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Design and Implementation of CoAeLearn Modules for Personalized Game Based-Learning within Computer Architecture Course*

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This paper presents personalized game-based modules for Computer Architecture eLearning (CoAeLearn Modules) which integrates personalized learning based on students' learning styles and preferences (individual properties, goals and needs) with elements of multimedia games. Modules are intended for effective and efficient learning on the Computer Architecture Course by means of entertainment incorporated into interactive game-based applications. Furthermore, the CoAeLearn Modules should motivate the students and provide them with challenging games, action and victory. Moreover, the modules allow a visualization of computer architecture elements as well as a traceability of actions stored in the memory registers. The challenge for educational researchers is to determine how to design games which would achieve the instructional objective. Here we present an idea of making the components, integrated in CoAeLearn Modules, which explicitly support learning goals via guidance, directive feedback and multimedia presentation essential for efficient learning. Presenting the modules by entertaining interactive approach, along with a visual indication of the task execution flow, enables the students to master the methods of solving the tasks in various subject areas and surmounting different levels of complexity of teaching material. Multimedia Modules are presented in the form of a software package and Adobe Flash CS4 is used to create multimedia content. The Modules can be distinguished by pedagogical parameters such as: the degree of guidance in the module, a module support by HELP and feedback information about the correct answers.

Keywords: game based-learning; personalized multimedia modules; e-learning system; teaching strategies

1. Introduction

Educational research has shown that by discerning how one learns, one can become a more efficient and effective learner. There is no one single method of learning and the most effective approach depends upon the task, context and learner's personality. The learning will be more effective if learners can choose from a wide range of possible learning methods, if they know when to apply them and which approach is the best for them. Peter Honey and Alan Mumford [1] identify four distinct styles or preferences that people use while learning. Kolb [2] and other educational psychologists suggest that in order to learn effectively one needs to keep moving around the following cycle:

- Experiencing—doing something;
- Reviewing—thinking about what has happened;
- Concluding—drawing some conclusions;
- Planning—deciding what to do in the future.

To become a more effective learner one should engage in each stage of the cycle, and that may imply resorting to activities and styles that one would not normally choose.

On the other hand, anthropologist Levi-Strauss predicates that brain uses a story oriented structure to store and recall life experiences [3]. Furthermore, Heo has asserted that even facts, ideas, and theories are learnt more effectively if these are linked as a narrative [4]. Storytelling provides a powerful model of effective communication because it links with a basic human need: to create emotional engagement and movement [5]. According to Hassenzahl and Tractinsky, "*User experience is a strange phenomenon: readily adopted by the human– computer interaction (HCI) community—practitioners and researchers alike—and at the same time critiqued repeatedly for being vague, elusive, ephemeral*". However, they attempt to convey the experience to users by considering the following three aspects [6]: the experiential (dynamic, complex, unique, situated, temporally bounded), beyond the instrumental (holistic, aesthetic, and hedonic) and emotion and affect (subjective, positive, antecedents and consequences).

Digital Educational Games (DEGs) are systems that use digital technology to create games for enhancing learning outcomes. They have been recognized as engaging and effective pedagogical tools. Law and Kickmeier-Rust state that:

"*DEGs offer exciting and dynamic environments which engage gamers in meaningful and motivating learning activities, inspiring them to explore a variety*

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of topics and tasks. Simulative characteristics of DEGs can contribute substantially to knowledge construction of individual gamers, and their social aspects can enhance gamers' collaborative learning skills" [7].

There are three main challenges related to developing, using and evaluating digital educational games:

- *Personalizing learning experience*, developing games that can provide content and experience to match various learning styles;
- *Reusing the learning objects* created for the same or other games;
- *Evaluating* user experience and learning outcomes obtained by game learning.

In order to develop an effective educational computer game, one needs to consider different game genres, learning activities and techniques, and learning styles. With respect to various learning styles, this paper attempts to present cooperation and establish a relationship between interactive multimedia games, learning techniques and teaching strategies. Felder Silverman learning style model is incorporated into educational games. The paper also presents various aspects involved in the development of digital educational games as well as in the evaluation of students' experience.

We have analyzed learning styles and teaching strategies that match the game features and as a result of that analysis personalization and teaching strategies have been embedded into game. Furthermore, this paper specifies the design and implementation of Computer Architecture eLearning (CoAeLearn) Modules, which integrate personalized learning based on the students' learning styles and preferences with multimedia game elements. Initial theoretical background is followed by the problem analysis. The paper continues with a description of a relationship between learning styles and teaching strategies on the one hand, and game features on the other. Section 4 contains the design and implementation of the CoAeLearn Modules and Section 5 offers an evaluation of CoAeLearn Modules application method. Section 6 concludes the paper.

2. Theoretical background

2.1 Student learning styles and learning strategies

Many researchers agree upon the fact that learning materials should not just reflect the teacher's style, they should also be designed for all kinds of students and all kinds of learning styles. A learning style is defined as the characteristics, strengths and preferences in the way people receive and process information [8]. It refers to the fact that everyone has their own method or a set of strategies when learning. According to Sewall, there are several theories about learning styles [9]. Recent investigations [10–12], try to integrate learning styles into the design of applications.

Combinations of mental abilities comprise cognitive controls. These, in turn, define cognitive styles, Jonassen and Grabowski [13]. The learning styles lie at the most general level of all. The term learning style refers to "adopting a habitual and distinct mode of acquiring knowledge" as summarized by McLoughlin [14]. From 71 models of learning styles identified by Coffield et al. [15], for the sake of analysis it is possible to select 13 major models with their associated measuring instruments.

