Using a game-based learning model as a new teaching strategy for computer engineering

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Abstract

Interactive multimedia simulations and computer game elements can be successfully combined in order to create new advanced educational resources for teaching today’s generation of students. Such a learning environment, a game-based learning model (GBLm), has been designed as a research prototype. This paper describes one type of GBLm for computer engineering, which we have used in the subject of computer graphics for the teaching unit Z-buffer algorithm, in order to facilitate the learning process. The implementation of a GBLm for graphical algorithms (GBL4CAI) is presented in detail as a multimedia interactive learning module designed to motivate students by making learning a more enjoyable process. During the design of the GBL4CAI module, special attention was paid to the integration of pedagogical and game-play aspects.

Key Words: Game-based learning, learning model for computer engineering, Z-buffer algorithm, graphical algorithms

1. Introduction

Although video games have been around for nearly 40 years and game-based learning (GBL) has been researched for over 20 years, the uptake of this technology in the classroom has been slow. The major barrier has been and still is a lack of knowledge of how to use the game resource in the context of teaching. Teachers are trained in a traditional way, and thus they do not include the elements of games in the curriculum. Educational games are used to reinforce learning that has been introduced in traditional ways, offering immediate feedback and recurring gratification. They prolong the interest of learners, keeping them on task while reinforcing the
Using a game-based learning model as a new... concepts taught, and, at the same time, motivate them by making learning enjoyable. Moreover, games can be used to support students who learn differently. GBL is designed to reach a balance between game-play and teaching, and to make the players capable of applying their knowledge into the real game-play environment. It is set to connect single or multiple learning objectives to a series of stages for the purpose of natural learning in the games. With the help of game-play, the players are motivated to participate in the games and complete their tasks.

Educational computer games can draw the attention of the students, allowing them to develop their cognition and experience along with the evolution of the games [1]. Game-based multimedia learning elements are combined to enhance the attention of the students and foster their concentration, interest, creativity, and community relationships [2]. There are numerous books, articles, and journal special issues that explore the connections between gaming and learning [3–6].

In the teaching and learning environment, gaming and online learning are being discussed, but usually within the context of interactive technologies. These articles and the others mentioned above point out the importance of using games and applying them to a variety of different pedagogical applications, but, at the same time, they do not consider online game-based technologies, which can be applied to teaching and learning. Therefore, the important improvement researched here is related to the practices of integrating game-play and pedagogy.

In this paper, we describe the designed model, named the GBL model for computer engineering (GBLm4CE) curriculums, which is based on research in the field of learning theory, learning strategies, learning style, etc., on one hand and computer game features on the other hand. It has been observed that the learners’ profiles may influence the way they learn and play; thus, this may have to be taken into consideration when designing the model GBLm4CE. Therefore, the model connects the game-play, pedagogy, and student profile determination. Furthermore, the GBL module for graphical algorithms (GBL4GAl) has been implemented and an experimental study has been conducted with the aim of investigating whether learning and teaching enriched with GBL, supported by a GBL4GAl module, will increase students’ learning outcomes compared to the classical approach of teaching and learning.

The organization of this paper is as follows: in Section 2, the pedagogical and psychological background for GBL is summarized; Section 3 adduces the problem, proposes the solution, describes the GBLm4CE curriculums, and elaborates on a matching game with the learner’s profile and teaching methodology; the implementation of the GBL4CAI, its architecture, algorithm, and playing scenarios are presented in Section 4; Section 5 gives an example of learning with the GBL4GAl module; Section 6 discusses the experimental results; and, finally, Section 7 concludes the paper.

2. Pedagogical and psychological background for GBL

After analyzing the final exam results, as well as the score of achieved points and final marks for the subject of computer graphics, for preceding generations of students, low success results were noticed, especially from the parts of the subject area that are related to the abstract way of thinking, capability of multidimensional space visualization, and capability of the designed solution imagination. Moreover, we point out that the curriculum of computer graphics comprises a specific educational domain, where computer GBL concepts and approaches have a high learning value.

These facts led us to the decision to present part of the subject content using multimedia computer games. With the aim of designing the game in a proper way, i.e. to be useful and to best suit the students’
needs, we analyzed the different aspects of the learning theories, learning strategies, cognitive styles, learning styles, and the theory of multiple intelligences. On that theoretical foundation, we defined computer game-based e-learning requirements and proposed some uses of the educational methodologies in the game-based e-learning environment, especially taking into account the new generations of students who are born in the computer and Internet era. The aspects and theories that were considered are given in the next subsections.

