Artificial Intelligence-Based Student Learning Evaluation: A Concept Map-Based Approach for Analyzing a Student's Understanding of a Topic

G. Pankaj Jain, Varadraj P. Gurupur, Jennifer L. Schroeder, and Eileen D. Faulkenberry

Abstract—In this paper, we describe a tool coined as artificial intelligence-based student learning evaluation tool (AISLE). The main purpose of this tool is to improve the use of artificial intelligence techniques in evaluating a student's understanding of a particular topic of study using concept maps. Here, we calculate the probability distribution of the concepts identified in the concept map developed by the student. The evaluation of a student's understanding of the topic is assessed by analyzing the curve of the graph generated by this tool. This technique makes extensive use of XML parsing to perform the required evaluation. The tool was successfully tested with students from two undergraduate courses and the results of testing are described in this paper.

Index Terms—Concept maps, evaluation, probability distributions, XML parsers

1 Introduction

Concept maps, which are visual representations of a particular topic and its subcomponents, have been used in multiple settings to teach information. The power of the concept map lies in the fact that it requires the elucidation of the relationships between the subcomponents of a particular topic. The effectiveness of using concept maps for knowledge retention over other forms of summarizing information has been demonstrated in multiple studies [1] and in naturalistic settings [2]. In addition, concept maps can be used as a form of evaluation of student learning [3], [4]. When a particular topic is taught, concept maps can be utilized to determine what the student knows about a subject, rather than using more traditional forms of assessment such as multiple-choice exams.

We are in the process of developing a tool to evaluate student learning using concept maps [5], [6]. Here, a student would be given a topic to learn and build [7] a concept map based on their understanding of the topic. This tool, coined as artificial intelligence based student learning evaluation tool (AISLE), would then evaluate [8], [9] the concept map and assess if the student has captured enough concepts from the given topic. This will help the instructor in evaluating a student's understanding of the topic.

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The objective of this project is as follows:

- To develop a tool that understands student psychology in terms of the learning process [5], [6] undertaken by student using concept maps.

This project can have the following impact on the academic community:

- It will provide a better understanding of the student learning process, which will have practical curriculum and classroom applications for educational psychologists [10].
- The project will provide the school districts in northeast Texas with a new educational tool to use in their classrooms.

The research question targeted in this project is as follows: "Can we use a concept map-based approach in validating student performance?" While many concept map-based approaches have been proposed for assessing a student's knowledge of a particular topic, AISLE provides the following core contribution: "Development of a comparitive analysis using probability distribution to compare concept maps developed by students." In this paper we first discuss some related work. We then present a detailed discussion on methodology involved in using AISLE and details pertaining to the processing involved with algorithms, examples and details of the analysis of the input. To conclude, we provide results of experimentation, comparison with related tools and sections describing the usefulness of this tool.

1.1 Related Work

Some of the investigators dealing with concept maps have developed assessment systems using this tool. Here we would like to note that most of these systems.

1.1.1 *Intelligent Knowledge Assessment System*

The knowledge assessment system presented in [39] by Lukasenko and Vilkelis provides a structured approach to asssessing a student's knowledge on a particular topic. The

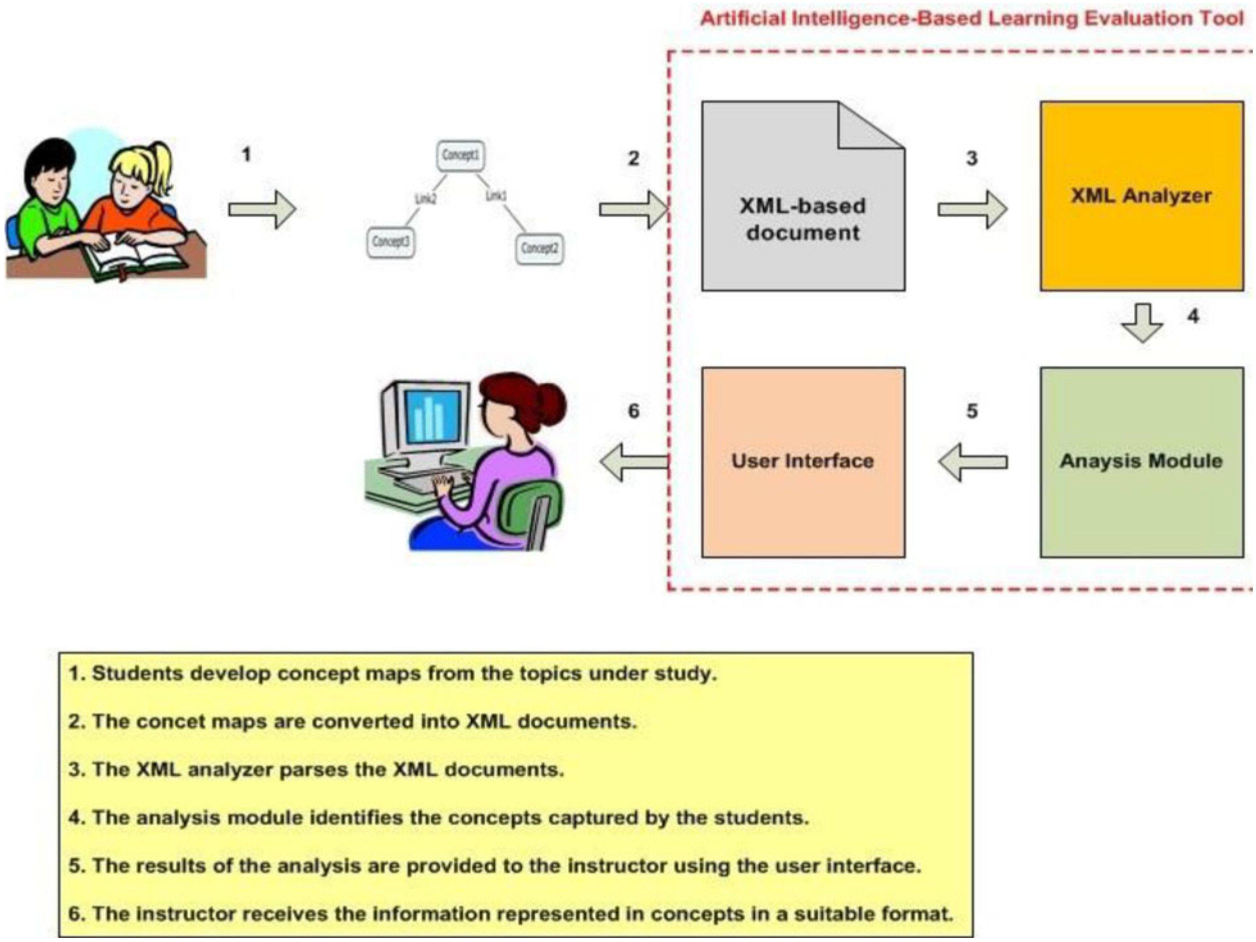

Fig. 1. Overview of the methodology used in AISLE.

software application associated with this system presents questions to the user and generates an analysis using the answers provided to these questions. This system uses a well defined structured approach in gathering the required information and performing the required analysis. Moreover, this system provides feedback to the student as well as the teacher. Some of the key contributions of this system are: a) Providing necessary feedback to students in restructuring their acquired knowledge, and b) Providing feedback from the teacher to the student by using the system.