When researching learning styles certain models are frequently used: Myers Briggs Type Indicator (MBTI) , the students' learning style categories by Felder and Silverman [16, 17] and Chris J. Jackson's neuropsychological hybrid model of learning which provides a core biological drive of curiosity, learning and exploration [18–23].

Learning strategies are the strategies used to remember, learn and use information. In this case, responsibility lies with the students (comprehension and text writing, problem solving, etc.). Students go through a process during which they recognize new knowledge, review previous concepts, organize and restore the previous knowledge, match it with the new one, assimilate it and interpret everything that had previously been demonstrated on the subject. Didactic teaching strategy refers to an organized and systematized sequence of activities and resources that teachers use while teaching. The main objective is to facilitate the students' learning [24]. Teaching strategies are the elements given to the students by the teachers to facilitate a deeper understanding of the information. The emphasis is on the programming, acquiring, elaboration, and design of the learning content. Teaching strategies must be designed in a way which encourages the students to observe, analyze, express an opinion, create a hypothesis, look for a solution and discover knowledge by themselves.

2.2 Game-based learning

Many researchers suggested that game-based learning environment can function through a combination of challenge, engaging play, situated learning and problem-based learning and thus help learners construct knowledge [25, 26]. There was considerable research regarding the application of games for learning. Although there has been much written about negative aspects of computer games, it has been recognized that computer games may have a positive effect on learning [27, 28]. The context of a

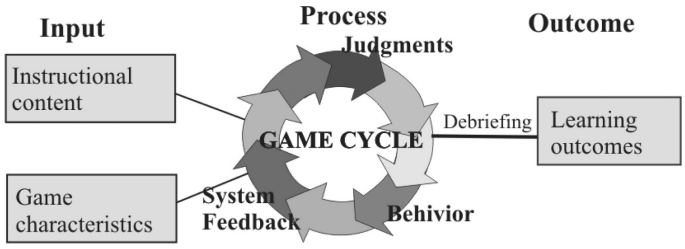

Fig. 1. A Model of GBL [32].

game can produce a simplification of reality encompassing learning strategies to support knowledge construction, clarification and consolidation. Hence, game-play can be employed as a cognitive tool for enhancing knowledge construction [29].

There are several initiatives [30] that focus on facilitating and improving the learning process by introducing digital games into learning, and Buchanan [31] listed the game characteristics as follows: fantasy, curiosity, challenge, control, skill-based learning outcomes, affective learning outcomes, and cognitive learning outcomes.

A model of GBL is shown in Fig. 1 [32]. There is a link between simulation and the real world, a relationship between the game events and real-world events and that connects the game experience to learning.

2.3 eLearning personalization

With the aim to provide the highest degree of education efficiency the personalized eLearning systems have to include variations in students' intellectual profiles, the influence of the ability theories, Gardner's theory of multiple intelligences, cognitive controls, and in turn, cognitive styles and the learning styles.

Several approaches in this direction are currently investigated, ranging from *federated or distributed learning repositories* e.g. [33], which focus on the dynamic and networking aspects, *learning management systems,* which focus on course delivery and administrative aspects, and *adaptive web-based educational systems* [34–36] that offer personalized access and presentation facilities to learning resources for specific application domains.

An interesting design of a service-oriented reference architecture for personalized e-learning systems (SORAPES) and validation of the architecture is described in [37]. The SORAPES is designed by reusing web services and learning objects with layered architecture and highly-scalable personalized e-learning system. The work described in [38] is a part of the open learning project, where business practitioners and university researchers aim to combine the most frequently used e-learning technologies with the benefits of customized systems to develop an innovative personalized learning content delivery system.

Discussion how learning styles and theories are currently used within personalized adaptable e-learning adaptive systems is extensively presented in [39]. This paper aims to establish conditions for creating versatile online courses adjusted to individual learner's needs which enable the students to choose their own learning path. Research efforts on shaping the student's knowledge on the basis of learning styles by using specific tests whose update depends on the student's progress are presented in detail in [40, 41].

2.4 Relationship between visual design, computer games and learning

An impact of visual design quality on the learning is relevant to the design of computer games-based learning. Graphics can support learning in a variety of ways, such as drawing attention to key elements, providing links to existing mental models and supporting the creation of new models, simplifying presentation to minimize mental effort, and supporting the transfer of knowledge. The field of visual design is complex and encompasses many areas. Vanderdonckt [42] describes a detailed taxonomy for understanding visual design, including physical techniques such as balance and symmetry. Mayer [43] describes multimedia effects on learning presented in Table 1.

The aspects of visual design quality (interface design, aesthetic design and graphic design) that influence playability in entertainment games, increase understanding in the educational games domain. The main elements that define the visual design quality are described in Table 2.

3. Problem definition and proposed solution

3.1 Problem definition

Most of the teaching systems that integrate learning styles are based on the premise that adapting the

Table 1. Multimedia learning effects

Principle	Description
Multimedia	Learning is better from words and pictures than from words alone.
Spatial contiguity	Learning is better when corresponding words and images are closer together.
Temporal contiguity	Learning is better when corresponding words and images are presented simultaneously rather than one after the other.
Coherence	Learning is better when gratuitous images (and sounds) are removed.
Modality	Animation and narration is more effective for learning than learning than animation and on-screen text.
Redundancy	Animation and narration is more effective for learning than animation, narration and on-screen text.
Individual differences	Effects are stronger for low-knowledge and high-spatial learners.