2.1. NETgen “digital natives”

Today’s children are “digital natives”, having grown up in a digital world. Prensky [7] stated that the average graduate would have spent less than 5000 h of his or her life reading books, but over 10,000 h playing video games.

2.2. Learning style (individual approaches to learning and understanding)

In review of e-learning theories, frameworks, and models, Mayer described the 3 broad theoretical stands that have shaped the development of pedagogical principles in the design of technology-enhanced learning environments [8]. Ability theories are developed to encompass a general concept of intelligence [9]. Guilford gave specific ability notions of intelligence [10], and Sternberg described information-processing approaches to cognitive ability [11]. Gardner proposed 8 primary forms of human intelligence [12]. Coffield et al. [13] identified 71 models of learning styles, from which it is possible to select 13 major models, with their associated measuring instruments, for analysis.

2.3. Learner and teacher influence on learning experience

Practical experience has shown that active participation of the learners is an important part of the learning process, which has to enable active work by learners to allow them to share knowledge in groups, and to enable teachers to develop learning content cooperatively. The illustration in Figure 1 shows the input types, based on learner and teacher involvement, that influence the learning experience.

![Figure 1. Influential factors in the learning experience.](image-url)
The learner model captures information about the prior knowledge, competencies, goals, and capabilities of the learner, while the teacher model captures information about preferred teaching strategies and learning goals. Both of these models are queried during the composition of the learning experience [14].

Sarıel and Akgün considered the user preference and accordingly designed the user model (user profiling system model), and in their paper [15], they presented a general multiagent system model for systems serving users according to their demands. User preference is mainly considered to provide the appropriate services for the user. In the model, the agents are allowed to communicate with each other to provide a social information exchange.

2.4. Games (interactivity - multimedia - visualization - simulation)

Many scientists have stated that computers and hypermedia could be used as a cognitive tool for learning, and they have also outlined a number of other potential advantages that computer-aided learning offers. There are several initiatives [16] that focus on facilitating and improving the learning process by introducing digital games into learning, and Buchanan [17] listed the game characteristics as follows: fantasy, curiosity, challenge, control, skill-based learning outcomes, affective learning outcomes, and cognitive learning outcomes.

Here, we investigate some psychological and pedagogical inductions of games to the individual learning process and point out the following conclusions: Druckman [18] stated that games enhance motivation and increase student interest in the subject matter. Cordova and Lepper [19] showed that enhanced learning that is fun can be more effective. David et al. [20] and Thornton and Cleveland [21] claimed that interactivity is an important aspect of a game. Johnston and Felix [22] suggested that the dynamic visual elements, rules, goals, and interaction are the essential features. Baranauskas et al. [23] stated that the essence of playing is challenge and risk. Cognitive abilities such as memory retention and analytical skills are improved by repeated digital game playing [24].

Another example of using simulations and interactions in computer-assisted learning is presented in a study by Friedrich [25], where he showed the role of object-oriented technology in producing pedagogical tools and then demonstrated the use of a basketball simulation program for instruction in Newtonian mechanics, covering different topics such as mass, acceleration, force, and motion equations. Developed applications can be easily adapted to specific user demands and interactive user interfaces, and also include features for graphical animation and multimedia.

A model of GBL is shown in Figure 2 [26]. One can see the debriefing process between the game cycle and the achievement of the learning outcomes. Investigation provides a link between simulation and the real world; it draws a relationship between the game events and real-world events and connects game experience and learning. This part of the model corresponds to the “doing, reflecting, understanding, and applying” process of study in a game, as stated in [27].

![Figure 2. A model of GBL [26].](image-url)
3. Design of the GBLm4CE

3.1. Problem definition and the proposed solution

After analyzing the final exam results for a computer graphics course at the College of Electrical Engineering and Computing Science Professional Studies in Belgrade, we came to the conclusion that the results differed significantly for different groups of exam questions. Performing an analysis, we discovered that the questions referring to the topic of hidden surface techniques, and especially the Z-buffer algorithm, taught in the computer graphics course had an unusual ratio among correct, incorrect, and “I don’t know” answers. Although the students had the same learning materials for all of the course topics to prepare for the exam, different results for this teaching unit showed that this particular topic was quite complex and abstract for them. Therefore, it was necessary to take some steps in order to improve the approach to learning regarding this teaching unit, and to improve the final exam results, as well.

