A Personalized Brain-Based Quiz Game for Improving Students' Cognitive Functions

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Abstract. Brain-based learning is the understanding of the human brain functions and its application in educational environments for meaningful learning. Brain-Based Learning adapts the learning process based on the function of human brain, providing a learner-centered tutoring environment. To this direction, a personalized brain-based quiz game was developed applying the principles of brain-based learning and Marzano Taxonomy for promoting meaningful learning and improving students' higher order cognitive functions. Thus, the system adapts quiz content based on student knowledge level, emotional state and the learning goal set. Regarding the control grouped pre-test and post-test experiment; the results reveal that this approach has a positive effect on students' performance, outperforming the traditional e-assessment systems.

Keywords: Brain-based learning · Cognitive functions · E-learning · Marzano Taxonomy · Personalized learning

1 Introduction

Information and Communication Technologies (ICT) have evolved rapidly affecting all fields, such as learning technology [1]. The educational challenges in digital learning require new pedagogical approaches combined with technological advances for providing innovative learning environments and improving learning outcomes [2]. Therefore, helping students to reach their highest potential has been of great importance in the development of effective e-learning systems [3].

Nowadays, some methods and strategies in learning process are revised based on the research in neuroscience field. The findings in this field have provided a better understanding of the human brain and how individuals learn. Thus, a new learning approach has arisen, namely Brain-based Learning [4]. This strategy admits the brain's rules for meaningful learning instead of memorization, adapting teaching methods based on these rules, namely the principles of brain-based learning [5, 6]. Brain-based learning is oriented to maximize learning and tutoring through a motivating and positive process. Several studies indicate the positive impact of this approach on academic achievement compared to traditional instruction [4, 7–9].

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In brain-based learning model, the learning environment should be developed in such way that it should: (1) challenge students' cognitive skills; (2) be pleasant and learner-centered; (3) promote active and meaningful learning [10]. These facts provide opportunities for students to advance their cognitive functions.

In view of the above, this work presents a personalized quiz game based on the brain-based learning theory in order to provide a brain-based assessment which promotes meaningful learning. The aim of this system is to improve students' cognitive functions instead of memorization on which traditional approaches mainly focus. Thus, the Marzano Taxonomy was applied to the design of assessment items for corresponding to the four level of cognition, namely knowledge retrieval, comprehension, analysis and knowledge utilization. Moreover, appropriate hints messages were designed for each assessment item in order to motivate students and help them to improve their learning outcomes. Thus, the system adapts quiz content based on student knowledge level, emotional state and the learning goal set. For system evaluation, control grouped pre-test and post- test experiment has been applied on undergraduate students of computer science in a public university. The research reveals that the personalized brain-based quiz has a positive effect on improving students' learning outcomes and obtaining higher order cognition.

2 Personalized Brain-Based Quiz Game

Brain-based learning involves tutoring practices, curriculum designs, and programs that focus on the current scientific research about how the brain learns, including several aspect, such as cognitive development, i.e. how students learn in a different way as they become older, grow, and mature socially, emotionally, and cognitively.

The logic architecture of the personalized brain-based quiz game developed for improving students' cognitive functions is shown in Fig. 1.

The system takes into consideration three characteristics regarding students, as follows:

- Knowledge level: This is a key characteristic for the assessment of students [2]. For example, difficult assessment units are more suitable for students who have a high knowledge level and easy assessment units can be better targeted to students who have a lower knowledge level. The system defines three knowledge levels for students, namely beginner, intermediate and expert.
- Emotional state: Emotional state is an important determinant for students' assessment [11]. Indeed, emotion is significant in education—it drives attention, which in turn drives learning and memory. For instance, if a learner is happy, s/he will probably have a better performance in assessment. The system specifies several basic emotions, such as happiness, sadness, boredom, and anger.
- Learning goal: Learning goals help learners to target to what they are supposed to learn [1]. Furthermore, they are closely related to the efforts of students. Based on specific learning goals, assessment can be more accurate by considering students' abilities. The system offers the possibility to students to select the level of learning goals that they want to achieve using the choices "Easy", "Normal" and "Challenging".

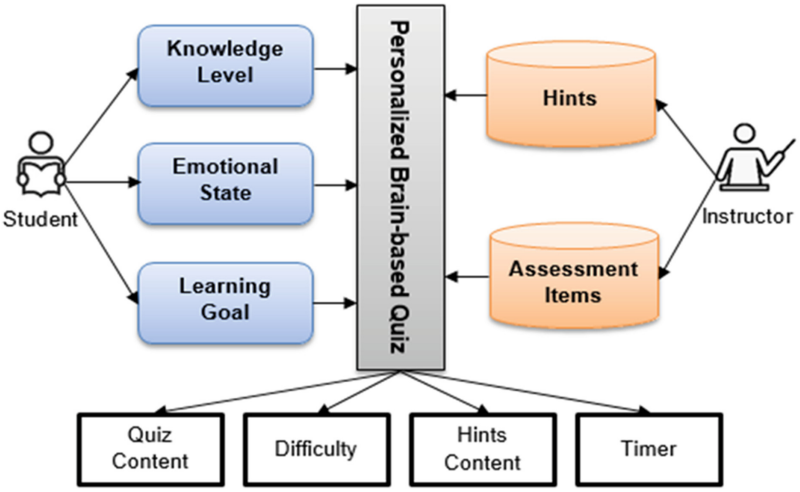

Fig. 1. System architecture.