Table 2. Elements of visual design quality

Element	Description
Style	The overarching visual theme (e.g. photo-realistic, cartoon, abstract).
Realism	The degree to which the visual design looks like the real world.
Color	The choice of palettes and individual colors.
Perspective	The player's view on the game world (e.g. first person, third person).
Dimensionality	Whether the world is viewed in two or three dimensions.
Fidelity	The reproduction quality.
Professionalism	Aspects such as attention to detail, appropriateness and design skill.

teaching strategies to students learning styles will give better results [44, 45]. Various adaptations to learning style systems are done in terms of content adaptation, navigation routes or the use of multiple navigation instruments.

We have noticed several problems. Firstly, most of the systems evaluate the chosen learning styles dimensions and adapt to them, and then apply these learning styles to different learning systems. However, various problems still need to be solved, such as matching teaching contents with the student's learning style. Secondly, the main difficulty is linking learning styles with hypermedia applications and including the learning styles in a game genre. The problem is not how to create electronic learning materials, but how to locate and utilize the available information in a personalized way. Finally, students are sometimes lazy to learn and it is hard to move them towards learning, especially if the course content is too abstract and if there is no obvious relationship between its components.

Students love the digital game-based learning system. Learning by Doing achieves personalized learning, brings the entertainment of games and fun into education, achieving the purpose of edutainment. The game-based learning is abundant in characteristics, such as Representation, Fun, Play, Goals, Outcomes and Feedback, Win states, Competition/Challenge, Problem solving, Task, Story and so on [46, 47], to increase the learning motivation of students. Games are used to improve a dull and hard course, where course content corresponds to game levels, making the knowledge and skills of the course teaching available through game-based learning.

3.2 Proposed problem solution

In this regard, in order to address the stated issues we have dealt with what we can personalize and with the way in which it can be realized by using game-based learning. Additionally, we have been investigating the influence of multimedia and game characteristics over the learning process and we propose to embed personalization and teaching strategies in the game as a method of solving the stated problems. In this work we have analyzed and incorporated Felder Silverman learning style model into educational games, and we have designed and implemented personalized game-based modules called CoAeLearn Modules for Computer Architecture Course learning. The students used CoAeLearn Modules for mastering certain parts of Computer Architecture curriculum. Subsequently, we have conducted a survey to determine the effects of personalized game-based learning and applied teaching strategies on learning motivation and student's success with didactic methods incorporated in the game.

In accordance with this objective, we have analyzed the students' learning style categories developed by Felder and Silverman [8] and used the Index of Learning Styles® (ILS) [48], which is a forty-four-item forced-choice instrument developed in 1991 by Richard Felder and Barbara Soloman to assess preferences on the four scales of the Felder-Silverman model. A learning style refers to the fact

that every person has their own method or set of strategies when learning. We have selected Felder and Silverman Learning Style Model, as the basis of our taxonomy for personalized game-based learning. It divides the learning process into five dimensions: Perception, Input, Organization, Processing, and Understanding, each dimension having two opposing learning styles, as described in Table 3 [49].

For each dimension, learning style 'a' is more physical, and style 'b' is more intellectual. Most people use a learning style somewhere between the two extremes, but with a bias towards physical or intellectual learning. The aim of any learning system should be to offer alternative learning styles for the same subject matter, so that individuals can choose the one that matches their preferred learning style.

Analyzing the results of ILS, we have noticed that learning style 'a' is more dominant for all tested students. Bearing in mind that games intrinsically provide a more active or physical learning experience, we have designed and implemented the CoAe-Learn Modules for personalized game-based learning on Computer Architecture Course. Therefore, it is important that a game-based system should also provide more intellectual activities, to balance and reinforce the learning gained from the game.

3.3 Models for problem realization

In general, the personalization might be examined in the following aspects [50–52]:

- Personalization of the learning content, based on learner's preferences, educational background and experience, learning content tailored to individual learning style of the user;
- Personalization of the representation manner and the form of the learning content (for example, learning content in the form of the adaptive learning sequences of learning objects).
- Full personalization, which is a combination of the previous two types.

After analyzing the students' learning modalities, as well as their preferences and learning styles, we will be suggesting the ways of learning, presentation, navigation and interaction which should be adopted and thus we will be embedding personalization and teaching strategies into the game.

To apply the personalized game-based eLearning to a student profile, i.e. students' learning styles and preferences, we have upgraded the designed Personalized eLearning Course Model (PeLCoM) [53], and Information Learning Object Model for Personalized eLearning (ILOMPeL) [54] with the fourth dimension W called *processing*. The granular units of the Model are eLearning Objects (LO) and each LO is described by a set of metadata which are presented by four-dimensional vector WXYZ.

