Assessing Student Learning Outcomes Using Mixed Diagnostic Tests and Cognitive Graphic Tools

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***Abstract*—In this paper, we provide an approach to assessing student learning outcomes by using mixed diagnostic tests. These tests represent an optimal compromise between unconditional and conditional components and facilitate the development of individual learning paths, which, in turn, would provide students with the opportunity for self-guided learning. To construct individual learning paths, we apply an intelligent learning and testing system. Thus, each student becomes able to predict their learning outcomes following the respective learning path designed. In addition, we describe a cognitive graphic tool the 2-simplex prism to cognitively visualize the results of student learning assessment. We assume that our approach can be used when assessing student learning outcomes within any subject and propose applying this approach as a tool to enhance both student and teacher activity.**

***Keywords*—intelligent learning and testing system, cognitive graphic tools, blended learning, mixed diagnostic tests, semantic network, 2-simplex prism, e-learning course, student-oriented approach, prediction of learning results**

I. Introduction

Among the existing approaches to student activity assessment, we outline using cognitive graphics as a promising avenue for education research. The importance of cognitive graphic tools in education has been pointed out by an extensive body of literature [1]–[3]. A group of researshers in [1] highlighted the fact that using cognitive graphics for assessment can enhance student learning performance by giving an opportunity to design a learning path for each student. Moreover, effective tools of cognitive assessment contribute to learning content improvement, revealing successful ways for teachers to design learning activities.

Axelrod [4], Pospelov [5], Zenkin [6], Kobrinskiy [7], [8], Albu and Horoshevskiy [9], Kolesnikov et al. [10] and Yankovskaya et al. [1] have contributed significantly to the development of cognitive graphic tools for different problem areas. In 1996, Yankovskaya [11] introduced a versatile means of assessing student knowledge of a particular topic by using mixed diagnostic tests (MDTs). These tests represent an optimal compromise between unconditional and conditional components. We will illustrate the essentials of MDTs design in the next section.

In their research, Kulikovskikh, Prokhorov and Suchkova [12] outlined the following essential learner characteristics to be assessed: 1) learning style, 2) background, 3) motivation, and 4) level of knowledge. The researchers also provided a versatile tool to assess test results and reveal the probability of guessing for each student. Moreover, using fuzzy learning performance assessment proposed by Proknorov and Kulikovskikh [13] facilitates the enhancement of student learning and the development of cognitive graphics.

Nevertheless, as well as positive findings that have accrued, taking into account the specificity of e-learning, an increasingly critical research agenda is emerging. For example, different learning activities require different assessment approaches. Moreover, both students and teachers need to monitor systematically all the aforementioned learner characteristics and visualize them in a single reference frame by cognitive graphic tools.

We wish therefore to focus on issues associated with the cognitive visualization of student learning assessment. Furthermore, we present an Intelligent Learning and Testing System (ILTS) that guides students through the learning module and provides the cognitive visualization of their activity.

II. Construction of Mixed Diagnostic Tests

We constructed MDTs [11] using a syllabus for the discipline of "Power Electronics". Briefly, in the course of training, students perform learning activities and do these tests. At first, students take an unconditional diagnostic test to reveal their initial level of knowledge. The questions in such a type of test are randomly presented to a learner to estimate the basic knowledge of a subject. Then, if a student has passed the unconditional diagnostic test, they take a conditional diagnostic test. In this type of test, each subsequent question depends on the answer to the previous one. Thus, the result of the test strongly depends on the learner decision.

We represent the construction of MDT on a graph diagram (Fig. 1). In the upper part of Fig. 1, you can see a table with the rows denoting the questions of the unconditional diagnostic test. The number of answers to each question corresponds to the columns of the table. In this case, n is the number of

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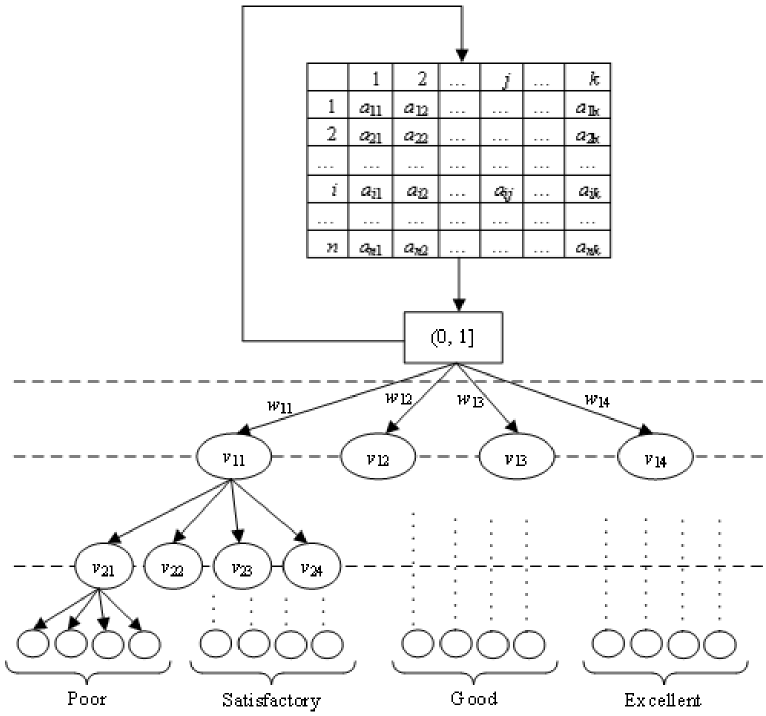

