Use of Kolb's learning cycle through an adaptive educational hypermedia system for a constructivist approach of electromagnetism

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Abstract: - In this paper we describe the outcomes of experimentation with technical school students (of the same degree as senior high school students) on Physics teaching. Our first goal was to find out if the application of the Kolb's learning cycle on Physics teaching improves the performances of students. The unit of the chapter of electromagnetism we presented was the following: "Motion of a charged particle in perpendicular to the dynamic lines of a uniform magnetic field". This unit was presented in four different teaching methods through our Web-based Adaptive Educational Hypermedia (AEH) system under development. Our second goal was to investigate which combinations between *Abstract* and *Concrete* learning styles of students, helps them to improve their performances. The results showed that the majority of students improved their performances. Also, their performances were in close relation to the students' learning styles and their abstract and concrete dimensions. The results of experimentation will help to adapt the educational material according to the learning style of each individual student and to support adaptive collaboration through our AEH system.

Key-Words: - Adaptive Educational Hypermedia, Learning Styles, Collaborative Learning, Adaptive Presentation.

1 Introduction

A primary principle of individualized learning is that no single instructional strategy is best for all students. As a consequence students will be able to achieve learning goals more efficiently when pedagogical procedures are adapted to their individual differences [3]. The learning style describes individual differences in learning. Many researchers study the learning styles and learning preferences of the learners to adapt teaching methods in a way the learners prefer to learn.

Rezler and Rezmovic [13] define learning preferences as simply the choice of one learning situation over another.

Kolb [7] identifies a number of commonly used learning methods and whether each is helpful to a particular learning style or not [11]

AEH systems build a model of the individual learner, and apply it for adaptation to that user. A student in an AEH system will be given a presentation that is adapted specifically to his knowledge of the subject [2], and a suggested set of most relevant links to proceed further [1]. The goal of adaptive presentation technology is to adapt the content presented in each hypermedia node (page) to student goals, knowledge, and other information stored in the student model [1]. Recently, another source of information for adaptation is learner's cognitive or learning style. For example, in INSPIRE [12] the learning styles determine exclusively the adaptation of the presentation and it is reflected in different sequences of activities in function of them. INSPIRE uses the Honey & Mumford's learning styles.

The criteria to select the learning style model are: the theoretical and empirical justification, if it possess assessment instruments, if it describes the instructional strategies associated to each category, the cost and if it is appropriate for the learning context [15]. According to these criteria, we chose the Kolb's Learning Style Inventory for adaptive presentation of the educational material and we describe it in section 2.

This work aims to investigate how the use of Kolb's learning cycle through our AEH system improves the performances of students and especially how the collaborative problem solving within groups consisting of Abstract and Concrete type of students is improved. The aim of adaptive collaboration support through our AEH is to use the knowledge about different learners in order to form a matching collaborative group so that the learning experience of the two participants can be shared between them [1].

2 Theoretical background

2.1 Experiential learning theory

Experiential learning theory (ELT) draws on the work of prominent 20th scholars (e.g., Dewey, Lewin, Piaget, Rogers, and others) who gave experience a central role in their theories of human learning and development to develop a holistic model of the experiential learning process and a multilinear model of adult development [7]. The theory is built on six propositions that are shared by these scholars.

1. Learning is best conceived as a process, not in terms of outcomes.
2. All learning is relearning.
3. Learning requires the resolution of conflicts between dialectically opposed modes of adaptation to the world.
4. Learning is a holistic process of adaptation to the world. Not just the result of cognition, learning involves the integrated functioning of the total person- thinking, feeling, perceiving, and behaving.
5. Learning results from synergetic transactions between the persons end the environment.
6. Learning is the process of creating knowledge.

ELT proposes a constructivist theory of learning whereby social knowledge is created and recreated in the personal knowledge of the learner. This stands in contrast to the ″transmission″ model on which much current educational practice is based, where pre-existing fixed ideas are transmitted to the learner.