1.1.2 Personalized Assessment System Supporting Adaptation and Learning (PASS)

The personalized assessment system supporting adaptation and learning [40] provide an assessment of a student's present knowledge and helps identify the knowledge areas that the student may not have covered. This helps the student analyze the progress made in the learning process and identify the areas where more learning may be required. Some of the key contributions of this system are: a) identification of prior knowledge of the student; b) diagnosis of concepts unknown to the student; and c) identifying the growth in a student's overall understanding of the topic.

1.1.3 Knowledge Assessment System

The knowledge assessment system presented in [41] makes use of the concept maps developed by domain experts in analyzing a student's understanding of the concepts. It makes a comparison between these concept maps and the concept map developed by the student. This approach is based on the assumption that the concepts identified by the experts would represent the complete knowledge domain while the concept map developed by the student would be somewhat incomplete.

2 Methodology for Using AISLE

As indicated previously, the method used by the tool to evaluate student understanding of specific topics as discussed in the class is different than the regular methods used, with differing qualities such as quizzes, oral presentations, and projects. While most instructors attempt to measure a student's understanding of topics discussed in the class by personally evaluating the student's work, this tool automates the task of evaluation. The method used by the tool can be used by having a deeper measurement of a student's understanding [11], [12] of the domain in discussion by inspecting the areas of the domain concepts in which the student may be interested [5], [6]. Fig. 1 provides a brief description of the methodology involved in using our tool. As reflected in Fig. 1, this methodology involves the following steps:

- Students develop concept maps after studying the prescribed material.
- These concept maps are converted into XML-based documents [13].

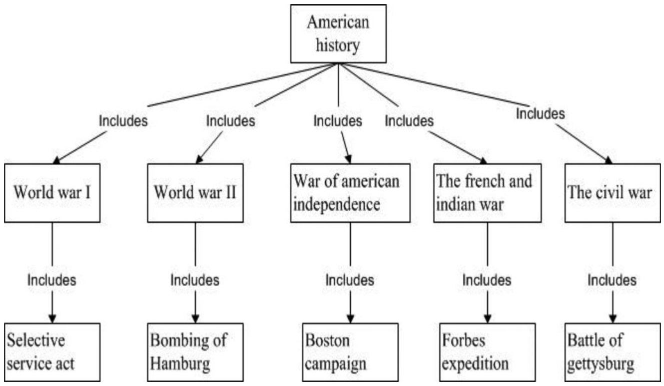

Fig. 2. Concept map 1 for instructor.

- The XML analyzer module of our tool extracts the concepts embedded in the XML document [14].
- The analysis module makes an assessment of the importance of the concepts captured by the students and provides a summary of the results of the user interface module.

The instructor perceives the result from the user interface and makes a judgment on the study carried out by the student.

3 Implementation

3.1 Analysis of Concept Maps

AISLE is a tool that helps the instructors analyze a student's understanding of a particular topic. This analysis is based on the concept maps developed by the students for a particular topic under study. The instructor uses the concept map and runs it on AISLE to receive the statistics based on probability density function [15], [16], [17]. To generate these statistics in AISLE, we use the hierarchy of the concepts involved in the concept map. For example, consider the following concept map in Fig. 2 and how the statistics can be obtained for this particular concept map. The analysis is based on a concept map that is developed by using IHMC tools [18], which is used by the students for a particular topic under study. We take this concept map and extract the XML documents and develop statistics based on probability distribution functions. To get the required statistical results from these concept maps, we use the hierarchy of the concepts involved in the concept maps. The concept maps are then converted into an XML-based file to provide machine-actability. The following steps provide a brief description of the use of concept maps to develop the system:

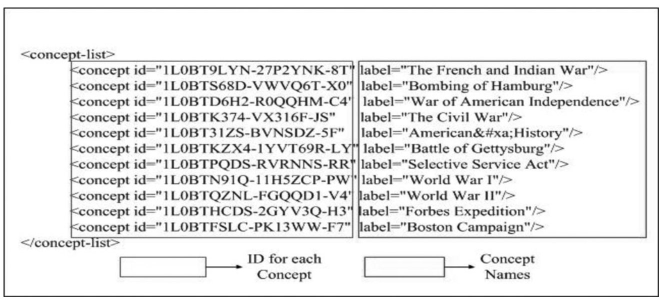

Fig. 3. XML file representing concepts.

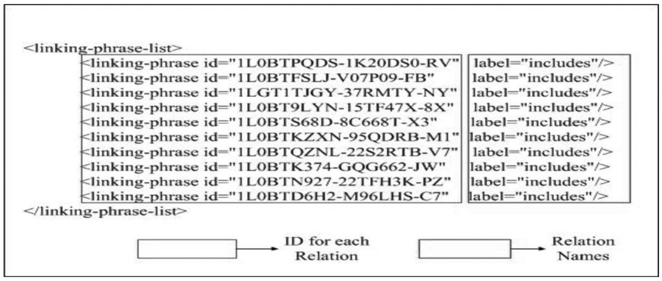

Fig. 4. XML file representing relations.

- In the first step, the concept map is developed by the instructor, and then is used as reference for evaluating the concept maps which are developed by the students.
- In the next step, we convert the concept map into an XML—based document.
- A suitable parser is used to extract concepts and relations from the XML file.
- Finally, the extracted information is used to develop the statistics required to derive the necessary conclusion.

As mentioned before, we convert the concept map into an XML file. This XML file contains all the required information on concepts and their associated relationships. The linking phrase between any two concepts represents the relation and the technique, which comprehends these relations among different concepts, and is called "Concept Mapping" [19]. In concept mapping, we identify the concepts and hierarchically organize these concepts and differentiate the concepts into different levels where the lower most level represents the important information [14], [19] in understanding the topic. Fig. 3 gives a preview of this XML file.

From Fig. 4, we observe that each and every concept is assigned with a unique "concept id" which helps the developer in programmatically extracting the concept name by using these "concept ids." By using these XML files, software developers write programs to extract the "concept id" and its corresponding "label" concepts [20] present in concept map.