Starting from the fact that this teaching unit is relatively simple and that, unexpectedly, the students’ results were worse for this than for the other topics, we began searching for an answer to the question of how to offer students teaching material that would be more useful and adequate for learning.

Computer graphic students start the learning process by learning computer techniques and algorithms for generating 2-dimensional and 3-dimensional graphical objects. This subject is very good for teaching through games. Such games can be used by both beginners and those more advanced who want to improve their skills. While playing, the learner gains theoretical knowledge and an experience of graphics algorithms. If he is really interested in the game, he will turn to external information (books, Internet) and, in that way, will study advanced graphic algorithms.

After performing an analysis of the existing Internet simulations and applications used in the teaching process, we came to the conclusion that it was necessary to introduce some of those contemporary teaching resources in the computer graphics course, so that students could learn the planned material in the best possible way. We consider that the main objective of computer techniques in games is awakening interest in computer graphics through the concept of a game.

We suggest the use of the game concept, which will be based on 2 components:

- Learners must get the course information through its interpretation in the game environment.

- Learners must see the result of the played algorithm in a game context.

In order to solve the noticed problem, we propose designing a GBLm4CE, which solves these problems by:

- Enabling students to learn the rules and check them in practice using different examples of graphic algorithms.

- Multiple repetitions of tasks, whereby performing the same operation many times increases learning efficiency.

- Evaluation of the score in solving the problem and comparison of it using predefined criteria that show whether or not a student has learned the topic.

We decide to implement a new GBL4GAi curriculum, founded on a GBLm4CE, which will include players learning and their playing style, incorporated with basic game elements, such as result, time, and difficulty levels. These new modules can be used for multimedia-based learning for computer engineering students.
3.2. Matching the game with the learner’s profile and teaching methodology

The first step in designing the GBLm4CE model was to define the starting guidelines:

1. To determine the pedagogical approach.
   
   (a) To include the inductions of learning theories, learning strategies, cognitive styles, learning styles, and the theory of multiple intelligences in the educational process.
   
   (b) To design and tailor learning experience according to the specific individual learner’s needs and properties.

We summarized the listed starting points, and we suggested a GBLm4CE model to be developed based on those starting points and to include multimedia in computer games for computer engineering curriculums. The GBL curriculum for computer engineering implemented according to the GBLm4CE would be based on a constructivist learning approach and collaborative learning. Players will learn to understand and combine different points of view. By playing different roles, students will learn and obtain both basic knowledge and practical experience, and will gain the soft skills that are needed for the organization of modern industrial manufacturing.

Thus, we promote teaching by playing and learning using a GBLm4CE model. The abstract multidimensional spaces and vectors, which are combined with the possibilities of taking different colors and which can produce a different front image according to all of the mentioned aspects, can be easier understood, imagined, and seen as a picture when learning with a GBLm4CE model. Moreover, this model provides an easier way to analyze and compare the designed solutions, especially because of the possibilities of visualization and simulation incorporated in the game.

With the aim of incorporating pedagogy into the game environment, and to connect the teachers’ and students’ influences of the learning experience, we have defined a way to match the chosen types of learning theory, learning strategy, and learning style, which in our opinion will best suit the defined problem of learning computer engineering, and the corresponding sets of didactics and methodic processes that have to be implemented in the GBLm4CE model. Matching learning with game characteristics is described in Table 1.

The main aspects and features of the proposed GBLm4CE model are:

1. **Domain:** The design of an educational game for the domain of the computer engineering curriculum as a collection of mini-games that address different facets of vector space and multidimensional space characteristics (different colors, brightness, position of layers, and so on), including the appropriate level of interactions.

2. **Constructivist method:** Learners are active participants in knowledge acquisition and are engaged in restructuring, manipulating, reinventing, and experimenting with knowledge to make it meaningful, organized, and permanent.

3. **Personalization:** The creation of a game that can adapt during play for different student learning and playing styles. The game has to recognize and accommodate these differences and tailor the game scenario, which will be an ideal educational game experience for the individual user.

4. **Student profile:** The dynamic identification of student learning style [28] and play style during play and the creation of a student’s profile database so that the game will know how to optimize the experience.
Table 1. Matching learning with game characteristics.

