International Journal of Applied Engineering Research ISSN 0973-4562 Volume 11, Number 1 (2016) pp 479-483

A Novel Evaluation Scheme using Formal Concept Analysis

Sushma Hans
Research Scholar, Department of Computer Engineering
Netaji Subhas College of Engineering, Sector 3, Dwarka, New Delhi, India.
E-mail: sushma.nsit@gmail.com

S. Chakraverty
Professor, Department of Computer Engineering
Netaji Subhas College of Engineering, Sector 3, Dwarka, New Delhi, India.
E-mail: apmahs.nsit@gmail.com

Abstract

We consider that the simple accomplishment of knowledge is not sufficient. This article attempts to look at the importance to understand the required fundamental learning skills such as creative skill, critical skill etc. that facilitate the incorporation of knowledge appropriately**.** Thus, it is needed that a course must be studied systematically in terms of the required learning skills. In this paper, we present a novel evaluation scheme for a course that focus on the various sets of learning skills required for each concept of the course. We employ Formal Concept Analysis on a complete set of questions prepared by experts covering all the concepts of a given course. This procedure generates a lattice of formal concepts, each presenting a group of questions that involve a common circle of learning skills to resolve them. These formal concepts can serve as performance parameters for assessing the students in a skill-centric fashion.

Keywords: Learning Skills, Evaluation, Assessment, Performance Parameters, Formal Concept Analysis.

Introduction

The present study focuses on evaluating a course in terms of its required learning skills. Evaluation requires collection, analysis and interpreting information about learning a course in order to make cued decisions that improves student achievement and develop their learning skills [1-4]. Evaluation is a process that involves the following components:

1) Identifying and gathering relevant information
2) Having thoughts that are valuable and useful to learners in their lives and professions
3) Examining and interpreting information to learners.
4) Articulate the purpose of the educational system

In classroom teaching, teachers themselves analyze the questions and determine the learners' weak points and their shortcomings. They then utilize these results of the assessment of their teaching to make their teaching practice more efficient. Assessment is basically performed in order to distinguish whether or not the learning has been successful or not as well as to clarify the expectations of the teachers from the pupils [5].

Assessment of learners focuses on these points:

1) Quantifying learners' progress over time
2) Inspires learners to study effectively
3) Assessing the teaching methods
4) Ranking the learners' abilities in relation to the whole class evaluation

The main purpose of assessing and evaluating students is to determine their knowledge and abilities. The evaluation process can focus on different aspects of teaching and learning.

A prime concern in learning a course is whether learners attain the objectives of the curriculum. Objectives refer to the goals of a course of instruction. We consider the goal of learning a course is to develop the technique of applying a set of learning skills together to solve any kind of problem.

There is a clear cut difference between assessment and evaluation. Assessment is one important aspect of evaluation. It only involves the measurement and analysis of information about student learning. The evaluation process goes beyond the student achievement and it involves the educational decisions that are derived from various forms of assessments. The authors also believe that the purpose of evaluation is two-folds: one is to enhance student's learning and the other is to help teachers to improvise their teaching practice as well [6-9].

In this paper, we put forward a method to comprehensively examine the questions pertaining to a course. Each question in the examination is tagged with different skills that are required to solve them. The questions in the examination are utilized to identify well-defined skills based performance parameters of the course. The assessed marks of the examination are utilized to evaluate the students' in terms of these PPs to derive their knowledge and the ability to apply these skills in various combinations to solve various problems. The contributions of this paper are summarized below:

(i) We apply Formal Concept Analysis (FCA) to draw up the lattice of formal concepts that depict the course domain in terms of sets of questions and the skills needed to resolve them. These formal concepts serve as effective skills-based Performance Parameters (PP) to assess students. To the best of our knowledge, it is for the first time that a formal method has been used to dissect a course in terms

of the core learning skills that are required to use its concepts in solving complex problems effectively.

(ii) We augment the traditional method of question-wise evaluation with an automated mechanism to examine groups of questions to evaluate the skill levels attained by scholars.

Formal Concept Analysis

FCA offers a rationale for examining the data related to a domain of objects having certain attributes by mining conceptual entities from the data.

Formal Context: It takes as input a data table, *i.e.* formal context $\langle A,B,I\rangle$, that describes the relation I between the set of objects A and a set of attributes B [10, 11]. The notation $\langle a, b\rangle \in I$ shows object a has attribute b.