Application profile is a set of metadata elements, policies, and guidelines defined for a particular application. Application profile for the Personalized eLearning Course Model describes the role and attributes of every LO in the Personalized eLearning Course Model by a set of metadata

Table 3. Felder Learning Styles Dimensions Model

Learning Style Dimension	**Type**	**Description** ***Learning Style Preference***
Perception	a) Sensitive	Sensitive (external agents), places. sounds, physical sensations. Rather deal with facts, raw data and experiments, they're patient with details, but don't like complications. Like learning facts.
	b) Intuitive	Intuitive (internal), possibility, ideas, through hunches. Rather deal with principles and theories, are easily bored when presented with details and tend to accept complications. Prefer discovering possibilities and relationships.
Entry Channel (Input)	a) Visual	Visual (images, diagrams, graphics). Easy for them to remember what they see: images, diagrams, time tables, films, est. Remember best what they see, pictures diagrams, flow charts.
	b) Verbal	Verbal (spoken words, sounds). Remember what they've heard, read or said. Get more out of words: written and spoken explanations.
Processing	a) Active	Active through physical activities and discussions .Learn by working in groups and handling stuff Doing something active with it : discussing, applying or explaining it to the others.
	b) Reflexive	Reflexive through introspection. Learn better when they can think and reflect about the information presented to them. Work better alone or with one more person at most. Prefer to think about it quietly first.
Understanding	a) Sequential	Sequential with continuous steps. Follow a lineal reasoning process when solving problems and can work with a specific material once they've comprehended it partially or superficially. Gain understanding in linear steps, with each step following logically from the previous one.
	b) Global	Global through leaps and an integral approach. Take big intuitive leaps with the information, may have a difficulty when explaining how they got to a certain result, need an integral vision. Learn in large jumps, absorbing material almost randomly without seeing connections.

based on SCORM Meta-data Information Model (ADL, 2010). The mentioned set of metadata is represented by a vector WXYZ, where: W = (W_1, W_2...W_i), X = (X_1, X_2...X_i), Y = (Y_1, Y_2...Y_j), Z = (Z_1, Z_2...Z_k), i, j, k € N. For every functional type of a LO, there is a defined set of metadata that describes the purpose and attributes of the LO in question.

3.4 Personalized characteristics of CoAeLearn modules

All dimensions of the learning style model were considered in the process of developing personalized game-based e-learning system by adding the following features:

- Different types of learning support tools included with the aim of providing pedagogical support and encouraging students' information *processing.*
- Imaginative and practical types of examples have been used for each part of the studied subject in order to facilitate students' *perception* on learning materials.
- Video, audio, picture-based and text-based content presentations of each topic were provided to facilitate the students' way of *getting the information*.
- In order to encourage *understanding* of the subject, a sequential or free selection learning path was developed.

To implement the eLearning game-based personalization founded on the student profile, i.e. students' learning styles and preferences, we have designed and implemented three interactive types of modules for game-based learning in the field of Computer Architecture:

- *Type1*—AOR1 for learning unary operations,
- *Type2*—AOR2 for learning operations of storage space with different ways of addressing,
- *Type3*—PLK for learning implementation of programmable logic, using knowledge of logic gates.

Module AOR 1 contains help option that is shown upon student's request. Basic navigation for this module type is a graphical element in the form of an arrow. This type of module employs a low level of navigation because a hint for the next step is shown by using an arrow. Module AOR2 has a help option that is constantly open. There aren't any graphical elements for pointing out the correct task solving course for this module. Return information about the correctness of a solution is shown in a form of a graphical symbol of confirmation (check). This way of showing the correct answer is a complete return information about the correctness of a completed task. Module PLA is a type of module which does not offer any help. High level of navigation is employed by using a different color to point out a part of a picture or by adding frames of different shapes. Module does not show correct or incorrect answers upon completing a part of the task. Due to the high level of navigation a student is navigated to a correct solution of the task, so the student is not shown an incorrect answer warning.

In paper [55], the authors have reconstructed Felder and Silverman mapping between teaching styles and students' learning styles by means of eLearning dimension and reflections of the FSLSM in the classroom and on the system. Furthermore, we have expanded the aforementioned mapping with corresponding game features and matching type of CoAeLearn Modules, which is summarized in Table 4.

The proposed taxonomy implies the matching of different learning styles with different game components and teaching strategies, implemented through suitable game modules posing as channels for its representation, thus personalizing it for every student. CoAeLearn Modules provide personalization from the aspects of:

1. Adaptation to the Knowledge Level and Learning Objective by offering the possibility of choosing a different starting point, practicing and learning different curriculum content, and approximating the convergence to different learning objective-learning result which the student wishes to achieve.
2. Adaptation to the students Behavior (learning style) and to the Learning Modalities (Gardner theory of multiple intelligence) by choosing the manner of learning: a) static or interactive; b) verbal or visual (multimedia); c) system driven or individually routed steps for the realization of the task; d) with different levels of system feedback (no feedback, particular feedback, total feedback or feedback on demand).

Short learning style category description and corresponding multimedia, teaching strategies and personalization included into CoAeLearn Module for making game-based learning experience adapted to the individual student's needs is described in Table 5 (the part of the Table which is related to the first learning style category *Perception*).

4. Implementation of CoAeLearn modules

4.1 Module AOR1

Module AOR1 is designed to teach students the basics of unary logical operations and their practical usage through examples with virtual registers and randomly generated content which are parts of computer's ALU (Arithmetic Logic Unit). AOR1

Table 4. Mapping the Learning Style Dimension Model with the Corresponding Game Features and Matching Type of CoAeLearn Modules