The ELT model portrays two dialectically related modes of grasping experience-Concrete Experience (CE) (learning from feelings) and Abstract Conceptualisation (AC) (learning from thinking) and two dialectically related modes of transforming experience-Reflecting Observation (RO) (learning from watching) and Active Experimentation (AE) (learning by doing) [8]. These approaches to learning are associated with the four stages of the Kolb's learning cycle (Fig.1).

Experiential learning is a process of constructing knowledge that involves a creative tension among the four learning modes that is responsive to contextual demands. This process is portrayed as an idealized learning cycle or spiral that the learner ″touches all the bases″-experiencing, reflecting, thinking, and acting [7].

According to Kolb [7] learning is defined as ″the process whereby knowledge is created through the transformation of experience″.

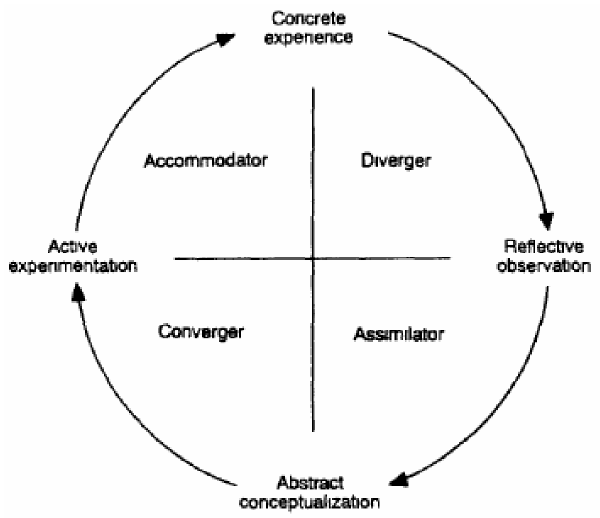

Fig.1: Kolb's learning cycle

2.1.1 Kolb's learning styles

The Kolb's ELT is a theory of cognitive learning styles provided as the basis of Kolb's Learning Style Inventory (LSI), which measures a learner's preference for specific stages of learning cycle. From these, it is possible to identify four learning styles: Converger (AC/AE), Diverger (CE/RO), Assimilator (AC/RO) and Accommodator (CE/AE). Individuals with different learning styles tend to learn differently from different teaching methods. Convergers have a strength on the practical applications of ideas. Divergers have the ability to view concrete experiences from a number of perspectives. Assimilators have the abilities to formulate theories and prefer abstract concepts. Accommodators have a strength on doing things. [7, 8]

Kolb [7, 8] considers that the Divergers and Accommodators have Concrete ″learning style″ and the Convergers and Assimilators have Abstract ″learning style″.

In our work we consider that the most appropriate didactical approaches for each Kolb's learning style are these we present in Table 1 and they were chosen according to specific researches done by Svinicki & Dixon [16] and Harb et al [5].

2.2 Collaborative Learning

Team-projects enhance the communication opportunities, help learners to share their experiences, ideas, opinions and findings before creating their own understanding of the subject [4].

Sandmire and Boyce [14] investigated the performance of two-person collaborative problem solving teams in an allied health education anatomy, physiology, and pathology course.

Learning style	Didactical approach
Diverger	Thought questions, Visualizations (video)
Assimilator	Theory, Examples
Converger	Exercises (interactive problem solving)
Accommodator	Activity (based on explorations and guided discovery)

Table 1: Didactical approaches to Kolb's learning styles

They compared a group of high Abstract-high Concrete student pairs with a group of Abstract pairs and a group of Concrete pairs. The Abstract-Concrete pairs performed significantly better on a simulated clinical case than the Abstract pairs and slightly better than the Concrete pairs, indicating the value of integrating the Abstract and Concrete dialectics of the learning cycle [6].

In our experimental classroom, according to Kolb's [7] consideration, we formed two groups of Abstract-Abstract pairs (one Assimilator-Assimilator pair and one Converger-Converger pair), two groups of Concrete-Concrete pairs (one Diverger-Diverger pair and one Accommodator-Accommodator pair) and two groups of Abstract-Concrete pairs (one Diverger-Assimilator pair and one Accommodator-Converger pair).

