about learner’s understanding, provide feedback to learners, and enable learners to set and attain meaningful learning goals.

Concept Maps are excellent tools to provide instructors with diagnostic pre-assessment prior to beginning a unit and formative assessments during learning activities (Grundspenkis 2009). Angelo & Cross (1993) indicate that concept maps develop learner abilities in certain critical areas like, the ability to draw reasonable inferences from observations, the ability to synthesize and integrate information and ideas, the ability to learn concepts and theories in the subject area. Concept Maps were chosen as a strategy to empower learners to be more effective readers and knowledge creators (Dias 2010). Concept Map can also be used to enhance the interaction of teaching and learning with the goal to foster high order thinking, i.e., analyzing a problem situation, evaluating possible solutions, and creating innovative ideas for problem solving (Novak 2010). Concept Map based teaching and learning can motivate and improve learner’s participation in higher order thinking activities (Angelo & Cross 1993).
Several ontology mapping systems have been proposed to address the semantic data integration issues in different domains (Bittencourt et al 2009). E-learning systems propose a wide variety of tools and services for content, knowledge and learner’s management to support an effective teaching-learning process (Teo & Gay 2006). In e-learning several ontologies have been developed and experimentally used to describe the learning contents, model the elements required for the evaluation of interaction between learners (Lau et al 2009), teaching-learning strategies (Shishehchi et al 2012), learner’s profile (Lau et al 2009), authoring (Ivanova 2011), tutoring and for assessing the learners for giving grade to achieve flexibility (Gladun et al 2009), adaptability (Cuéllar et al 2011), knowledge integration and reuse. Fuzzy domain ontology extraction algorithm is used for concept map generation based on the messages posted in online discussion forums (Lau et al 2009). In this chapter, a well known assessment tool, concept map is used. The concept map is transformed to ontology for usage in teaching-learning process of e-learning and is mapped with reference ontology for effective assessment of learning of the learners.

3.7 PROPOSED MODEL

This chapter proposes a model that involves the application of ontology mapping technique for the automatic assessment of learner learning by comparing the concept maps developed by the learners and a reference ontology created by the expert. There are four models in any e-learning system: i) Teacher Model ii) Learner Model iii) Pedagogical Model iv) Assessment Model. The process begins with the Teacher Model, through which the subject expert (teacher) generates the course content and also the “reference ontology” for the content to be learnt by the learner. After learning the subject, the learner generates the concept map on the subject learnt. This concept map is given as an input to the Assessment Model, which is the main focus of this research work. There are three phases in this model. First phase
is Concept Map processing, which takes CM as input and process the concept map created by the learner. Concept map ontology generation phase generates the ontology document for the learner’s concept map. Ontology mapping phase maps the reference ontology with the concept map ontology and returns the learner learning percentages. This learning assessment can be used by Learner Model to learn the learner and in turn Pedagogical Model can decide the learning path. The system is implemented as a Web-based three-tier client-server application consisting of the following architectural layers:

- a data storage layer represented by data base management system PostgreSQL
- an application logic layer composed of the application server (Apache Tomcat), server side code, and a special persistence and query framework – hibernate
- the representation layer based on swing, JGraph, and JGoodies libraries.

Figure 3.2 gives the architecture of the proposed model.

![Figure 3.2 Architecture of the proposed model](image-url)
3.7.1 Concept Map Processing

CMs represent knowledge in the form of a graph which consists of labelled nodes displaying concepts in a knowledge domain and arcs showing relations between pairs of concepts. The main elements of a CM based on (Graudina & Grundspenkis 2011) are: concept, relation, cross-link, concept example, and prepositions. The various kinds of possible relations between two concepts are: hierarchical, instance, semantic, property, value, and complement. In concept map processing stage, the main elements of CM are identified. According to Anohina-Naumeca et al (2011), it is possible to determine the seven types of relations in a concept map.

The learners can create CMs and are also provided with the use of learners’ support, managing types of concept explanations, provision of feedback to teachers through questionnaires, viewing and configuring the learner model. Figure 3.3 shows the CM creation interface for learners and Figure 3.4 shows the sample CM created by a learner.