Learning Style Preference		Corresponding teaching styles in classroom		Corresponding eLearning system features	Corresponding Game features	CoAeLearn Modules
W—Processing	Active	Active	Student participation	Learning support tools: discussion, forum, chat	Interactive With different level of system feedback: total feedback	*AOR 1, PLK*
	Reflexive	Passive		Learning support tools: mind map, note taking	Static, No feedback	*AOR2*
X—Perception	Sensitive	Concrete	Content	Practical subject examples	Puzzle oriented curriculum presentation	*PLK*
	Intuitive	Abstract		Imaginative subject examples	Tetris oriented curriculum presentation	*AOR2*
Y—Entry Channel (Input)	Visual	Visual	Presentation	Content presentation by text and audio	Multimedia—by graphical design, graphical user interface with questioning and answers	*PLK*
	Verbal	Verbal		Content presentation by picture and video	By graphical design turned to text expression (help features)	*AOR1 AOR2*
Z—Understanding	Sequential	Sequential	Perspective	Sequential learning pathway	System driven steps for the realization of the task	*AOR1, PLK*
	Global	Global		Random learning pathway	Individually routed steps for the realization of the task	*AOR2*

Table 5. Multimedia, teaching strategies and personalization by CoAeLearn Module with respect to learning styles

Learning Style	**SENSITIVE**. Students with a sensitive learning style prefer practical content connected with the real world, and methods that allow the solution of problems. They learn best when: there is an obvious link between the topic and a current need; they are shown techniques with clear practical advantages; they can try things out with feedback from an expert; they can copy an example, or emulate a role model
Multimedia	Multimedia game based education by implementation of animations, should contribute to support this learning style.
Teaching strategy	The appropriate teaching strategies are based on the practical work (simulations and games, learning based on problems and role playing). CoAeLearn Module PLK allows Presentation, Question and answer method, and Learning based on problem solving.
Personalization	While working with PLK module, a student is required to implement functions with 4 input variables: F(x, y, z, w) into PLA 4x4x8 component. First, student has to recognize appropriate input variables for AND circuit (matrix). After correctly solving input combination for AND matrix, a student is offered the next step towards completing task (determining input combination for OR matrix).
Interactivity	Interactive module. System driven steps for the realization of the task. level of system feedback: total feedback.
Learning Style	**INTUITIVE**. Students with the intuitive style, prefers concepts oriented to theory and meanings, with abstractions and mathematical formulae, avoiding repetitive methods. They learn best when: an activity is backed up by ideas and concepts that form a model, system or theory; in a structured situation with a clear purpose; they have the chance to question and probe; required to understand a complex situation.
Multimedia	Multimedia game based education by implementation of help features, based on reading allow to adapt teaching strategies for this learning style.
Teaching strategy	An exposition strategy and a discussion panel can meet their requirements. Also, intuitive persons are innovators, so a brainstorming session can also meet the objective. CoAeLearn Module AOR2 allows studying, analyzing and deriving conclusions by using help options with well described and documented tasks. Simulations is also available.
Personalization	In Instruction window of module AOR2, a student needs to choose one of offered functions. Upon choosing, a student is asked to choose correct memory location and enter the appropriate data in it. Interactivity of this module is based on two kinds of interactive objects: selection field (choosing the correct square) and text field (typing in the text).
Interactivity	Interactive module. No system driven steps for the realization of the task. Level of system feedback: particular feedback.

is a type 2 module which contains help option shown upon request. The main navigation is a graphical element designed in a form of an arrow. The arrow appears after opening the module to let students know that they should choose one logical operation from the Unary logical operation window. Then it appears at a specific location to visually suggest the use of Register 2 (Fig. 2).

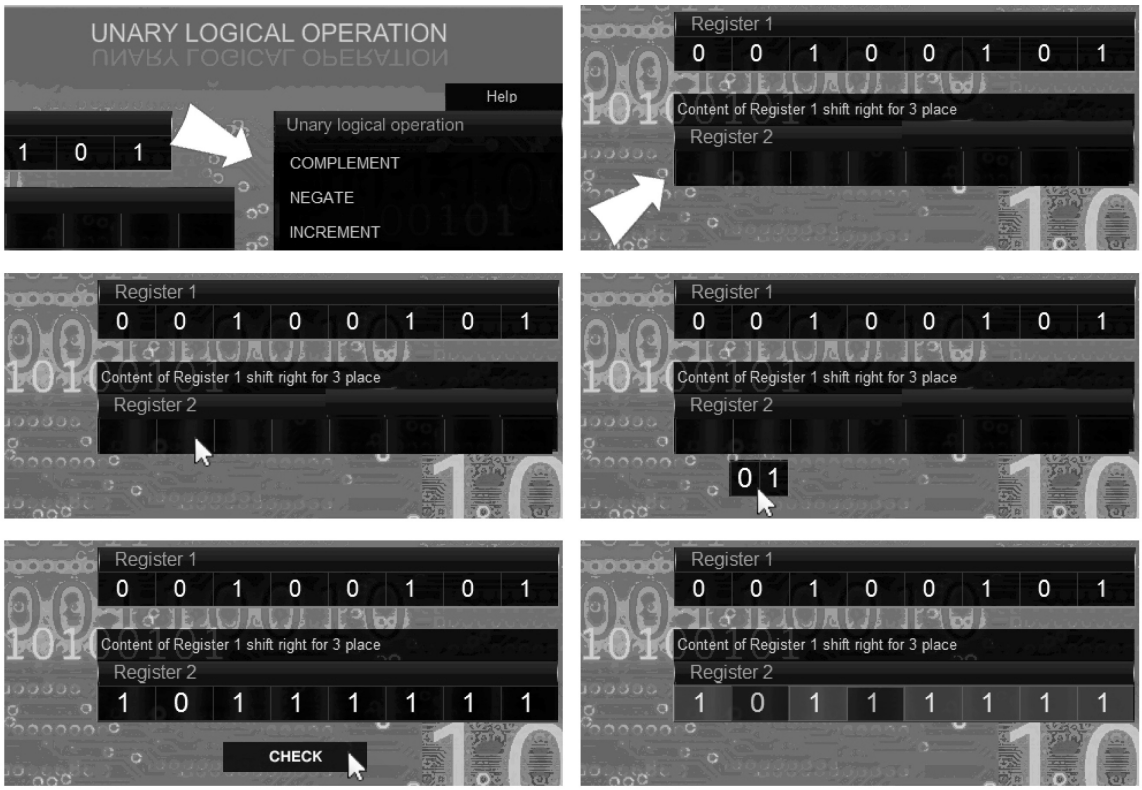

Fig. 2. Steps in solving the task of Module AOR1.