2.3 Explorations & Guided Discovery

An exploration is a structured lab where the student makes predictions about a program's behaviour, then runs the program to compare the actual result with the predicted result. The questions are deliberately designed to challenge common errors and preconceived notions of computers and programming languages. Guided questions help the students refine their mental models of computers [10].

In our work the activity is supported by explorations as follows. The student makes predictions about the motion of a particle in a uniform magnetic field and also, he makes computations for the basic concepts (e.g. radius, period). Then he runs simulations to compare the actual results with predicted results. Additional processes such as cooperation in pairs, feedback, and ″dialog″ with the system helps him to reflect and to revise his points of view.

Guided discovery learning is a learner-centered approach that combines didactic instruction with more student-centered and task-based approaches. The main purpose of the guided discovery methodology is to lead learners to discover domain concepts with various learning facilities such as simulation, demonstration environments, and so on. That is, the guided discovery methodology focuses on how to guide learners in their own discovery.

3 Experimental Process and Results

3.1 Participants

The experiment was conducted in a technical school (of the same degree as senior high school) in Philadelphia, Athens, Greece in January 2007. Twelve eighteen year old boys from C′ Class participated in the experiment. The Kolb's LSI test was given to 26 students. Also, the students were given a 10 gap filling type question pre-test on relative prior knowledge of the unit and on the basic knowledge on the subject unit we would present. The selection criteria we used to choose the participants were their performances in the pre-test and their learning styles. In agreement with these criteria, we chose 12 students out of 26 students. These students were 3 Divergers, 3 Assimilators, 3 Convergers and 3 Accommodators who achieved higher scores at the pre-test than others. The reason we chose the participants in this way was their higher prior knowledge.

During the experimentation the AEH system initially adapts the most appropriate teaching method according to the students' individual learning style. That is, students who had different learning styles studied different stage of the learning cycle. Since the students have studied the subject material of one stage of learning cycle then they choose the next stage to study. According to Kolb [7], to have better learning results, the students must pass all the stages of the learning cycle many times.

3.2 Educational Material

The educational material for the four learning styles is presented through our AEH according to the didactic approaches in Table 1. In short, we will describe the subject material of our AEH for the four stages of Kolb's learning cycle bellow.

3.2.1 Stage CE/RO: Thought questions, Visualizations

In this stage the educational material consists of 11

thought questions, most of them based on the visualized particle motions (videos). In fig.2 a page in which the content is a thought question is presented. For this question four answers were given out of which one is correct. The student chooses one only answer and then clicks on the feedback button to receive feedback.
Fig.3 shows the feedback that is presented to the student when he clicks on the feedback button. Feedback is considered by cognitive psychologists one of the vital sources of information for students because it helps them to reconstruct their cognitions and it also supports them in metacognition processes [9]. The feedback method we used is the response-contingent with answer-until-correct method. This method provides the student with additional knowledge related to the question he has been asked and it also explains why the correct answer is correct and why the wrong answer is wrong.

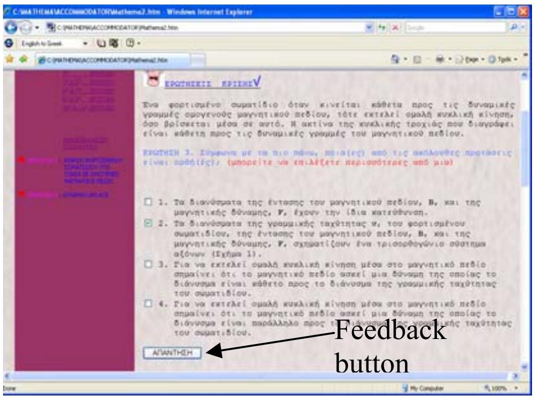

Fig.2: Thought question

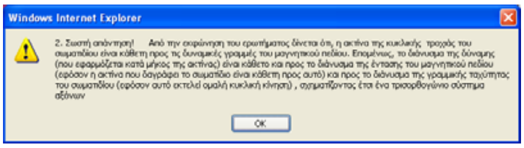

Fig.3: Feedback for the chosen answer of Fig. 2

3.2.2 Stage AC/RO: Theory, Examples
In this stage the educational material consists of two pages of theory and three pages of three practical exercises on the theory of the subject unit. In Fig.4 a page of the content related to the theory of the subject unit is presented.