<table>
<thead>
<tr>
<th>Theory/type</th>
<th>Characteristics of the GBL model, GBLm4CE</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Learning theory</strong></td>
<td></td>
</tr>
</tbody>
</table>
| • Constructivist learning theory | • Exploratory approach to learning.  
• *Interactivity*, coping with problems, understanding of the whole.  
• Active participation in knowledge acquisition.  
• Engaging learners in restructuring, manipulating, reinventing, and experimenting with knowledge. |
| **Learning strategy** | | |
| • Cognitive strategy | • Improving the learner’s cognitive abilities, such as memory retention and analytical skills, by repeated playing.  
• Sequencing the flow of different learning processes.  
• Sequencing different types of presentation lessons (mathematical-logical, linguistic, musical, visual, etc.). |
| **Learning style** | | |
| • by Felder-Silverman | • Presenting the “virtual” world and fantasy in the context of the game leads to greater interest on the part of the student, as well as increased efficiency of learning.  
• Setting up the flow of the learning process (opportunities to make choices that have direct consequences; players control the game development).  
• Understanding of the whole. |
| **Gardner’s theory of multiple intelligences** | | |
| | • Interactivity + multimedia + visualization + simulation.  
• Different knowledge presentation views.  
• Applying the knowledge within the virtual world. |
| **Affective characteristics** | | |
| • Motivation | • Game feedback stimulates motivation.  
• Repeating the actions increases self-confidence.  
• Testing how the outcome of the game is changed based on their decisions and actions. |
| **Learning objectives** | | |
| • Bloom taxonomy | • Define clear goals for the activities.  
• Choice of difficulty level.  
• Challenge to upgrade to the appropriate level of difficulty. |
for each individual player-learner [29]. The learner’s profile is based on the Felder-Silverman model by an “Index of Learning Styles” questionnaire and preference test.

5. **Motivation:** Versus interactivity and repetition of the cycle. The game’s feedback stimulates motivation, and so the learner repeats cycles within a game context. Learners combine knowledge from different areas to choose a solution or to make a decision at a certain point, and learners can also test how the outcome of the game changes based on their decisions and actions.

6. **Matching learning outcomes:** With Bloom’s taxonomy. The GBL approach, supported by a GBLm4CE model, will reach the educational goals and objectives that fit Bloom’s taxonomy. Only the order of acquiring and adopting knowledge is different from the academic procedures of step-by-step learning.

The process of deriving the GBLm4CE from the learner’s profile and the teaching methodology is described in Figure 3. Moreover, expected learning outcomes are presented, and it is outlined that the GBL approaches will reach educational goals and objectives that fit Bloom’s taxonomy.

4. **Implementation of the GBLm4CE model**

The innovative way of checking knowledge with multiple answer computer tests has served as the main idea for the way in which teaching material could be given to students. With the use of techniques for first class innovative testing of ‘select/recognize’ [30], we came to the idea that answers in the multimedia interactive learning module can be given as a series of image fields on which a student should click. Since the buffer that we use in the Z-buffer algorithm uses 16 bits, the task of this module is to determine the value of each bit,

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**Table: LEARNING OUTCOMES**

<table>
<thead>
<tr>
<th>Skill-based learning outcomes: Performance of technical or motor skills</th>
<th>Cognitive learning outcomes: Declarative knowledge</th>
<th>Affective learning outcomes: Beliefs or attitudes regarding an object or activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bloom’s Taxonomy</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Remembering</td>
<td>Understanding</td>
<td>Applying</td>
</tr>
</tbody>
</table>

**Figure 3.** Deriving the GBLm4CE from the learner’s profile and teaching methodology.
i.e. the contents of the registry in various situations presented in the task. The conceptual module for learning graphic algorithms based on the GBLm4CE model, named the GBL4GAl module, is shown in Figure 4. The basic terms that explain the principles of graphic algorithms are reached by selecting the ‘Help’ option in the game. When a student starts learning using the GBL4GAl or experiences difficulty while solving tasks generated by the application, ‘Help’ serves to accelerate the finding of the right solution. This means that the formulation of definitions and theorems within ‘Help’ is the key moment in designing the entire application.