![Completion of a concept map based task at 4 difficulty degree](image)

Figure 3.3 Learners CM creation
The equivalent OWL coding is written for the main elements of CM. Algorithm for converting CM into ontology is given in Figure 3.5.

**Algorithm OntoGen (G:ConceptMap)**

Mark all concepts in G ‘unvisited’

For each concept C directly related with G do

    If not visited (C) then
        Create a OWL class for C
    Else
        It is cross-link.
    Endif

Find the type of relation (R) between C and G

    If R is hierarchical then
        Make C as the sub class of G
    Endif
Endif
If R is instance relation then
    Make C as the instance of G
Endif
If R is whole-part then
    Make C as the part of G
Endif
If R is property then
    Make C as the property of G
Endif
If R is value then
    Make C as data property of G
Endif
If R is Complement then
    Make C as the complement of G
Endif
If R is any other then
    Make C as the object property of G
Endif
OntoGen(C)
Endfor
Endalg

Figure 3.5 Algorithm for Ontology learning from Concept Map
3.7.2 Expert Ontology (Reference Ontology) Creation

The Experts in the system are subject experts / teachers who can manage learners, groups, and courses, configuring feedback, setting initial values of the coefficients used in scoring learners’ CMs, and configuring initial values of the learner CM. The teacher can create reference ontology, viewing learners’ results, managing differences between learners’ and teacher’s CMs, changing the coefficients affecting learners’ scores, viewing statistics concerning learners’ use of concept explanation types, managing questionnaires and learners’ answers to them. Figure 3.6 shows the interface for creating ontology by subject experts.

![Figure 3.6 Expert ontology creation by teacher](image)

3.7.3 Ontology Mapping Phase (Assessing Learning Level of the Learner)

Ontology instant mapping approach is used to map the concept map ontology with the reference ontology. The mapping value is the score
assigned to the learner learning. Let H be the reference ontology created by
the expert and T be the ontology constructed from concept map created by the
learner. The edge set of H, E(H) and edge set of T, E(T) is:

\[ E(H) = \{h_1, h_2, h_3, \ldots, h_n\} h_i, i = 1, 2, \ldots, n \]
\[ E(T) = \{t_1, t_2, t_3, \ldots, t_m\} t_j, j = 1, 2, \ldots, m \]

To find the matching between every edges in H with every edges in
T, the Cartesian product of E(H) and E(T) is taken.

\[ E(H) \times E(T) = \{(h_i, t_j) / i = 1, 2, \ldots, n \text{ and } j = 1, 2, \ldots, m\} \]

Let the end vertex of \(h_i\) be \((v_{i1}, v_{i2})\) and the end vertex of \(t_j\) be \((u_{j1}, u_{j2})\).

Let the edge weight of \(h_i\) is \(W_i\) denotes the weight assigned by the
expert in the reference ontology.

The matching between \(h_i\) and \(t_j\) is as follows:

\[ m(h_i, t_j) = \frac{Sim(v_{i1}, u_{j1}) + Sim(v_{i2}, u_{j2})}{2} \times W_i \]  

(3.1)

where \(m(h_i, t_j)\) is an integer value, \(Sim(v_{i1}, u_{j1})\) is the similarity between the
two vertices \(v_{i1}\) and \(u_{j1}\) and \(Sim(v_{i2}, u_{j2})\) is the similarity between the two
vertices \(v_{i2}\) and \(u_{j2}\). Wikipedia based semantic relatedness similarity measure
is used to find the similarity between two vertices.