Each concept is assigned with a unique "concept id." This information also provides the total number of concepts that are present in the concept maps. These concepts may or may not relate to each other [21]. But the interconnection of concepts that are linked to each other is not taken into consideration in this list. That is, we still have to extract the relationship that exists between these concepts in the concept map. We may have the concepts that can have no relation to other concepts or that have at least one relation that exists between two concepts [18], [22]. For example, the concept "War of American independence" has relation "includes," and the relation "includes" is further interlinked with "Boston campaign". The concept "Boston campaign" does not have any further relation.

Hence the relationships between the concepts play an important role as they are useful in determining the actual layout of these concepts and help in understanding the topic which is understood by the student. Therefore, the concept maps developed by the students are required to be completely verified by the instructor. To achieve the relation

```xml
<connection-list>
        <connection id="1L0BTFSLP-1RJLNQG-FM" from-id="1L0BTFSLJ-V07P09-FB"
                                              to-id="1L0BTFSLC-PK13WW-F7"/>
        <connection id="1L0BTPQDS-3VJB04-S4"  from-id="1L0BTPQDS-1K20DS0-RV"
                                              to-id="1L0BTPQDS-RVRNNS-RR"/>
        <connection id="1L0BTK374-29Q8YXQ-JZ" from-id="1L0BT31ZS-BVNSDZ-5F"
                                              to-id="1L0BTK374-GQG662-JW"/>
        <connection id="1L0BTS68D-90HBCD-XD"  from-id="1L0BTS68D-8C668T-X3"
                                              to-id="1L0BTS68D-VWVQ6T-X0"/>
        <connection id="1L0BTD6H2-2B1M8GM-CB" from-id="1L0BT31ZS-BVNSDZ-5F"
                                              to-id="1L0BTD6H2-M96LHS-C7"/>
        <connection id="1L0BTS68D-16CJKY1-X6" from-id="1L0BTQZNL-FGQQD1-V4"
                                              to-id="1L0BTS68D-8C668T-X3"/>
        <connection id="1LGT1TJH1-25CWVVX-P1" from-id="1L0BT9LYN-27P2YNK-8T"
                                              to-id="1LGT1TJGY-37RMTY-NY"/>
        <connection id="1L0BTN927-FJ73GC-Q7" from-id="1L0BTN927-22TFH3K-PZ"
                                              to-id="1L0BTN91Q-11H5ZCP-PW"/>
        <connection id="1L0BTK374-79JPZP-K4" from-id="1L0BTK374-GQG662-JW"
                                              to-id="1L0BTK374-VX316F-JS"/>
        <connection id="1L0BTFSLP-1FSK0QQ-FF" from-id="1L0BTD6H2-R0QQHM-C4"
                                              to-id="1L0BTFSLJ-V07P09-FB"/>
        <connection id="1L0BTPQDS-7W5PWN-RY" from-id="1L0BTN91Q-11H5ZCP-PW"
                                              to-id="1L0BTPQDS-1K20DS0-RV"/>
        <connection id="1L0BT9LZ4-23VJDQP-90" from-id="1L0BT31ZS-BVNSDZ-5F"
                                              to-id="1L0BT9LYN-15TF47X-8X"/>
       <connection id="1L0BT9LZ4-1DRN89M-95" from-id="1L0BT9LYN-15TF47X-8X"
                                              to-id="1L0BT9LYN-27P2YNK-8T"/>
```

Fig. 5. XML file representing connections.

between the concepts, the XML document contains a "linking-phrase id," which is assigned to each relation that is present from the concept map. Fig. 6 briefly describes how the "linking-phrase id" is assigned for each and every relation that is extracted from the concept map as shown in Fig. 4. Fig. 4 describes how the relation of the above concepts are assigned with a unique "linking-phrase id". Using, this "linking-phrase list" has a developer who can easily extract the corresponding ids and labels for the relationships that are connected with the concepts from the concept map. With this, we will have the total number of relations that are present in the concept map. However, the problem of interconnecting the concepts based on relationships is not solved. That is, we do not have any clear form of data that tells us how the concept is interlinked with the other concept. In order to overcome this problem, the XML file contains a tag with "connection-id," "from-id," and "to-id." By using these ids, we can clearly distinguish how these concepts are interlinked and the relation that joins them together, with the help of their unique ids, which are assigned to each individual concept and to each relation that are present in the concept map. Here, the "connection-id" is a unique id that represents the linked form of concepts. For example, we have a concept "War of American Independence" related with "Boston campaign" using the relation "includes." Here, two unique connection-ids are created: one describes the connection from "War of American Independence" to "includes," and the other describes the connection from the relation "includes" to the concept "Boston campaign." Using this information, a developer can easily programmatically differentiate the interlinkage of concepts with their relations. Fig. 5 briefly describes how the data is organized using the above mentioned ids. From Fig. 5 we can see that the "connection-id," "from-id," and "to-id" comprise a set of issued ids which are used to form the interconnection between the concepts. Here, "connection-id" is a unique id that is issued to each connection from a concept to a property and vice versa. This connection can be described as follows:

- Concept "War of American Independence" is assigned with a unique id "1LOBTD6H2-R0QQHM-C4," which is interlinked to the concept "Boston campaign," which is also assigned a unique id "1L0BTFSLC-PK13WW-F7".
- These two concepts are interlinked with a relation named "can be," which is assigned a unique id.

```xml
<concept id="1L0BTD6H2-R0QQHM-C4" label="War of American Independence"/>
<linking-phrase id="1L0BTFSLJ-V07P09-FB" label="includes"/>
<concept id="1L0BTFSLC-PK13WW-F7" label="Boston Campaign"/>

<connection id="1L0BTFSLP-1FSK0QQ-FF" from-id="1L0BTD6H2-R0QQHM-C4"
                                      to-id="1L0BTFSLJ-V07P09-FB"/>
<connection id="1L0BTFSLP-1RJLNQG-FM" from-id="1L0BTFSLJ-V07P09-FB"
                                      to-id="1L0BTFSLC-PK13WW-F7"/>
```

Fig. 6. Linking concepts and relations.

In order to identify the connection between the concepts, the XML file creation process creates a connection-id that helps in identifying the connection. The XML file creates this connection in the form of "concept-> relation" and "relation-> concept". Based on this connection we can develop hierarchy of concepts that can be implemented in AISLE. This can be perceived by the example depicted in Fig. 6.

From Fig. 6, we can see that there are two new and unique connections created where one id represents the connection between "1L0BTD6H2-R0QQHM-C4," which depicts the concept "War of American Independence," and "1L0BTFSLJ-V07P09-FB," which delineates a relation "includes". And the other connection id represents the connection between "1L0BTFSLJ-V07P09-FB," which is the relation "includes," and "1L0BTFSLC-PK13WW-F7," which happens to be the concept "Boston Campaign". From this, we can clearly identify that the concept "War of American Independence" is linked with "Boston Campaign" with the relation "includes".