Formal Concept: A formal concept is portrayed by a group of objects demonstrating a concept called *Extension* and a distinctive combination of attributes that is applicable for the entire group called *Intension.* For a formal context $\langle A, B, I\rangle$, a formal concept is a pair $\langle X, Y\rangle$ of Extension $X \subseteq A$ and Intension $Y \subseteq B$ such that $X^{\uparrow} = Y$ and $Y^{\downarrow} = X$ where,

$X^{\uparrow}$represents the set of all attributes that are common to the objects of X as computed in *eq.* 1:

$$X^{\uparrow} = \{b \in B \mid \text{for each } a \in X: \langle a, b\rangle \in I\}, \quad (1)$$

$Y^{\downarrow}$ represents the set of all objects sharing all attributes from Y calculated using *eq.* 2.

$$Y^{\downarrow} = \{a \in A \mid \text{for each } b \in Y: \langle a, b\rangle \in I\}. \quad (2)$$

Concept Lattice: Concepts are partial ordered by inclusion in a formal context. Suppose X and Y are concepts, we define a partial order $\leq$ by saying that $X \leq Y$ whenever $Extent(X) \subseteq Extent(Y)$. Equivalently, $X \leq Y$ whenever $Intent(Y) \subseteq Intent(X)$. A concept lattice is inclusive lattice that presents the partial ordering of all the formal concepts that can be derived from the data. It represents the super-concept sub-concept relationships between the formal concepts.

We employ In-Close algorithm to compute all formal concepts in a given formal context. This algorithm carries out implicit searching through lexicographic approach to find out incremental closures. It is computationally easy and needs no matrix preprocessing.

Skills based Evaluation of the Course

A. Learning Skills

A learning skill is an intellectual ability that a scholar must be equipped with to learn and assimilate the concepts of a knowledge area and apply the learnt concepts effectively. The 21st century learning skills are called the 4C's: Creative Thinking, Critical Thinking, Collaborating and Communicating. These skills help student learn, so these are significant to attain success in life [12].

Creative Thinking: Creative thinking is open-ended invention, expansive and discovery of possibilities. Some of the most common critical thinking skills include brainstorming ideas involves asking a question and rapidly listing all potential solutions, innovating something new, improvising a solution in a novel way, creating, designing, imagining, problem solving that requires the exercise of many creative skills to figure out potential answers.

Critical Thinking: Critical thinking involves careful and focused analysis of something to better understand it. Some of the main critical thinking skills are analyzing, classifying, comparing, defining, describing, evaluating, explaining, *etc.*

Collaborating: Collaborating skills involve allocating resources, decision making, goal setting, handling time, solving differences and team building.

Communicating: Communicating skills includes analyzing the situation, evaluating messages, listening actively, reading, speaking, writing, and so on.

Each learning skill in itself is a combination of various other skills. The moot point is, these skills help in the assimilation of knowledge and in employing the knowledge gathered to solve simple as well as complex problems. In short, they help students learn better. For the sake of discussion in this paper, we shall consider only five learning skills named as A, B, C, D, and E.

B. Preparing the Formal Context

Given a course, we characterize a formal context $\langle Q, S, R\rangle$ as a Relation R between Q, a set of Questions that comprehensively cover all the concepts included in its syllabus and S, a set of learning skills that are needed to effectively answer them. We name the formal context as Questions Skills Table (QST). The formulation of the formal context by designing questions and generating the QST is done manually by course experts.

Preparing Questions: This is a critical part of teaching. Experts prepare and regularly update a database of questions, giving wide coverage to all the concepts included in the prescribed course of study for an exam. A gamut of objective and subjective questions must be projected in order to assess the students' extent of learning various concepts and their expertise in employing the required learning skills to resolve problems linked to these concepts.

Questions-Skills Table: Experts mark each question based on the required skills to solve them. Some questions may possibly call for a combination of various skills. For example, in a research-based question, a student would require creative as well as critical skills to apply rules and theorems to manipulate them and writing skills to present the concise conclusions. In an explanatory question, a student typically needs to recollect and correlates ground facts with her critical skill and also present it persuasively with her writing skill. Thus, different questions need diverse kinds of skills that can either be used in isolation or in conjunction to solve them.