The total matching of all edges is:

\[ k = \sum_{i=1}^{n} \sum_{j=1}^{m} m(h_i, t_j) \]  

(3.2)

k is the score assigned to the learner learning.
3.8 EXPERIMENTAL RESULTS AND DISCUSSION

To evaluate the effectiveness of the innovative approach, two experiments were conducted. First experiment was conducted to find the effectiveness of concept map as assessment tool (Wu et al 2011). It is a questionnaire based experiment and prepared two questionnaires one for learners and another one for teacher. A total of 73 learners belonging to two different classes and 10 members of faculty participated in this study. The average age of the learners was 21 years. All learners learned the topic Genetic Algorithm in Soft Computing course. After completing learning, the learners were asked to generate concept map for the topic learned by them. Out of 73 learners, 51 learners supported concept map as learning tool. The prime reason given by them is that this learning approach can help to learn the contents from a new perspective and this learning system enables better understanding of the learning content. They are happy with the feedback and explanation for each concept given by the system. They are able to understand the concept more clearly. Unexpected results have been analysed as well. The main challenge faced by the learners is that this approach requires thinking differently about the learning content and this makes the current learning activity more challenging. They are not able to link the concepts.

To the surprise, all 10 faculty members expressed that they were satisfied with concept map based approach. The main reasons given by them were: i) easy to assess ii) easy to add/update concepts iii) easy for quantitative and qualitative analysis.

Second experiment was designed to evaluate the effectiveness of the proposed approach. The performance measures such as True Positive Rate (TPRate), True Negative Rate (TNRate), False Positive Rate (FPRate), False Negative Rate (FNRate), F-Measure and Accuracy are used and their values
from experiment are given in Table 3.2. From this Table, it is clear that the proposed model can assess the learners with 94.14% accuracy.

**Table 3.2** Measures and their values

<table>
<thead>
<tr>
<th>Measure</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>TPRate</td>
<td>0.93</td>
</tr>
<tr>
<td>TNRate</td>
<td>0.87</td>
</tr>
<tr>
<td>FPRate</td>
<td>0.13</td>
</tr>
<tr>
<td>FNRate</td>
<td>0.07</td>
</tr>
<tr>
<td>F-Measure</td>
<td>0.9</td>
</tr>
<tr>
<td>Accuracy %</td>
<td>94.14</td>
</tr>
</tbody>
</table>

### 3.9 COMPARISON OF THE PROPOSED MODEL WITH THE TEXT MINING APPROACH

To compare the proposed method to assess the knowledge level of the learner in e-learning with the EduMiner (Hsu et al. 2011) that uses text mining techniques to assess the learners, two standard measures from information retrieval: precision and recall, defined as follows are used.

\[
\text{Precision} = \frac{\text{No. of learners assessed correctly}}{\text{No. of learners assessed}}
\]

\[
\text{Recall} = \frac{\text{No. of learners assessed correctly}}{\text{Total learners}}
\]

where no. of learners assessed correctly is the number of learners assessed correctly by the system, number of learners assessed is the total number of learners assessed, Total learners is the total number of learners. To compare the performance, the proposed approach and EduMiner approach have been
tested on the same set of 73 learners and calculated the average precision and recall values. In the experiments illustrated in Figure 3.7 both methods are represented by the average precision and recall values. Experiments were conducted with 73 learners.

![Comparison of precision and recall values](image.png)

**Figure 3.7** Comparison of the proposed method with Edu Miner using average precision and recall values

Comparing the mean precision, the proposed method scored the highest rank (0.877) than the EduMiner which scores only 0.73. Comparing the corresponding mean relative recall values, the proposed method has the highest recall (0.93) and the EduMiner has only 0.63. The result in Figure 3.7 demonstrates that the proposed approach outperforms the EduMiner that uses text mining approach.

### 3.10 SUMMARY

The system discussed in this chapter is an ideal environment for automatic knowledge assessment of learners. This chapter focuses on how
concept map and ontology mapping can be used for assessment of learners in e-learning system. The effectiveness of teaching-learning process in e-learning system depends on the appropriate teaching and knowledge assessment methods (Moule 2007). Concept map provides valuable information for teaching-learning process. Since, concept maps have structural similarity with ontology, it is possible to convert concept map into ontology efficiently (Graudina et al 2011), by applying ontology mapping technique. Experimental results show that the proposed model can assess the learning of learners effectively. Formative assessment is useful in the process of monitoring learners’ progresses of knowledge construction in e-learning. But, the major bottleneck of putting formative assessment into practice lies in its labor-intensive and time-consuming nature, which makes it hardly a feasible way of achievement evaluation especially when there are usually a large number of learners in e-learning environment.