Remember that there is always a unique relation id that exists for each relation in XML files, though there may be more than one same relation name in the concept map. The ids "from-id" and "to-id" are used to represent all the connections between the concepts to the relation and relation to the concepts that forms a link from one concept to another concept from the concept maps. Therefore, by using the above interconnection of information, we propose the hierarchy of the concepts which are based on this connection-list. We propose three levels, and the concepts can be in any of these levels.

- A concept is said to be in Level 0 if the concept-id is only present in "from-id."
- A concept is said to be in Level 1 if the concept-id is present in "from-id" and "to-id."
- A concept is said to be in Level 2 if the concept-id is only present in "to-id."

Hence, for the above concept map represented in Fig. 7, the concepts that are present in the hierarchy of the AISLE system.

4 Theory and Techniques

4.1 Overview of the Technique

The hierarchy of concepts plays an important role in understanding the topic represented using concept maps. This can be explained as follows:

- There is always single root node [18], [20] that is present in the concept map. This usually represents the name of topic in the concept map.

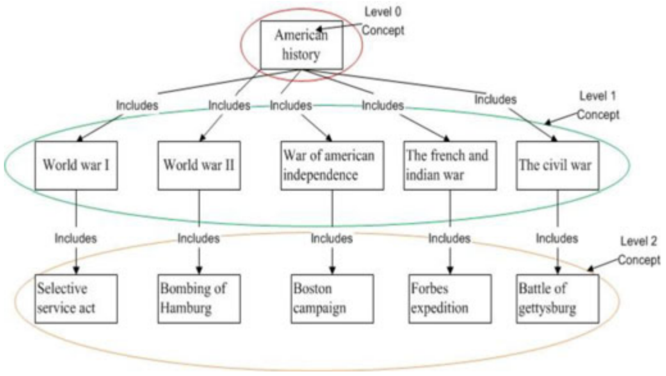

Fig. 7. Hierarchy of concepts in a concept map.

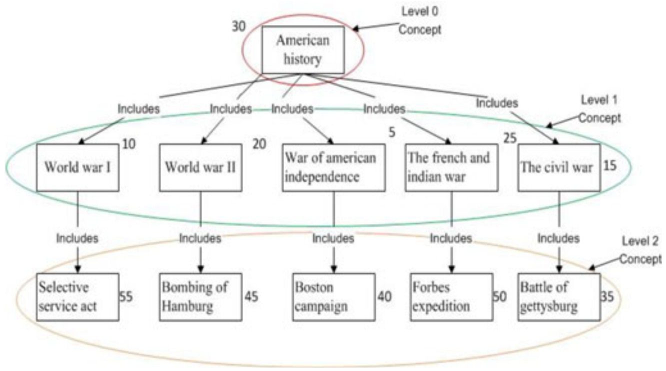

Fig. 8. Scoring individual concepts in a concept map.

- There are concepts that are connected to the root node and are related to other concepts. These represent some aspect of the overall topic covered by the concept map.
- We have concepts that are interlinked with other concepts. These represent in-depth knowledge [9], [19] about the topic in the concept map.

Hence, there is only one concept that is always present in the Level 0 and it is always the root node of the concept. The concepts after the root node are considered to be in Level 1 and concepts interlinked to these Level 1 concepts are found in Level 2. This system of hierarchy still remains if there are more concepts beyond Level 2. The concepts beyond Level 2 will be recursively and iteratively identified as either a Level 1 or Level 2 concept.

An important characteristic of concept maps is that the students develop them and they tend to be unique. This means that different students will very rarely have the same hierarchy or the same name for the concepts. In our process, each student develops a concept map which is translated into an XML file [23], [24], [25]. These files also tend to be unique to avoid plagiarism. Based on the depth of the hierarchy of concepts, we have developed a random scoring system that provides a discrimination of random scores for each concept at a particular level represented by the student.

A particular concept may be related to another concept with a relation; this relation is pivotal in identifying the level of hierarchy involved in the concept map. The more concepts a student represents in the concept maps with its relation [26], [27], the more we believe he or she understands the idea about the topic in study. Thus, the number of concepts identified in a concept map plays a significant role in identifying the depth of knowledge for that particular topic conceived by the student. The scoring analysis is carried out in two steps:

1) First, a random score [15], [16] is given for each concept represented in the concept map.
2) Second, a random score value depends on the level of the concepts in the hierarchy.

Scoring [8], [9] in AISLE is assigning scores in the form of numbers to every concept that is presented in the hierarchy of concept (Fig. 8). The scoring strategies used here are concerned with the total number of concepts existing at a particular level in the hierarchy. This scoring system is described as follows:

1) All the concepts at Level 1 are given equal increments of a random score to each of the concepts.
2) A concept at Level 0, which happens to be the root node, is given a random score after the scores are assigned to Level 1 concepts.
3) All the concepts in the Level 2 are given an equal increment of random scores after assigning the score to Level 0 concepts (for this particular example).

Remember that scoring of concepts at each level is random. Hence, we develop the algorithm for all these concepts, which is present in the hierarchy of the AISLE system. A score of 5 is first given to first concept at Level 1. The algorithm is as shown below.

Scoring Algorithm:

Score[$\text{count}(Concept_{level})$]
Score[0] $= 5$
for i:1 to $\text{count}(Concept_{level1}) - 1$ do
  score[i] $=$ score[i-1] $+ 5$
  score[$\text{count}(Concept_{level1})$] $= 5 +$ score[count
  $(Concept_{level1}) - 1$]
for i: $\text{count}(Concept_{level1}) + 1$ to $\text{count}(Concept_{level1}) + 1 + \text{count}(Concept_{level2})$ do
score[i] $=$ score[i-1] $+ 5$

As mentioned above, we assign a random score to each concept present in the hierarchy. We would like to bring to your notice that in the first iteration, the Level 1 concepts have been assigned scores, followed by the root concept and Level 2 concepts. The random score will be high for all Level 2 concepts when compared with Level 0 and Level 1. This is because Level 2 concepts signify the depth about the topic and hence a higher score is provided to Level 2 concepts. Fig. 8 shows that a random score is given to each concept present in the hierarchy of the concepts in the concept map. Observe that in Level 1, the concept “War of American Independence” has been given a score of 5 randomly and then we incrementally assign the score of 10 to “World War I”. After assigning scores to Level 1 concepts, a score of 30 is provided to the root concept. Finally, Level 2 concepts are assigned scores starting from 35. This scoring system, implemented in AISLE, is based on the structure of the concept map [18], [19]. We believe that the depth of the hierarchy involved in the concept map determines the level of the student understands of the topic in study.