The QST in Fig. 1 has a row for each question and a column for each skill attribute. It includes 25 questions and 5 skills as described before. A table entry '1' in (r,c) signifies an incidence relation between r and c, that the skill c pertains to question r, while '0' indicates that the skill is

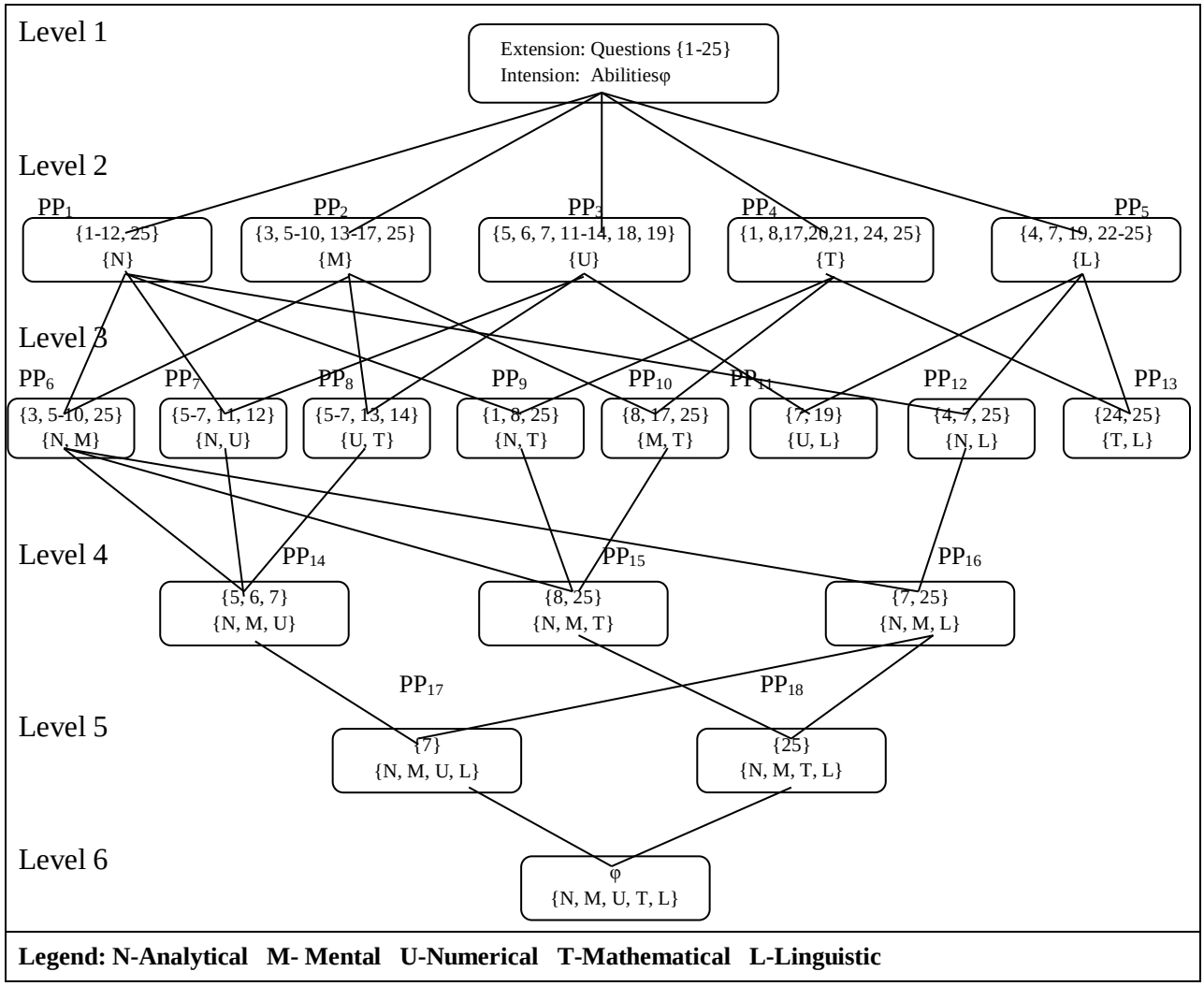

Figure 1: Concept Lattice generated for the QST in Table 1

irrelevant to it. We will use this QST as a leading example for our explanation and experiments.

C. Extracting the Performance Parameters

The system makes use of Formal Concept Analysis (FCA) to the QST to extract a lattice of formal concepts [10, 11]. FCA provides a rationale for examining the information pertaining to a domain of objects having certain attributes by extracting conceptual entities from the data.