3.2.3 Stage AC/AE: Exercises (interactive problem-solving)
In this stage the educational material consists of five exercises based on the interactive exercise- solving. In Fig.5 a page in which the content of an exercise and its possible solutions is presented.

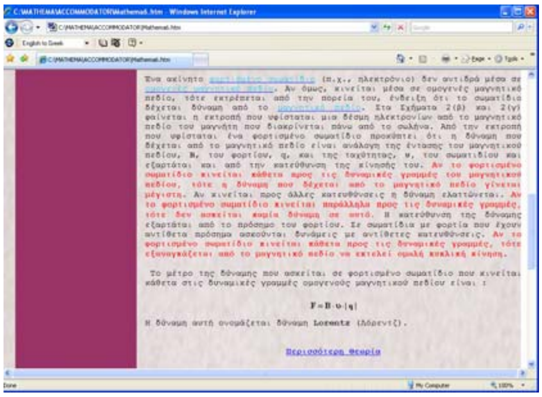

Fig.4: Theory of the subject unit

In Fig.6 a choice of the answer upon the student's clicks on the feedback button and the agent who answers the student's clicks on the feedback button is clearly distinguished.
As the agent speaks a text with the same content appears on the screen. In this way, the agent supports the dual coding method.

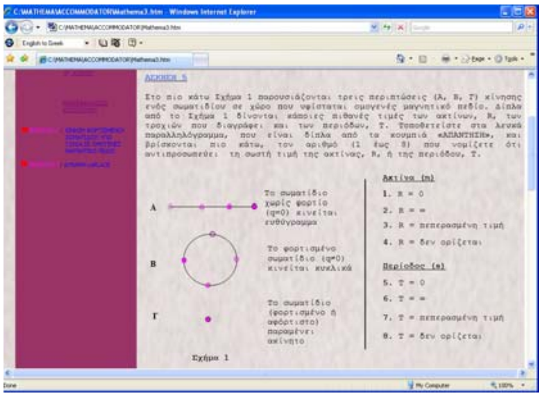

Fig.5: An exercise of the subject unit

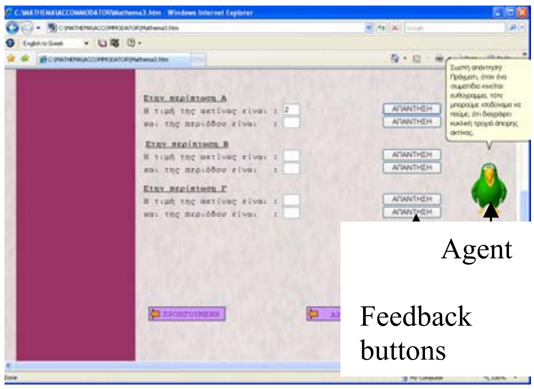

Fig.6: Interactive exercise-solving

3.2.4 Stage CE/AE: Activity
The activity is designed according to explorations and guided discovery methods. A specific goal of

the activity is the confrontation of student's misconceptions and learning difficulties that the Physics' formalism generates in the chapter of electromagnetism.

At the beginning of the activity the student is asked to prove the formulas about radius, R, and period, T, of the particle circular motion in terms of the magnetic field, B, the particle velocity, v, and the particle charge, q.

Then the students apply these formulas in assignments of Table 2 and Table 3 in order to calculate the values of radius, R and period, T. Also, they predict the kind of the particle motion (no motion, clockwise circular motion, anticlockwise circular motion, straight motion) making use of the right hand rule.