TABLE 1
Standardized Values of Z-Scores for Every Concept in the Concept Map

Concept Number	Name of Concept	$z_{concept}$
1	War of American Independence	−1.53
2	World War I	−1.26
3	The Civil war	−0.98
4	World War II	−0.70
5	The French and Indian War	−0.42
6	American History	0.12
7	Battle of Gettysburg	0.40
8	Boston Campaign	0.68
9	Bombing of Hamburg	0.95
10	Forbes Expedition	1.23
11	Selective service act	1.51

From these random scores assigned as shown above, we calculate the mean of concept scores for all the concepts and the standard deviation for these scores using the basic formulas [15], [16].

4.2 Using Z-Scores of Concepts to Perform Analysis

Based on the aforementioned scores, we calculate the z scores for every concept in the concept map by using the formula [28], [29], [30] below:

$$z_{concept} = \frac{Score_{concept} - Meanofconceptscores}{StandardDeviation_{Score}}, \quad (1)$$

where $StandardDeviation_{Score} \neq 0$

$z_{concept}$ is known as z-value of concept or z-score of concept. Now that the z-score of concept is calculated for every concept in the concept map [5], [6], the random score [6], [28] and is now standardized with the z-scores of concept. The Standardization of z-scores is needed for these random scores which can be explained as follows:

- A Standardized value has no units [15], [16].
- Standardizing value into z-scores does not change the shape of the distribution [15], [16].
- We can easily compare all the concept maps developed by the students to that of the reference of the instructor in a standard manner [16].

The properties of standardizing these scores are as follows:

1) The mean of z-scores is always zero [15].
2) The standard deviation of z-scores is always one [15], [16].
3) The distribution curve for standardized scores is the same as non-standardized scores [15], [16].

These standardized values are tabulated as shown in Table 1.

As depicted in Table 1, a Concept Number is given to each and every level concept in the hierarchy of AISLE. This Concept Number is used to avoid the confusion for the names that are used in two different concept maps. Also, we observe that z-score of concept can be positive or it can be zero, or negative. The significance of the z score of concept is as follows:

1) If the z-score of concept is negative ($z_{concept} < 0$) [16], this means that the concept specified by the student to that value is located below the mean of scores of all concepts.
2) If z-score of concept is positive ($z_{concept} > 0$) [16], this means that the concept specified by the student to that value is located above the mean of scores of all concepts.
3) If z-score of concept is zero ($z_{concept} = 0$) [16], this means that the concept specified by the student is equal to the mean of scores for all concepts.

The standard form of probability distribution function [17], [31] in AISLE is given by the equation

$$P(concept) = \frac{1}{StandardDeviation_{Score}\sqrt{2\pi}} e^{\frac{-(score_{concept} - Meanofconceptscores)^2}{2(StandardDeviation_{Score})^2}}, \quad (2)$$

where $StandardDeviation_{Score} \neq 0 \& 0 < score_{concept} < \infty$

The above Equation (2) clearly represents that mean of scores [15] [16] and standard deviation [16] of scores play an important role in obtaining the normal curve for the concepts covered at a particular level of hierarchy.

As the scores are standardized with the z-scores of concept, the probability density equation for AISLE has to relate with the z-score of concept. The relation of z-score of concept and probability density function for AISLE can be derived as shown below:

We know from Equation (1):

$$z_{concept} = \frac{Score_{concept} - Meanofconceptscores}{StandardDeviationofscore},$$

$$Score_{concept} = z_{concept}(StandardDeviation_{Score}) + Meanofconceptscore. \quad (1a)$$

Now if we differentiate the equation (1a) on both sides, we get:

$$dScore_{concept} = (StandardDeviation_{Score})(dz_{concept}),$$

$$\text{i.e., } dz_{concept} = \frac{dScore_{concept}}{StandardDeviation_{Score}}. \quad (1b)$$

As mentioned, we have done standardization of scores by using z-score for each concept. Hence, the probability distribution for all concepts in the hierarchy of concepts must also be the function of standardization of these scores. Therefore, by substitution, we get

$$P(z_{concept}) = \frac{1}{\sqrt{2\pi}} e^{\frac{-z_{concept^2}}{2}}. \quad (3)$$

The above equation is used in AISLE to calculate the probability values for each concept present in the hierarchy. For a single concept map, we calculate the values for each concept and the results are tabulated as shown in Table 2.

From Table 2, we calculate the standard probability distributions in AISLE for every concept present in the hierarchy. The concept number is mainly used to evaluate the

TABLE 2
Probability Values of Concepts Listed in Fig. 2

Concept Number	Name of the Concept	$P(z_{concept})$
1	War of American Independence	6.18
2	World war I	10.34
3	The civil war	16.24
4	World war II	23.98
5	The French and Indian war	33.39
6	American History	44.97
7	Battle of Gettysburg	34.31
8	Boston campaign	24.78
9	Bombing of Hamburg	16.87
10	Forbes Expedition	10.81
11	Selective service act	6.49

concept maps, which are drawn by students to ensure that no complications arise because of the concept name when a chart is plotted for all these values. As seen from the table, the root node of the concept has the highest probability distribution of all concepts in the hierarchy. This is because the score of the concept is centered at its mean. Also, the concepts in Level 2 indicate the depth of the topic, and at the same time, it indicates the level of understanding about the topic. When a chart is drawn by taking these probability distributions on vertical axis and the concept number on horizontal axis, the resultant line chart for all these distributions is shown in Fig. 9. The above chart shows the standard probability distribution values for all the concepts present in the hierarchy. The root concept is exactly at the center of the mean of all values. The mean of this curve is zero and the standard deviation of this curve is equal to one. The number of concepts present for this concept map is 11, and they are indicated by their concept number. The concept number on the left side of the curve represents Level 1 Concepts, which are necessary, and the concept numbers on the right side of curve represent Level 2 concepts, which indicate the depth of the concepts in the concept map.