![Figure 4. The conceptual model of the GBL4GAl module.](image)

4.1. Algorithm for the GBL4GAl module

For every pixel on the screen, this algorithm keeps a record of the object depth in the scene in relation to an observer, plus a record on the intensity of the color used for the object description. In a situation where a new polygon is to be presented, the value of the depth and the color intensity are calculated for each pixel positioned within the borders of that polygon. If the value of the polygon pixels is closer to the observer than the value in the Z-buffer, the recorded values of the depth and color intensity are replaced with the previous values in the buffer [31,32]. Calculation of the Z value for every point on a scan line can be simplified due to the fact that some polygons are planar. The Z-buffer is often implemented with 16- to 32-bit integer values in hardware, but software (as well as some hardware) implementations can use values with movable points. Although the Z-buffer algorithm demands a huge memory space, it is easy for implementation. The procedure for placing pixels in the Z-buffer algorithm is as follows:

```
Procedure SetPixel (x:Xres; y:Yres; z:Zres; v:Value);
Begin
  If z > depth[x,y] then
    Begin
      depth[x,y] := z;
      screen[x,y] := v;
    End;
End;
```

The GBL4GAl module named “Z-buffer” was made on the basis of a concept map created for this teaching unit, which is shown in Figure 5. Since 2 main concepts are given in the concept map (the depth and color test concepts), which are to be learned by students through this module, we present them as 2 levels with different
solving difficulties. Solving the task that presents operation of the depth test is shown in the module as the easier level, i.e. level 1.

**Figure 5.** A concept map for the Z-buffer algorithm.

### 4.2. Architecture of GBL4GA1

A student applies for the computer graphics course through distance learning system Moodle. To study the area of work for a Z-buffer algorithm, he starts the GBL4GA1 module “Z-buffer”. The system uses an outer XML file for the description of how the algorithm works, together with the game rules and the theory that is being shown in the Help window. The interface of the whole module system was made in Adobe Flash CS3, while the programming logic and code were created in ActionScript 3.0 language. The application takes user data through the Moodle system and, together with the game results, sends them to the exterior database to be processed for further research and testing of the GBL4GA1 module.

**Figure 6.** Architecture of the GBL4GA1 module.
4.3. The algorithm play of the GBL4GAi module

The task of the GBL4GAi module “Z-buffer” is to teach a student how the Z-buffer algorithm works, through 2 levels. The way a problem is solved, i.e. game play, requires a student to select squares of the correct color. In the first level, a student needs to choose a cube closest to the observer from a column of square matrices.

![Algorithm flow-chart of the GBL4GAi module.](image)

In the second level, a student needs to choose a square of that color that is a combination of the colors of 2 squares in the designated column of square matrices. In Figure 7, you can see a diagram of the game play for level 1.

5. GBL4GAi module “Z-buffer”

5.1. Module interface

The visual presentation of the module interface is adjusted to the type of student that it is intended for, i.e. to teenage students. The design of the user interface is founded on a visual game presentation and Aero interface in the Windows Vista and Windows 7 operating systems, specifically using the effects of brightness, transparency, and reflection, as well as other characteristics of new “fancy” technologies. In the functional sense, the interface of the GBL4GAi module comprises 6 thematic fields (Figure 8):

- The field in which the problem task is presented visually – field 1.
- The field that presents a solution to the task – field 2.
- Offering assistance – field 3.
- Description of the algorithm operation – field 4.
• The task text – field 5.
• The field for main playing information – field 6.

When a student starts learning with the use of the game or experiences difficulty while solving a task generated by the application, ‘Help’ serves to accelerate the finding of the right solution. This means that the formulation of definitions and theorems within ‘Help’ is the key moment in the designing of the entire application.

Figure 8. User interface for the GBL4GA1 module.

The correct answer to fill the content of 1 bit is 1 of the proposed answers presented to students in the form of squares to be selected. These squares, i.e. offered answers, are presented in 2 ways. In the first level of the module, the answers are offered in the form of a 13-square column. Answers in the second level are also offered as an array, but in the form of a 5-square row. This row, with the offered answers, is not constantly visible, but is shown only when the given bit is selected as a submenu in the menu list.

5.2. Scenario 1

The task in level 1 demands that students determine a pixel whose value will be written in the depth buffer. The student should select the appropriate square within the active field, which is determined by the current position of the scan line arrow. Observed from the aspect of concept maps, solving of the task in level 1 is reduced to recognizing concepts of the depth test operation.