Figure 1. Mixed diagnostic test construction.

questions, k is the maximum number of various answers to each question ($k \geq 2$). Some cells of the table can be empty. The element of the table $a_{i,j}$ is the weight of the j-th answer to the i-th question, $0 \leq a_{i,j} \leq 1$.

Each edge on the diagram (Fig. 1) matches the weight $w_{i,j}$, which corresponds to the complexity of a question in the conditional diagnostic test. Herein, i is the level number, j is the number of the edge. A test question corresponds to each node of the graph $v_{i,j}$, where i is a level number and j is a node number at the current level.

After completing the test, each student gets their result in the form of a conventional grade (poor, satisfactory, good, excellent) and visually observes the overall evaluation of their knowledge using cognitive graphics.

III. Essentials of the Intelligent Learning and Testing System

To introduce the automation of learning and cognitive assessment, we have been developing the ILTS for more than ten years. Here, we use a semantic web to represent the ILTS that supports a student within each learning module in the discipline of "Power Electronics" (Fig. 2).

Using the ILTS, we subdivided the student learning within each module into five subsequent steps.

- Step 1. The students learn all the necessary topics provided by the learning module, which include video lectures with an interactive multimedia content. To create the content, we use the module that transforms the knowledge into the teaching materials using the knowledge database [14].
- Step 2. The students take the MDT and obtain certain results. The tests are constructed by using the knowledge database as well as teacher expert knowledge.
- Step 3. The pattern recognition module converts the MDT results into the assessment using a cognitive graphic tool the 2-simplex prism. We will represent this tool in the subsequent section.
- Step 4. The assessment results are recorded in the outcomes database.
- Step 5. We interpret the assessment using learning outcomes interpretation module. At this stage, the teacher or an expert explains each student how to use the 2-simplex prism for their effective self-evaluation. This helps to reveal student strengths and weaknesses in particular topics of the module.

Student actions may be twofold after the above steps. Thus, if a student needs help with some topics of the module, which is revealed by the supplementary module, they may repeat the corresponding part of the course for better comprehension. Provided a student is satisfied with their learning outcomes, they may go to the next module.

Each learning step is essential for students to reveal and develop their individual approach to comprehending a particular module and spread this approach onto the subsequent learning modules. For this reason, the ILTS records each student step and creates a learner action card (LAC) [14]. The LAC is available to both the student and the teacher so that they

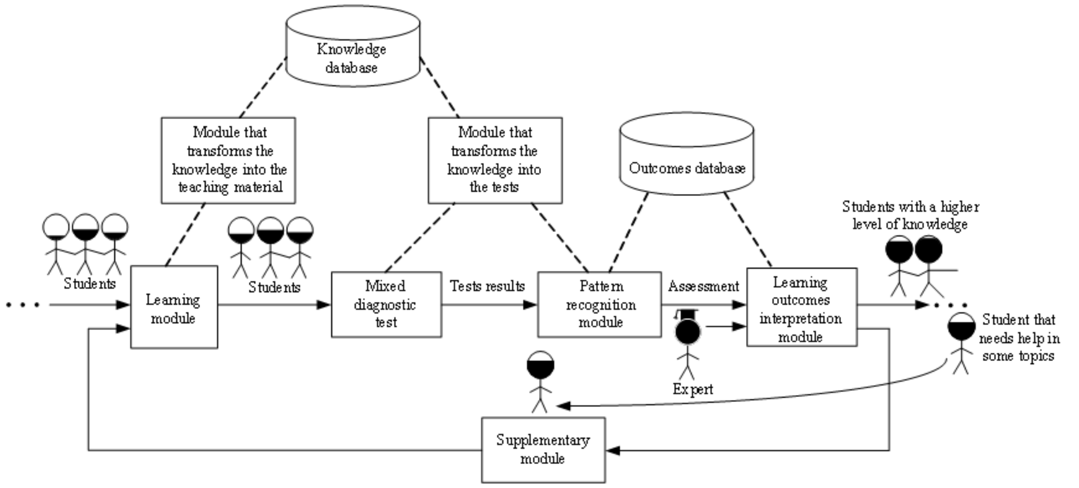

Figure 2. A semantic web illustrating the intelligent learning and testing system within one module of the discipline under study.

could analyze the student knowledge gaps and develop an appropriate learning path for better performance.