4.3 Evaluation of Concept Maps

So far, we have shown how the concept maps are used in AISLE. We would now like to describe the evaluation of these concept maps developed by students. The standard probability distribution of the curve is used as a reference

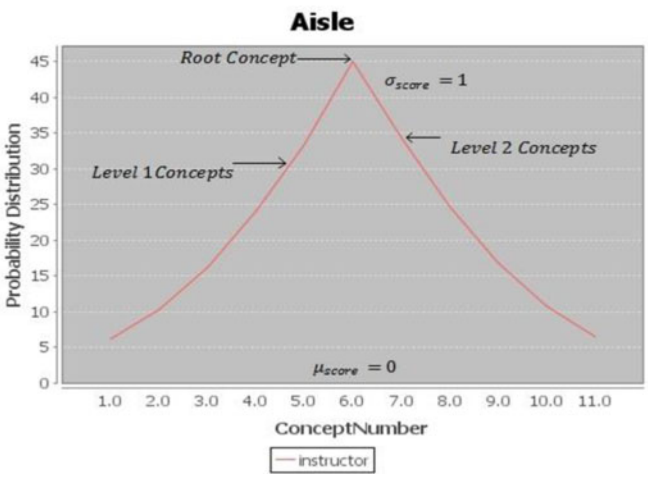

Fig. 9. Line chart distribution for concept map 1.

Fig. 10. Concept map developed by student 1.

curve to evaluate the concept maps drawn by the students. The concept map drawn by the students must be verified and validated by the instructor. To elaborate on the above discussion, we take two sample concept maps developed by two students for a homework assignment in American History. While Fig. 10 illustrates the concept map developed by Student 1, Fig. 11 depicts the concept map developed by Student 2. Fig. 11 shows that the student has mentioned an equal number of concepts in both the levels. We calculate z-scores for all the concepts present in the hierarchy and standard probability distributions. Table 3 below shows the comparison of two concept maps, which are depicted by the students.

The above table clearly shows that the number of concepts in both concept maps is same. Student 1 has more concepts in Level 1. This indicates that Student 1 has done well in understanding the basic supporting concepts about the topic. But the Level 2 concepts described by Student 1 are fewer in number when compared with compared to Student 2. This indicates that Student 2 has gone deeper into each topic with necessary supporting concepts. AISLE generates the chart combined for all of the values calculated for concept map of instructor and student. The observed chart is as shown below. As may be observed from the above chart, we note that the line curve for Student 2 deviates towards the instructor curve. This indicates Student 2 has more Level 2 concepts than Student 1. Hence we can say that Student 2 has gone deeper into the topic under study. Also observe that Student 1 has done well in having more concepts at Level 1. This is indicated in the chart by observing that Student 1 has a curve deviating on the left side.

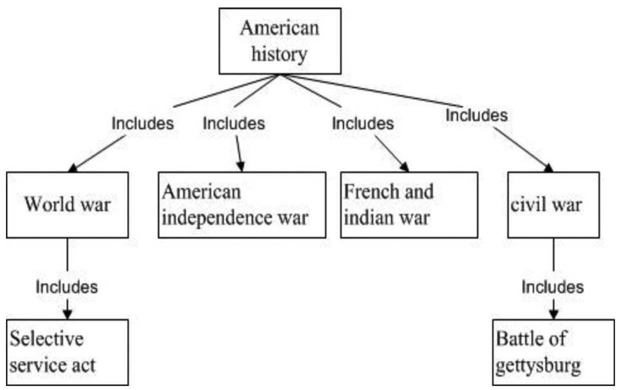

Fig. 11. Concept map developed by student 2.

TABLE 3
Concept Map Comparison for Students

Parameter	Student 1	Student 2
Number of concepts in the hierarchy of concept map	7	7
Number of Level 1 concepts in the hierarchy	4	3
Number of Level 2 concepts in the hierarchy	2	3

4.4 Why Not Bar Charts?

Since we now have the probability distribution values for concept maps of the instructor and students, these values can also be plotted on a bar chart as described in Fig. 12. As observed from Fig. 12, we can directly indicate the number of concepts that are present in the hierarchy. However, to ease evaluation, we do not prefer bar charts based on the reasons listed:

1) When the concept maps used for evaluation are higher in numbers, it will be difficult to show which student has done well in covering the depth of the topic.
2) Clear analysis of a large number of concept maps is difficult to achieve using bar graphs.

Hence, it is better to perceive line chart distributions for evaluating concept maps.

4.5 Parameters Used to Evaluate Concept Map in AISLE

To evaluate the concept maps in AISLE, the parameters that play an important role are as follows:

1) Height of the curve, which represents the standard probability distribution value where the mean of the curve is equal to zero.
2) Concept number, which represents the numeric values assigned to each of the concepts in the hierarchy.
3) Leaning of the curve with the standard curve, which represents the depth of the topic or supporting concepts about the topic. Table 4 shows the effect of parameters explained above in evaluating the concept maps.

5 Analysis and Results

5.1 Analysis of Concept Maps for CSCI 428 Using AISLE

Students registered for CSCI 428 (Object Oriented Programming) were requested to develop concept maps based on the use of design patterns and object oriented design principles used for one of their homework assignments. While the class strength was twenty, eight students volunteered to participate in testing this tool. These developed maps provided some indication of the depth of their knowledge in object oriented programming and design in providing a solution for the assigned problem. Students represented their different ideas demonstrating their knowledge. We evaluate these concept maps to observe the depth of a student's level of understanding of the topic. We took the concept maps, ran them on AISLE, and found the interesting results.

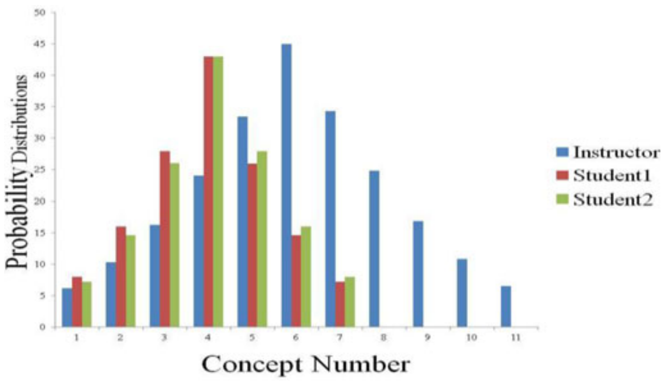

Fig. 12. Bar chart depicting standard probability distribution.

As seen from the above graph, clearly Student 1, Student 5, Student 6, and Student 8 have equal heights. Student 8 has the highest peak of all the concept maps; therefore, he has represented well in identifying the key concepts and represented depth in his knowledge. Student 5 has not identified the key concepts well for his implementation of the project, which can be seen in Fig. 13. Student 2 and Student 4 have represented fewer concepts and have not represented their information as in-depth. Student 1 and Student 3 have identified few key concepts and have gone deeper in representing the information for these concepts.

Since the tool provides a better representation of the concepts that are present in the hierarchy of the concept map, we use this as a measurement technique in evaluating the concept maps. Below, the table shows the concepts that are present in the hierarchy of the concept map.