Table 1: Questions - Skills Table

Q No.	A	B	C	D	E
1	1	0	0	1	0
2	1	0	0	0	0
3	1	1	0	0	0
4	1	0	0	0	1
5	1	1	1	0	0
6	1	1	1	0	0
7	1	1	1	0	1
8	1	1	0	1	0
9	1	1	0	0	0
10	1	1	0	0	0
11	1	0	1	0	0
12	1	0	1	0	0
13	0	1	1	0	0
14	0	1	1	0	0
15	0	1	0	0	0
16	0	1	0	0	0
17	0	1	0	1	0
18	0	0	1	0	0
19	0	0	1	0	1
20	0	0	0	1	0
21	0	0	0	1	0
22	0	0	0	0	1
23	0	0	0	0	1
24	0	0	0	1	1
25	1	1	0	1	1

Fig. 1 illustrates a concept lattice of 18 formal concepts derived for the QST in Table 1. Each formal concept ⟨R, V⟩ has two components: Its extension $R \subseteq Q$ of a formal concept encompasses a subset of questions and its Intension $V \subseteq S$ contains the specific skills that all these questions share in common. Each formal concept generated is a discrete Performance Parameter (PP). The complete sets of PPs are conceptual entities that give whole knowledge about the

domain of the course in terms of the skills required to solve the questions that are set to evaluate students' learning of the course.

The first node at Level-1 shows a super-concept that encompasses all the questions in its Extension but an Intension= φ (null) as none of the skills are common for all twenty-five questions. This node branches out to five PPs at Level-2, each of them containing questions that require one specific skill among those enlisted in the QST. Later, the concept lattice grows to include PPs that embodies questions requiring different combinations of skill set at Level-3, Level-4, and Level-5. Finally, Level-6 contains only one sub-concept that contains all the skills, but here the Extension is φ as there is no such question in QST that requires all five skills to resolve it. The PPs that are connected from one level to the next follow a super-concept sub-concept relationship.

D. Preparing the Student Assessment Table

The traditional assessment of students is carried out by human evaluators. Given a set of questions to be answered by students either in an examination or as assignments, evaluators follow the conventional assessment method of checking the answer to each question independently. The evaluator stores the performance of all scholars in a Student Assessment Table (SAT). Table 2 illustrates a sample SAT for 5 students. This table has a row for each student and a column for each question. A cell (r, c) shows whether the student r has provided an acceptable solution for the question c.

We set a performance threshold for each question that determines an acceptable level of expertise acquired. If a student's answer satisfies the threshold, her answer is considered acceptable and its corresponding entry in SAT is marked as '1'. Otherwise, the answer is considered below par and it is marked '0' in the SAT database. Therefore, each cell in the SAT contains a binary valued number that shows whether the student has reached the required performance threshold or not. Looking at the first row in Table 2, we find that student S_1 has successfully achieved the performance threshold for questions 1, 7, 8, 12, 13, 18 - 24, but has failed to deliver satisfactory answers for the remaining questions.

Table 2: Student Assessment Table

Students	Questions																								
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**
S_1	1	1	1	0	1	0	0	1	1	1	0	0	0	1	1	1	1	0	0	1	1	0	0	0	1
S_2	1	0	0	0	0	0	1	1	0	0	0	1	1	0	0	0	0	1	1	1	1	1	1	1	0
S_3	0	1	1	1	1	1	1	0	0	1	1	1	0	1	0	0	1	1	1	0	0	1	1	0	1
S_4	1	1	0	1	1	0	1	1	0	1	0	1	0	0	0	0	0	0	1	1	1	1	1	1	1
S_5	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	0	1	0	0	0	0	0	0	1

E. PP-Based Performance Evaluation

The automatic evaluation module now takes over from human evaluators to get their skills centric evaluation based on the PPs. The core behind PP-based evaluation is that the scholar is assessed by examining how well she has performed in *all* the questions in the extension of a PP. Based on this, the system decides to what extent is the student proficient in the skills that are included in the intension of that PP. The assessment is repeated for all the PPs generated by FCA.

As shown in Fig. 1, the automated evaluation module uses the concept lattice of PPs and the SAT as inputs and generates a record of all students' performance in a Performance Table (PT). The PT has one row for each student and one column for each PP. This module utilizes the following rules for evaluating a student:

(i) A student is considered *good* in a PP if, the SAT indicates she had given acceptable answers to 75% or more of the total number of questions included in the Extension of that PP. The corresponding cell in the PT receives an entry '1'.

(ii) A scholar is considered weak in a PP if she had served only 30% or less of the total number of inquiries in the Extension of that PP satisfactorily. An entry '3' is recorded in the corresponding cell in the PT.

(iii) If a pupil does not pass into either of the category i.e. good or weak, then she is regarded as mediocre in that PP. The corresponding cell in the PT receives an entry '2'.