IV. Results and Discussion. Interpretation of Learning Outcomes

In this section, we apply the approach to the usage of the 2-simplex prism as a tool to interpret student learning outcomes provided by the ILTS. The prism was first entirely described in [1]. We used the advantages of this tool to assess student performance in the discipline of "Power Electronics". An example of student learning paths designed using the 2-simplex prism is given in Fig. 3.

As shown in Fig. 3, the four points (the small circles of different colors) lie within the 2-simplexes (cross-sections of the 2-simplex prism). These points represent the results of the four tests. The prism faces correspond to grades: 1) "excellent", 2) "good", and 3) "satisfactory". The height from the point to a face within each of the 2-simplexes denotes the proximity degree of the assessment to the particular grade. The distance between two subsequent 2-simplexes indicates the interval between two tests. The dashed black line within the 2-simplex prism shows the evolution of student knowledge level based on the test results at time T_1, T_2, T_3 and T_4.

We observe in Fig. 3 that at time T_1 the student obtained the grade between "satisfactory" and "good", yet close to the level of "satisfactory". Then, having analyzed the test results, the student set a goal of improving the performance and developed a plan on how to achieve this goal (e.g. by taking additional classes or using supplementary tutorials). This led to better assessment results after the 2nd test at time T_2, when the grade was close to "good". Subsequently correcting the individual learning plan, the student finally was able to reach the goal. Thus, at time T_3, the grade was between "good" and "excellent", whereas at time T_4 it approached the level close to "excellent".

We note that we can use another grade system if a student encounters unexpected problems (e.g. health problems, moving, accident, etc.), that could affect significantly their learning performance. In this case, we should use the following grades: 1) "poor", 2) "satisfactory" and 3) "good". Moreover, we are able to switch from one grade system to the other in the course of training depending on the student performance. This means that we use two 2-simplex prisms taking into account the current student grade.

The efficacy of using the 2-simplex prism in the course of learning could be attributed to its versatility and cognitive properties. Although here (Fig. 3) we may observe a linear dependence of the assessment on time, further research is needed to confirm this idea and reveal the peculiarities of the cognitive process over time.

Conclusion

Cognitive visualization of a grade provides not only the assessment of student learning activities, but also sound information on how to achieve that grade and justify this decision. Therefore, each student has the opportunity to take appropriate actions towards the improvement of the grade on a particular topic of the discipline.

The LAC created by the ILTS alleviates revealing student knowledge gaps and helps to eliminate them on time.

The linear dependence of the assessment on time can give us a tool to predict student learning outcomes in the course of their training. This prediction involves using the first order polynomial and is based on the previous as well as the current grade.

In this paper, we have proposed a cognitive way to represent numerical data (grades) by associating a grade with the student knowledge level and visualizing it in a 2-simplex prism. This will presumably be the topic for our further research.

It is noteworthy that we also may use a letter grade assessment to describe student learning performance (A, B, C, D, F, etc.), which is especially relevant when developing learning courses using Bologna declaration [15] to ensure comparability in the standards and quality of higher education

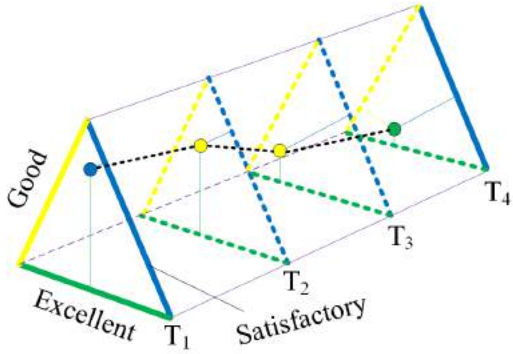

Figure 3. Learning outcomes assessment using cognitive graphic tool the 2-simplex prism.

qualifications. Consequently, the cognitive representation of the letter grade assessment system may also be a promising avenue in our future research.

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ОЦЕНКА РЕЗУЛЬТАТОВ ОБУЧЕНИЯ СТУДЕНТОВ С ПРИМЕНЕНИЕМ СМЕШАННЫХ ДИАГНОСТИЧЕСКИХ ТЕСТОВ И СРЕДСТВ КОГНИТИВНОЙ ГРАФИКИ

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В работе предлагается подход к оценке результатов обучения студентов с использованием смешанных диагностических тестов. Данный вид тестов представляет собой оптимальное сочетание безусловной и условных составляющих, что позволяет разрабатывать индивидуальную траекторию обучения, которая, в свою очередь, обеспечивает возможность самообучения. Для построения индивидуальных траекторий обучения применяется интеллектуальная обучающе-тестирующая система. Таким образом, каждый студент имеет возможность прогнозировать результат обучения в соответствии с построенной индивидуальной траекторией обучения. Кроме того, в работе описано средство когнитивной графики 2-симплекс призма для когнитивной визуализации результатов оценки студентов. Предлагаемый подход может быть использован для оценки результатов обучения студентов в рамках любой дисциплины. Этот подход полезен как для студента, так и для преподавателя с целью повышения качества обучения.