Furthermore, the system holds two repositories that can assist the process of personalized brain-based assessment, as follows:

- Hints repository: This repository holds information about the hints and feedback that can be delivered to students based on their personal model. Hints can be seen as a valuable tool in the process of assessment since it can help students to have a better performance, when needed. Especially in brain-based assessment, hints can play an important role since they are adapted to the different way each brain learns. Examples of the personalized hints to students delivered by the system are: "Very good effort! But you have to clear you mind while studying!", "Good! You can try more while you were not very well-prepared", etc.
- Assessment items repository: This repository holds units, tailored to the brain-based assessment of units. To achieve this, the Marzano's New Taxonomy is used [12]. In particular, the assessment items are designed based on the levels of cognition defined by Cognitive System of this taxonomy, namely Knowledge Retrieval, Comprehension, Analysis, and Knowledge Utilization (Table 1). Therefore, the quiz provides content that leads the students to achieve higher order cognitive skills instead of memorization.

Table 1. Level of cognition based on Marzano Taxonomy.

Level of cognition	Description
Knowledge Retrieval	Recall of knowledge previously learned
Comprehension	Identify the key elements of information
Analysis	Examine knowledge in detail and come to new conclusions
Knowledge Utilization	Apply or use knowledge in a new or specific situation

The outputs of the system are the question items of the quiz, its difficulty level, the content of the hints provided during the quiz, and the available time for answering it. These outputs are adjusted to students' characteristics in order to provide more personalized brain-based assessment units that aim to the improvement of students' cognitive functions.

3 Evaluation and Discussion

The population of the experiment consists of 100 undergraduate students of computer science in a public university, dividing into two groups of 50 students each one, namely the experimental and control group. This division was made by the instructors based on students' characteristics in order the two groups to be equal. Both groups used an e-assessment system for testing their knowledge in each course's chapter. In particular, the experimental group used the personalized brain-based quiz, whereas the control group used a conventional version providing to students simple tests.

For evaluating the effect of personalized brain-based quiz on learning outcomes, a control grouped pre-test and post-test experimental design has been used. In particular, the same pre-test and post-test, examining the 4 level of cognition based on Marzano Taxonomy, were given to students of the two groups at the beginning of the course and after its completion, respectively. Comparing the pre-test and post-test scores of each level of cognition for both groups, a paired t-test is applied (Table 2).

Table 2. Comparing pre-test and post-test scores of each level of cognition.

Level of cognition	Group	Pre-test Mean	Post-test Mean	Diff.	t Stat	P value
Knowledge Retrieval	Exp.	6,24	8,46	2,22	-22,1638	3,44E-27
	Con.	5,98	7,2	1,22	-11,2957	3,03E-15
Comprehension	Exp.	6,08	8,26	2,18	-23,3365	3,4E-28
	Con.	5,82	6,92	1,1	-10,5768	3,03E-14
Analysis	Exp.	5,96	8,12	2,16	-17,6435	7,19E-23
	Con.	5,74	6,86	1,12	-9,60969	7,42E-13
Knowledge Utilization	Exp.	5,92	8,04	2,12	-22,7475	1,07E-27
	Con.	5,56	6,64	1,08	-10,1607	1,18E-13

The results showed that the average scores of post-test had a significant improvement in all levels of cognition for both groups. However, these of the experimental group were greater than those of the control group, indicating that the personalized bran-based quiz played an important role in the development of higher order cognitive functions. The possible reason of this superior is that in the proposed system, the quiz content is designed based on Marzano Taxonomy and adapted according to student characteristics.

4 Conclusions

Brain-Based Learning adjusts the learning process according to the function of human brain, providing techniques and strategies for a more learner-centered educational environment. Thus, a personalized brain-based quiz game was developed following the principles of brain-based learning. This system aims to improve students' cognitive functions instead of memorization on which traditional approaches mainly focus. For this purpose, the quiz content was designed based on Marzano Taxonomy and adapted to student characteristics, namely knowledge level, emotional state and learning goal. The control grouped pre-test and post- test experiment reveals that this approach has a positive effect on students' performance, outperforming the traditional e-assessment systems in improving students' higher order cognitive functions.

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