Table 3 shows the PT generated in terms of each of the 18 PPs given in Fig. 2 using the SAT given in Table 2. To illustrate,

PP_1 includes 13 questions in its Extension, including questions 1 to 12 and 25. Thus, the minimal number of questions needed to be done correctly for achieving *good* category for this PP is 0.75*13=9.75, or 10 questions. A *weak* student answers a maximum of 0.30*13=3.9 or 4 correctly. If a student answers more than 4 but less than 10 questions correctly, then she is judged as *average* in PP_1. Considering the example of student S1 in Table 2, we find from the SAT that she has answered 8 out of 13 questions in PP1 correctly and is therefore average in PP1, recorded as '2' in cell (1,1).

The above approach of judging students on the basis of set of questions coherently gives a more refined assessment of their learning than the traditional evaluation method. It emphasizes not only on the knowledge that a student has gained, but also on the proficiency level in different learning skills that he or she has developed practically. The pedagogical benefits that build up due to our proposed approach are:

- Each PP has an intent that represents a combination of various learning skills. As students gradually improve

upon these PPs, they learn to apply a set of skills jointly to resolve many complex problems.

- Different concepts of a course may cover entirely different course matter, only the questions set to test these concepts may involve the same basic skills to resolve them. Thus, when students augment their proficiency in a particular set of skills, they actually gain strength on several concepts.
- The same set of skills may cover different courses. Hence, skills enhancement can facilitate a student to grasp and master different courses and facilitate interdisciplinary learning.

Table 3: Performance Table PT

Students	PERFORMANCE PARAMETERS (PP)																	
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**
s_1	2	1	3	1	3	1	3	2	1	1	3	2	2	2	1	2	3	1
s_2	2	3	2	2	2	3	2	2	2	2	1	2	2	2	2	2	1	3
s_3	1	2	1	3	1	1	1	1	2	2	1	1	2	1	2	2	1	1
s_4	2	2	2	1	1	2	2	2	1	2	1	1	1	2	1	1	1	1
s_5	1	1	1	2	3	1	1	1	1	2	2	2	2	1	1	1	1	1
Legend: 1-Good, 2-Average 3-Weak																		

In this way, we can derive performance parameters for any course. Then, we can do an evaluation of a course in terms of these performance parameters. This method of evaluation helps in improving student's learning as well as guide teachers to improve their way of teaching for overall development of students.

Conclusion

In this article, we set out with an innovative idea of performing a formal analysis of a course by applying formal concept analysis on its question bank to extract its formal concepts in terms of skills based attributes. These formal concepts were utilized as performance parameters to systematically re-assess the traditional and manual evaluation of students in a skill-centric manner.

References

[1] Jabbarifar, T. (2009). The Importance of Classroom Assessment and Evaluation in Education System. In Proceedings of the 2nd Conference of Teaching and Learning (ICTL), Malaysia, pp. 1-9.

[2] Gensee, F. and J. Upshur (1996). Classroom-based Evaluation in Second Language Education. Cambridge University Press.

[3] Rea-Dickens. P. and K. Geimanie (1993). Evaluation Oxford: Oxford University Press.

[4] O' Malley, J. M. and L. Valdez-Pierce (1996). Authentic Assessment for English Language Learners: Practical Approaches for Teachers. Reading. MA: Addison-Wesley.

[5] Biggs, J. (1999). What the Student Does: Teaching for enhanced Learning. Higher Education Research and Development, Vol. 18 (1), pp. 57-75.

[6] Carter, R. and D. Nunan (2001). The Cambridge Guide to Teaching English to Speakers of Other Languages. Cambridge: Cambridge University Press.

[7] Richaids, J. C. and C. Lockhart (1994). Reflective Teaching in Second Language Classrooms. New York: Cambridge University Press.

[8] Nunan. D. (1989b). Understanding Language Classrooms. London: Prentice Hall.

[9] Allwright, D. and K. Bailey (1991). Focus on the Language Classroom: An Introduction to Classroom Research or Language Teachers. New York: Cambridge University Press.

[10] Cimiano, P., A. Hotho, A., and Staab, S., 2005. Learning Concept Hierarchies fromText Corpora using Formal Concept Analysis. Journal of Artificial Intelligence Research(24), 305-339.

[11] Belohlavek, R., 2008. Introduction to Formal Concept Analysis. Springer, Olomouc.

[12] https://k12.thoughtfullearning.com/FAQ/what-are-learning-skills. Last Accessed on: 9th December 2015.