Important characteristics of this module are:

Goal: By using this module student can learn:
- The way that logical operation executes on the register level,
- How to recognize and compare content of the register in binary form, before and after the execution of unary operation.

Task: A student's task is to determine the content of the Register 2 which is equal to the Register 1 after selected option. Content of the Register 1 along with the task text are randomly generated by module and they appear upon choice of unary operation. Module interactivity comes down to choosing either option 0 or option 1 as bit content, which is directly written in the Register 2 field. Bit options in form of squares (selection fields) are chosen through drop-down menu.

Required knowledge for working with the module:
- Concept of unary logical operations,
- Types of unary logical operations.

4.2 Module AOR2

Module named AOR2 is used for learning and practicing the instruction set of the microcontroller. In addition, with this module students are being introduced to the types of instructions, address allocation, variables and program code organization. As a starting parameter for a module students need to choose appropriate instruction for learning/practicing. Once they have made the choice, the students' task is oriented towards randomly generated register value. The task consists of selecting the appropriate memory location in Data field and determining content of the selected location. In the case of certain instructions mandatory task is determination of the pointer value (Fig. 3).

Important characteristics of this module are:

Goal: A student using this module should:
- learn how to distinguish the instruction types of program code for microcontroller's functionality,
- learn where in the memory to type in the instruction value.

Task: In Instruction window students need to choose one of the offered functions. Once they have made the choice, students are required to choose the correct memory location and enter appropriate data. This module interactivity comes down to two types of interactive objects: selection field (choosing the correct square) and text field (typing in the text).

Required knowledge for working with the module:
- data types (dsb, dsw, . . .),
- types of addressing,
- constant concept.

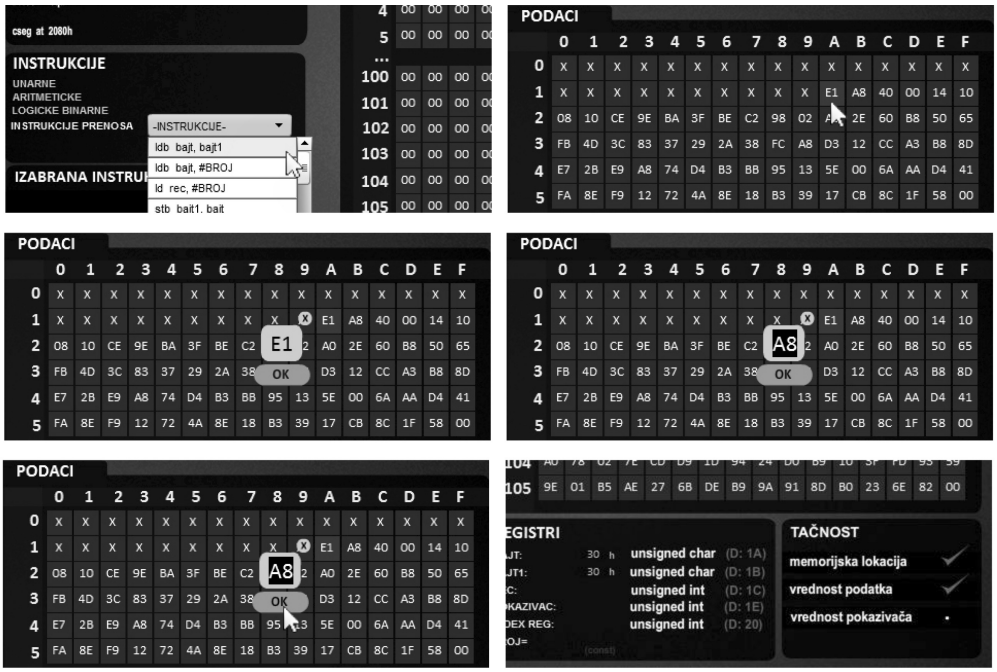

Fig. 3. Steps in solving the task of Module AOR2.

4.3 Module PLA

Module PLA comprises a specific task of using combinational circuits in the PLA logic. By solving the specific task of determining function F's final value, students apply the acquired knowledge in the field of logic circuits and combine it with programmable matrix. Within a PLA component any logical function represented by a sum of logical multiplications can be implemented. The number of logical functions a PLA circuit can process is limited by the number of output ports. AND matrix outputs are directed into OR matrix where sums of logical multiplications and final outputs of logical circuit are formed. All input signals can be brought directly into AND matrix or through inverter. Likewise, every OR matrix output can be inverted or non-inverted, by connecting it to the XOR logical circuit, while the other input is connected to logical 0 by means of programming (if inversion is not present) or to logical 0 (if inversion is required)—Fig. 4.