As seen from the Fig. 13, Student 1 and Student 5 have the same height, but they are differentiated by the number of concepts present in their hierarchy. As seen by the curve, Student 5 is leaning left of Student 1. This indicates that Student 1 has identified more key concepts in the hierarchy, which can be seen from Table 1. Similarly for the curves for Student 6, Student 7, and Student 8, we see that they lean more towards to the right of Student 1. Student 8 has represented a deeper knowledge and has done well in representing his idea on implementation of the project. Student 6 and Student 7 has identified the key concepts in Level1 but has not gone as deep in representing the information.

5.2 Analysis of Concept Maps for CSCI 359 Using AISLE

Students who registered for CSCI 359 (Systems Analysis and Design) were requested to develop concept maps for developing a project using Scrum. While the class strength was thirty, nine students volunteered to participate in testing this tool. Both the courses detailed in the study were taught by the same instructor. The concept maps developed contained Product Backlogs and Sprint Backlogs that may be perceived by the student. This assignment focused on the depth and detail of a student's comprehension of the project.

TABLE 4
Parameters Used to Evaluate Concept Maps in Aisle

Parameters	Explanation
Height of curve (Highest standard probability distribution value)	The greater the height of the curve when compared with the standard curve, the more will be the understanding about the topic the concept map represents.
Concept Number in the hierachy	The concept map is verified by the instructor. The more the concepts in the hierarchy, the more depth about the topic concept map represents.
Leaning of curve with reference to standard curve	The more leaning of curve to left side of the standard curve, the more information the concept map represents.

For Student 2's concept map, the height of the curve is more when compared to other concept maps. This indicates that concept map 2 is well structured and that the Student has a different perception, and he sees that he elaborated his ideas on the implementation of the project. He has a different perspective of identifying the key concepts regarding the implementation of the project. For Student 3, the height of the curve is less. This indicates he has simple ideas and he represents the interrelation with the key concepts that he has identified with the project. Overall, he has less understanding about the project ideas and representing those ideas. As the tool gives a better representation of the concepts that are present in the hierarchy of the concept map, we evaluate this as a parameter for evaluating the concept maps.

As seen from Table 6, we can identify that Student 7 has the highest number of concepts at Level 2. This indicates that he has done well in representing his total ideas in depth. Student 2, Student 5 and Student 8 have an equal number of concepts in Level 2, but Student 8 has represented elaborated knowledge with Level 1 concepts. Student 5 has done better in representing his ideology in representing his domain knowledge. Student 2 has gone to deeper in his idea of implementing his own project ideas.

Student 1 and Student 9 have an equal number of concepts in the hierarchy, but Student 1 has a deeper representation of knowledge when compared to Student 9 which can be observed from Fig. 14.

The concept map submitted by Student 4 has identified fewer concepts in the hierarchy. This indicates that the student has identified fewer concepts and has represented a simple concept map with some basic ideas of implementing his project. There is not much in-depth knowledge in his concept map.

5.3 Observation on the Use of AISLE for Classrooms

Based on the experimentation explained in Sections 4.1 and 4.2, we have made the following observations (Table 5):

- Use of AISLE considerably reduces the time involved in assessing a student's understanding of a topic in study for the instructor.
- Allows for the comparison of multiple students' understanding on a given topic, such that the

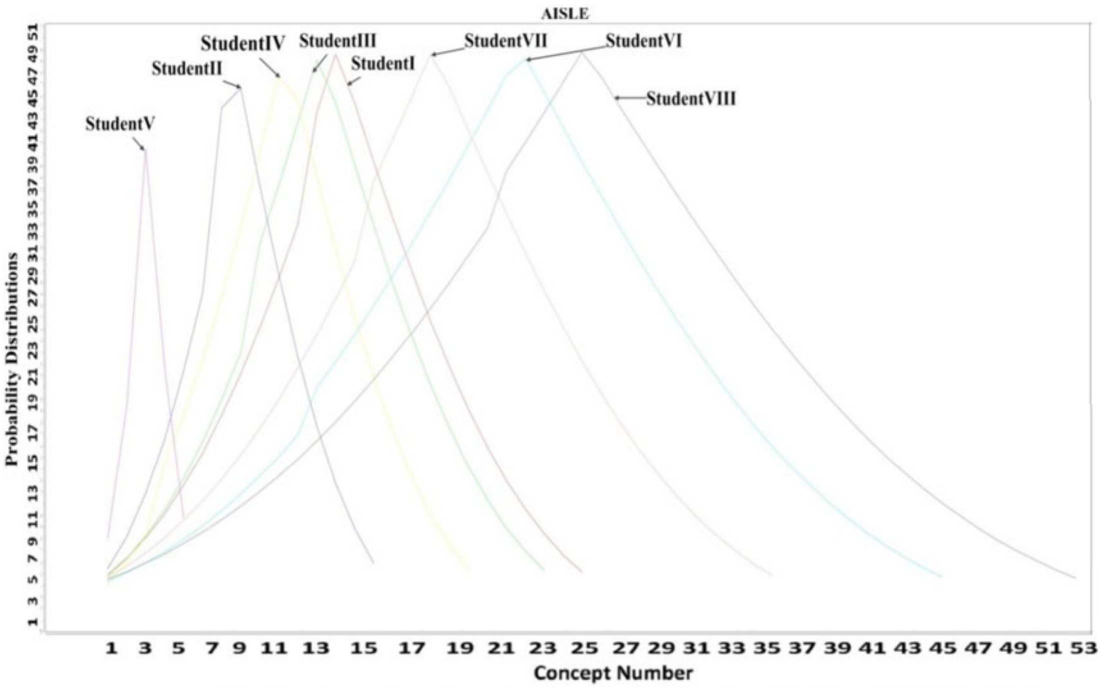

Fig. 13. Probability distribution curves for concept maps developed for CSCI 428.