Figure 9 is a screenshot from scenario 1, which teaches how to determine the right value of a pixel whose value will be written in the depth buffer. Learning with the GBL4GA1 gives students the opportunity to see what happens when one of the possible answers is chosen, and in a circle, the student can select some of the other answers and see the different effects using the visualized answer.
5.3. Scenario 2

In level 2, the students are requested to determine the color of the screen buffer on the basis of the displayed order of squares and the legend of color transparency given in the lower right corner of field 1. A student can select as an answer one of the offered colors that appear as a submenu when a specific bit is selected in the screen buffer. To determine the resulting value of the color in a case where the squares have a certain level of transparency, field 3 gives a part with colors whose transparency can be changed interactively, which helps in determining the value of the resulting color. The concepts to be recognized by students at this level are given in the picture of the lower concept map in Figure 10.

5.4. Scenario 3

For both levels in the GBL4GAl module, there is a Help window that is closed during usual circumstances. If students need help during task-solving, they can request it at any moment with the use of this window. The window contains a definition needed for understanding the task and gives an answer at the moment when the student does not know what to do next. The content of the Help window is actually the key thing, i.e. the concept that a student should learn at each level. An example of the open window in level 1 can be seen in Figure 11.

6. Experimental results

According to prior research and analyses about the influence of educative games, based on learning strategies and the learners’ profile (which includes learning style, etc.) in the e-learning process, we have conducted an experimental study to examine whether the model GBLm4CE and the realized GBL4GAl module “Z-buffer”,
with differently formatted game elements, game strategies, and game flow with corresponding visual results, had an influence on the learners’ success, efficiency, and motivation.

Figure 10. a) A concept map and b) user interface from scenario 2 in the GBL4GAI module.

We compared the performances of the students who attended the GBL4GAI module sessions with those who attended classical teaching sessions. Testing of learning efficiency with the use of the GBL4GAI module was performed during the summer semester of 2009/2010 for the teaching unit “Hidden surface techniques” in a course on computer graphics. The research included first-year students at the College of Electrical Engineering and Computing Science Professional Studies in Belgrade. The students were informed about the principles of
the Z-buffer algorithm operation. The professor presented the teaching unit with the use of a classic method, with a blackboard, and without modern teaching resources such as a projector, PowerPoint presentations, etc. After the lectures on the distant learning system, Moodle, the students also obtained the GBL4GAI module “Z-buffer” as additional material for exam preparation. After that, a pedagogical experiment was carried out, which consisted of monitoring the students’ activities in the period prior to taking the exam and analyzing their results for the final exam. The sample included 183 students.

![Figure 11. The Help window in the GBL4GAI module.](image)

The first step of the proposed experiment contained prior tests for all of the students included in the experiment, which consisted of the following. Test of prior knowledge: according to the achieved grades for the subjects in the last semester, the average grade for each student was counted. Test of student’s learning style: we analyzed the student’s learning style categories as developed by Felder [33] and used the Index of Learning Styles (ILS) [34], which is a 44-item forced-choice instrument developed in 1991 by Richard Felder and Barbara Soloman to assess preferences on the 4 scales of the Felder-Silverman model. Test of student’s preference: students had to finish the preference tests containing questions on student’s preferences, preknowledge, previous activities, etc. [35]. An example of the acquired data from the performed tests for students, from student ST_09, is summarized in Table 2.

<table>
<thead>
<tr>
<th>Resulting values of personalization tests</th>
<th>Preference test</th>
</tr>
</thead>
<tbody>
<tr>
<td>Felder-Soloman ILS questionnaire</td>
<td>Average mark</td>
</tr>
<tr>
<td>ST_09  A5   I3   Vi7   Glo3</td>
<td>1 2 3 4 5 6 7 8 9 10 11 12</td>
</tr>
<tr>
<td>ST_09 A5 I3 Vi7 Glo3</td>
<td>c b c c c c a b b b c</td>
</tr>
<tr>
<td>ST_09 A5 I3 Vi7 Glo3</td>
<td>c b c c c c a b b b c</td>
</tr>
</tbody>
</table>

The second step divided students into 2 groups, G1 and G2. The groups were uniformly structured based on the aspects of prior knowledge (each group consisted of the same number of students rated as excellent, good, and sufficient) and the students’ learning style and preferences. In the third step, the students in group G1 attended classical lectures and the students in group G2 attended lectures that were expanded with GBL using the GBL4GAI module. In the fourth step, the students in both groups took the same exams, practical
exams (skill-based learning outcomes), final tests (cognitive learning outcomes) and satisfaction and motivation questionnaire about their satisfaction with the learning process and the achieved degree of motivation (affective learning outcomes). Finally, in the fifth step, comparative analyses of exam results were conducted for students in groups G1 and G2. The achieved results in the fields of practical exams, final tests, and the satisfaction and motivation questionnaire are shown in Figure 12.