Important characteristics of this module are:

Goal: When using this module a student should:
- recognize a sum of logical multiplications with input variables that are given in analytical or tabular form,
- implement given logical function into a PLA circuit

Task: Basic task within the module is to determine the adequate position of a programmable switch for the lines inside the components. The program-

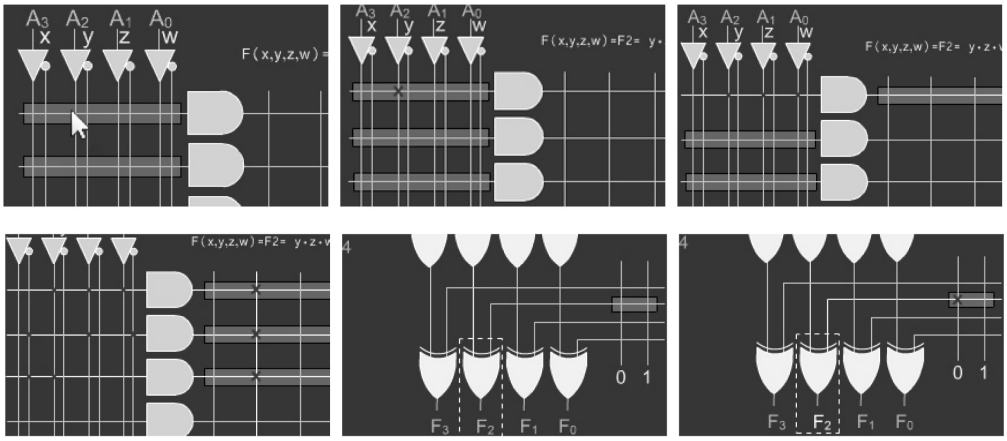

Fig. 4. Steps in solving the task of Module PLK.

mable switch is labeled with graphical element (sign X). This short circuit is shown to students upon clicking inside the marked input field (gray rectangle).

Required knowledge for working with the module:

- working function of logical circuits within a PLA circuit,
- type of display for output function within a PLA circuit.

5. Statistical results

In a game-based learning, the course content is mapped into the game to provide a learning environment scenario for constant self-learning, and the ongoing interaction and feedback can increase the learning interest and motivation. In order to evaluate the learning effects, this paper uses 2D game development tools and the course content corresponding to the game level content, similarly as [56].

The goal of this experiment is to discuss the effects of personalized game-based learning, the applied teaching strategies on learning motivation and student's success with didactic methods incorporated in the game. The Game modules CoAeLearn are used on the Computer Architecture course. There is a total of twenty-three students participating in this study of average age from 20 to 21 years old.

There are three main phases in conducting this experiment: first, the application of the Felder and Silverman learning styles questionnaire and the analyses of obtained results; second, the use of CoAeLearn Modules for mastering the curriculum, and third, conducting a survey of student's opinion and satisfaction when learning within CoAeLearn Modules. In the first phase, the Felder and Silverman learning styles questionnaire was given to 23 students and the results are presented in Table 6. Vi is a mark for Visual, Ve for Verbal, Sen for Sensitive, Int for Intuitive, Seq for Sequential, Glo for Global, Act for Active, Ref for Reflexive.

In the second phase, the students use CoAeLearn Modules for mastering certain parts of Computer Architecture course curriculum. According to the results of the learning styles questionnaire, the selection of an appropriate module is based on the students learning style, as well as on the dominant cluster of learning styles which include 79% of students and consists of the following {Visual/Sensitive/Sequential/Active}. When it comes to the dominant cluster, the content must be practical, the material must be linked to the real world with a highly visual approach and it should be easily applicable; teamwork must be encouraged too.

In the third phase the students have to answer the questions to express their satisfaction and opinion with respect to learning by CoAeLearn Modules. The survey consists of 26 questions, divided in 2 thematic groups:

- Whether Modules fulfill their didactic role;
- How the Modules influence the learning motivation;

The students have to evaluate each question in terms of the following marks: 4–excellent, 3–very good, 2–good, 1–bad and 0–very bad. The results of the questionnaire: *Do the learning modules meet their didactic role* are presented in the following Table 8. The questions are placed in the first column of the table, the second column contains an average mark for each question related to the module AOR1, AOR2 and PLK respectively. The average mark

Table 6. Results Felder and Silverman LSQ

Learning style	Vi	Ve	Sen	Int	Seq	Glo	Act	Ref
Percentage	87%	13%	83%	17%	74%	26%	65%	35%
No of students	20	3	19	4	17	6	15	8

Table 7. Questionnaire: Do the learning modules meet their didactic role

Modules	AOR1 average mark	AOR2 average mark	PLK average mark
Questions			
1. Assess the complexity of the task in modules.	3.00	2.87	2.61
2. Clearly defined task in modules.	3.09	2.87	2.87
3. A prior knowledge I needed to complete the task in module.	2.57	2.70	2.57
4. Assess the guidance of completing the task in modules.	2.78	2.65	2.83
5. Feedback about correct/incorrect answers is good show in modules.	2.87	2.70	2.61
6. Modules helped me to learn the material presented.	2.96	2.78	2.74
7. Assess the interactivity with users in modules.	3.04	3.00	2.91
8. Assess the answer mode in modules.	2.91	2.57	2.74
Average:	**2.90**	2.77	2.73

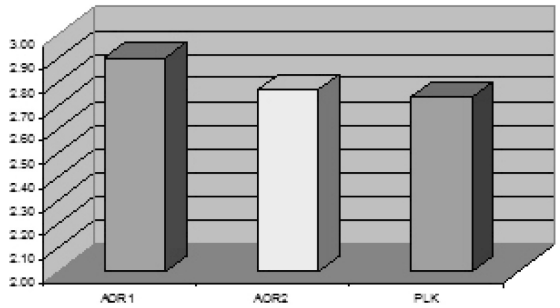

Fig. 5. Questionnaire: Didactic role.