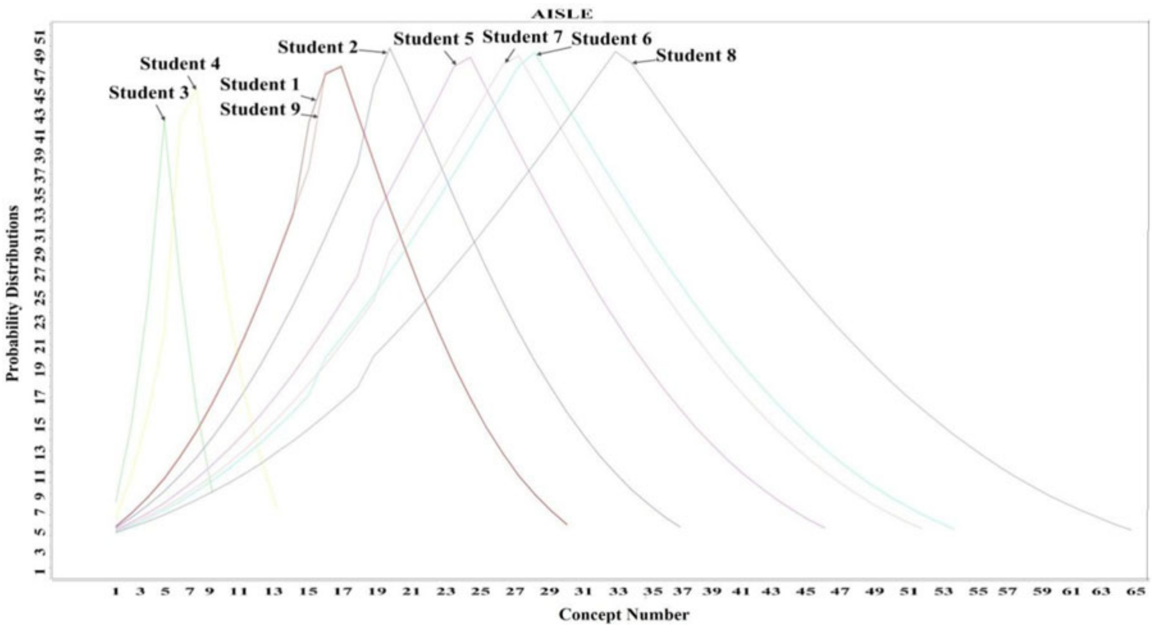

Fig. 14. Probability distribution curves for concept maps developed for CSCI 359.

instructor can assess how much variability there is between students.

- Provides an overall picture on the depth of a student's understanding of the topic.
- The technique used for assessment works well when the concept map developed by the student involves a good use of hierarchy. However, more sophisticated methods may be required to assess concept maps that do not involve hierarchy in representing information using concept maps.
- The experiment indicated that all students having a curve to the right made an excellent score on the related course item. A few students who had the curve to left made scores below the class average.

The limitations of our current approach include:

- The method used to assess concept maps does not work very well when the concept maps submitted by the students are not hierarchial in nature.
- The validation of the concepts contained in the concept maps has to be done manually by the instructor.

5.4 Comparison With Other Related Methods

The concept map-based intelligent knowledge assessment system presented by Lukasenko and Vilkelis [39], and Personalized Assessment System developed by Gouli et al. [40], attempts to individually analyze the depth of a student's knowledge by allowing them to add concepts and relations to the concept maps developed by the instructor. These systems provide emphasis on assessment of an individual student. However, it may be sometimes required that a comparative assessment of students' knowledge be carried out to ascertain the efficiency of the process involved in instruction. For example, Student 1 may score 78 and Student 2 may score 98 on a scale of 100 on a test given by the instructor. However, many other analysis methods may indicate that Student 1 has a better understanding of the topic than Student 2. This situation requires the need for developing an alternative method to compare the students in a course. The other issue associated with a system that assesses and compares student knowledge using concept maps would be the choice of method used to carry out that assessment. Annohina-Naumeca and Milasevicha [41] present a scoring technique for concept maps termed as "Knowledge Assessment System." In this system, they provide a broad theoritical framework for assessing concept maps based on concept-link-concept triples. This approach exploits the semantic relationships between concepts using XML. Zapata Rivera [42] were among the first to exploit semantic relationships using XML for developing

TABLE 5
Number of Concepts in Aisle

S. No	Concepts in Level 1	Concepts in Level 2
Student 1	14	11
Student 2	8	6
Student 3	15	8
Student 4	16	3
Student 5	2	2
Student 6	33	11
Student 7	21	14
Student 8	30	21

TABLE 6
Number of Concepts in Hierarchy of Aisle

S. No	Concepts in Level 1	Concepts in Level 2
Student 1	15	13
Student 2	19	16
Student 3	3	3
Student 4	6	4
Student 5	28	16
Student 6	39	13
Student 7	33	17
Student 8	47	16
Student 9	16	12

TABLE 7
Comparison between Aisle and Intelligent Knowledge Assessment System

	AISLE	Intelligent Knowledge Assessment System
1	Comparing concept maps to access student's understanding of a topics	Access an individual concept map for analyzing the depth of a students understanding of the topics [39]
2	Can be used to be used to validate the process used for testing and grading the students	Focused more on identifying an individual's understanding of the topic

TABLE 8
Comparison between Aisle and Personalized Assessment System Supporting Adaptation and Learning [40]

	AISLE	PASS
1	Validation of concept maps is left to the instructor	Supports investigation of unknown concepts and misbelieves [40]
2	Focus is on an individual's relative understanding of the topic with respect to other students	Provides focus on an individual's understanding of a particular topic

TABLE 9
Comparison between Aisle and Knowledge Assessment System

	AISLE	Knowledge Assessment System
1	Concepts maps are developed by the students from the scratch	Allows students to add to an existing concept map [41]
2	Uses a definitive scoring system to assess the strength of a concept map using probability distribution	The scoring system is more or less theoretical in nature

educational systems .Tables 7, 8, and 9 provide a comparison between AISLE and the aforementioned systems.

5.5 Teacher's Reaction to AISLE

As indicated before, AISLE was tested with two undergraduate classes in computer science. The instructor for these courses requested the students, who volunteered for the project, develop concept maps based on a homework question. The following observations were identified by the instructor:

- The scores the students made on the regular homework question somewhat reflected the observation made on the graph generated from AISLE. For example, a student who scored well on the homework question also had a curve leaning towards the right.
- The instructor also identified that AISLE could be used to validate the testing and grading procedures carried out in the course.

6 Conclusion and Planned Future Work

The implementation of AISLE can be extended by using Markov Chains. We are currently in the process of developing Markov Chain models by extracting all the required information from the concept maps developed by students. This information includes concepts, relations between concepts, and the scores [9], [13] which are given to each and every concept in the concept map. Markov Chain models have been used extensively for decision making [32], [37], and we use these models to predict the understanding of the concept maps developed by the students. These models use the transition probabilities [33] where all concepts undergo transitions from one state [32], [34] to another between a finite or countable number of all possible states [34]. The proposed model is applied and evaluated by developing Transition State Matrix (TSM) [35] and using the Markov Chain Monte Carlo (MCMC) [36] simulation technique where the next transition depends on current state but not on preceding steps.

In this paper, we have described our tool for the purpose of identifying the level of a student's understanding of a particular topic using concept maps. AISLE has been developed using Java and XML parsers associated with it to extract the necessary information from the concept maps [38]. As mentioned in the previous section, we are now in the process of advancing the assessment technique incorporated in AISLE by experimenting with other methods such as Markov Chains. Overall, we believe that our tool and the method associated with it will be useful for instructors in identifying and assessing their ability to induce good understanding of topics and improve their teaching methods.

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