	Particle charge, q (C)	Particle velocity, v (m/s)	Radius, R (m)	Particle motion
A1.1	0μC	0		
A1.2	0μC	2		
A1.3	+2μC	0		
A1.4	+2μC	2		
A1.5	+2μC	4		
A1.6	-2μC	0		
A1.7	-2μC	2		
A1.8	-2μC	4		

Table 2: Computations of the radius values and prediction of particle motion

	Particle charge, q (C)	Magnetic Field, B (T)	Period, T (s)
A2.1	0μC	2	
A2.2	0μC	3	
A2.3	+2μC	2	
A2.4	+2μC	3	
A2.5	-2μC	2	
A2.6	-2μC	3	

Table 3: Computations of the period values

In the next step of activity the students run the simulations we have designed for this experiment, using the Interactive Physics™ software and then they compare the actual results with the predicted results and they decide about the correct and wrong values and the wrong predictions of particle motions. In the next step of activity the students cooperate in pairs to share their experience, opinions and findings. Finally, they complete a common table like the Table 2. At the end of the activity each student checks up his values through a ″dialog″ with the system. Also, the students accept additional feedback on the solutions of the problem.

3.3 Results of the students' cooperation

In our research we formed groups of students pairs in the same way as Sadmire and Boyce did [14]. In each group, one of the participants performed better at pre-test than the others. The results of the cooperation are presented in Tables 4 and 5. In these tables the positive changes show that some student reduced his errors while the negative changes show that some students increased their errors.

Groups	Positive Changes	Negative Changes
Concrete - Concrete	+2	0
Concrete - Abstract	0	0
Abstract - Abstract	+8	0

Table 4: Corrections of the radius values by cooperation

Groups	Positive Changes	Negative Changes
Concrete - Concrete	+2	-1
Concrete - Abstract	0	0
Abstract - Abstract	+4	0

Table 5: Correction of the particle motion by cooperation

The post-test concludes 14 questions and it measures the students' performances for the subject material that they have studied in four stages of Kolb's learning cycle. Some questions of them measure the students' performances only for the activity in which they cooperate in pairs for problem solving.

The average grades of the students' groups at the pre-test and the post-test that measure the students' performances after their cooperation in pairs are presented in Table 6.

Groups	Pre-Test averages	Post-Test averages	Group's improvement
Concrete Concrete	5	11.57	131%
Concrete Abstract	7	10.94	56%
Abstract Abstract	6.25	12.67	103%

Table 6: Average grades of groups at the pre-test and the post-test

In Table 7, the average grades of the ″Concrete″ and ″Abstract″ participants are presented.

″Learning Style″	Pre-Test Averages	Post-Test Averages	Improvement
Concrete	4	10.73	168%
Abstract	8.33	12.71	52%

Table 7: Performances of ″Concrete″ and ″Abstract″ participants

3.4 The students' performances

The post-test was given to the participants 5 days after the presentation of subject material through the AEH system. The entire improvement of the participants from the pre-test to the post-test was found to be 92%.

4 Conclusions and future work

The average grade of the students' groups at the pre-test was 6.1 and at the post-test was 11.72 (maximum 20). Some of the participants improved their performances a lot.

The ″Concrete″ participants performed approximately three times better than ″Abstract″ participants.

The Concrete-Concrete pairs performed significantly better in problem solving situations than the Concrete-Abstract pairs and slightly better than the Abstract-Abstract pairs.

For the Concrete-Concrete pairs and Abstract-Abstract pairs the research of Sadmire and Boyce [14] is confirmed. The high Abstract-high Concrete pair in Sadmire and Boyce's research achieved the best performance, while in our research the Abstract-Concrete pairs achieved the least performance.

Generally, the participants helped by their cooperation corrected some of their errors but not all of them. The ″dialog″ with the system helped them to reflect and then corrected all their errors.

In conclusion, the participants' performances immensely increased through studying four stages of Kolb's learning cycle.

Further design of our adaptive educational hypermedia system will rely on the results of this research. Also, we will take into account the opinions we collected through a questionnaire we gave the participants after the presentation of the unit.

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