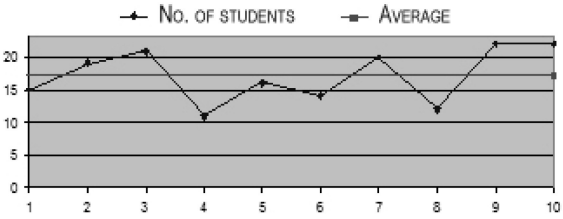

Fig. 6. Questionnaire: Positive impact.

the students gave with respect to the set of questions concerned with the didactical role of AOR1 module is 2.90, which is a very good score. The chart above Figure 5 shows the average rating for the didactic role of the module AOR1, AOR2 and PLK, and we observe that all students assessed these modules as *very good*.

Fig. 7. Questionnaire: Motivation with modules in learning.

modules on motivation in learning are given in the first column of the Table 8. The second column indicates the number of students who have positively responded to the question concerned with the positive impact of the module and it is shown on chart in Fig. 6.

Surveys concerning the negative impact of the modules on the processes of learning and motivation, as well as the number of students who expressed such an opinion are shown in Table 9. The total percentage of students who have positively assessed the impact of modules on the process of learning and motivation is 80% for all questions. The number of students who have negatively evaluated the impact of modules on motivation and learning is 20%, an average score for all questions, as it is shown on chart Fig. 7.

Table 8. Questionnaire: Do the learning modules have a positive impact on motivation in learning

Questions	Number of students
1. There was something interesting at the beginning of the modules that got my attention.	15
2. The interface design of the modules is eye-catching.	19
3. It is clear to me how the content of the modules is related to things I already know.	21
4. I enjoyed the modules so much that I would like to know more about this topic.	11
5. The content of the modules is relevant to my interests.	16
6. I could relate the content of the modules to things I have seen, done or thought about in my own life.	14
7. The content in the modules will be useful to me.	20
8. I learned some things that were surprising or unexpected with the modules.	12
9. The wording of feedback after the exercises, or of other comments in the modules, helped me feel rewarded for my effort.	22
10. If felt good to successfully complete the modules.	22
Average:	**17.2**

The issues relating to the survey of the impact of

Table 9. Questionnaire: Do the learning modules have a negative impact on motivation in learning

Questions	Number of students
1. I could not really understand quite a bit of the material in the modules.	3
2. The interface design of the modules is eye-catching.	3
3. The modules had so much information that it was hard to pick out and remember the important points.	2
4. The content of the game is so abstract that it was hard to keep my attention on it.	1
5. The activities in the modules were too difficult.	0
6. The modules was more difficult to understand than I would like for it to be.	17
Average:	**4.33**

6. Conclusions

This paper describes the design and implementation of three interactive types of modules for eLearning in the field of Computer Architecture: AOR1 for learning unary operations, AOR2 for learning operations of storage space with different ways of addressing, PLK for learning implementation of programmable logic, using the knowledge of logic gates. By using these three modules, the paper shows pedagogical approach to creation and implementation of game-based personalized learning styles in interactive multimedia systems for e-learning. CoAeLearn Modules provide personalization from the aspects of:

1. Adaptation to the Knowledge Level and Learning Objective by offering the possibility of choosing a different starting point, practicing and learning different curriculum content, and approximating the convergence to different learning objective-learning result which the student wishes to achieve.
2. Adaptation to the students Behavior (learning style) and to the Learning Modalities (Gardner theory of multiple intelligence) by choosing the manner of learning:
   (a) Static or interactive,
   (b) Verbal or visual (multimedia),
   (c) System driven or individually routed steps for the realization of the task,
   (d) With different levels of system feedback (no feedback, particular feedback, total feedback or feedback on demand).

By creating multimedia item types and applying personalized computer-based education CoAeLearn Modules enhance the capability to motivate learning by making the learners feel more engaged in the interactive environment and gain the advantage of individualized curriculum design, rather than a curriculum designed for an average student.

We have administered the questionnaire which dealt with how the students had accepted and responded to CoAeLearn Modules and how the students were satisfied with learning within the Modules, and we have concluded that Modules have increased the students' engagement and motivation, that they have led to transfer and complex problem solving and supported spatial skills. We have concluded that games are motivational and have tremendous potential for education.

Comparing the results from the survey on students' assessment of the Modules accessibility and previously derived students learning styles by *Felder* and *Silverman's* Index of Learning Styles *Questionnaire*, we have noticed [and the questionnaire confirmed it] that presented Modules have achieved specified /predicted learning goals. Analyzing the survey, we have noticed that the didactic roles of the AOR1, AOR2 and PLK modules are rated as very good. Modules impact on motivation and learning was assessed positively by 80% of the students. Consequently, we have drawn a conclusion that the CoAeLearn Modules, implemented and designed to include personalization, games and media, are rated as very good, that the role of multimedia is evaluated as very important and that 80% of the students found that modules affect motivation and learning very positively, which means that they have achieved a given goal.

Future development will include the design and implementation of a unique application system based on the personalized game-based learning with automatic recommendation of a particular way of learning, and defined on the basis of students profile information. In addition, we plan to conduct an experimental study to determine whether this teaching and training method could achieve better results than the traditional face to face learning.

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