![Graphs showing exam results for groups G1 and G2](image)

**Figure 12.** The comparative exam results for students in groups G1 and G2.

We noticed that the proposed GBL method implemented by the GBL4GA1 module approximately:

- Increased the students’ final results by 17%.
- Increased the students’ practical results by 26%.
- Increased the students’ satisfaction and motivation by 33%.

### 7. Conclusion

In this paper, we have researched an understanding of the multidimensional and multimodal relationships between learning theories and contemporary behaviors of the new “net generations” in order to develop game-based learning. The following aspects were analyzed:

- Influence of learning theories, learning strategies, and learning style on the learning process, as well as learner and teacher influence on the learning experience.
• Relationship between the type of intelligence and information technologies.

• Influence of motivation on the learning process and its impact on efficacy when achieving educational goals.

• Games by themselves, including interactivity, multimedia, visualization, simulation, and creation of a nonlinear, active-performance environment, into which there is the potential to incorporate varying levels of complexity.

We have analyzed the problems that are distinguished in learning curriculums for computer engineering, such as the abstract way of thinking, understanding, and application of complex algorithms for procedural or object programming, visualization of multidimensional space, imagination of the designed solution, etc., and we have nominated the model GBLm4CE and the GBL4GAI module in order to solve those complex problems.

The model GBLm4CE is founded on the constructivist learning theory, cognitive strategy, and the student’s learning style, and it reaches learning objectives that fit Bloom’s taxonomy. It supports the matching of learning with game attributes, as it matches among the chosen types of learning theory, learning strategy, and learning style that will, in our opinion, best suit the defined problem of learning computer engineering curriculums and the corresponding sets of didactics and methodic processes that can be implemented by game-based learning modules.

For example, the abstract multidimensional spaces and vectors, which are combined with the possibilities of choosing different colors and can attain a different frontal image according to all of the mentioned aspects, can be easier to understand, imagine, and see as a picture when learning with GBLm4CE. The GBLm4CE also provides an easier way to analyze and compare the designed solutions, especially because of the possibilities of visualization and simulation incorporated into the game. Moreover, the students’ preference and the aspect of “learning with fun” are included in the scope of the GBLm4CE design.

The entire design and architecture of the GBL4GAI module was done in the ActionScript 3.0 object-oriented program language, supported in the Adobe Flash CS3 package. Construction of the game interface demanded a long-lasting and extensive analysis, whose main objective was the adjustment of the environment and methods of task implementation to the affinities, the formerly acquired knowledge, and the age of the end users. The module interface was adjusted to the type of student for whom it is intended, i.e. to teenage students. We used the motives of contemporary applications, as well as the motives of the graphic interface Aero on the Windows Vista and Windows 7 operating systems. The graphics were adjusted to allow the students to enjoy the visually attractive effects of brightness, transparency, and reflection, characteristics of the new “fancy” technology.

A few scenarios for using the GBL4GAI module were presented. Testing of learning efficiency when learning with or without the GBL4GAI module was performed during the summer semester of 2009/2010 for the teaching unit “Hidden surface techniques” in a course on computer graphics. The sample included 183 students. The experimental study was conducted and we compared the achieved results of the students in group G1, who attended classical lectures, with those of the students in group G2, who attended lectures that were expanded with GBL using the GBL4GAI module. We noticed that learning expanded with GBL using the GBL4GAI module: use of the module increased the students’ final results by 17%, comparing passing grades in groups G1 and G2; increased the students’ practical results by 26%, comparing groups G1 and G2; and increased the students’ satisfaction and motivation by 33%, measuring for all of the students in group G1 as compared to G2.
Future development will focus on the creation of a game that can adapt during play for different students’ learning and playing styles, dynamic identification of student learning style (Felder-Silverman Index of Learning Styles questionnaire) and play style during play, and creation of a student profile database so that the game will know how to optimize the experience for each individual player-learner, as well as the other modules for the curriculums in the computer engineering environment that have to be developed and applied based on the model GBLm4CE.

Further realization of an experimental study is still going on, with stress on analyzing the relationships among the students’ profile characteristics, personalized recommendations, implemented game-based modules, and achieved success.

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References


KUK, JOVANOVIC, JOKANOVIC, SPALEVIC, CARIC, PANIC: Using a game-based learning model as a new...


