MATHEMA: A Constructivist Environment for Electromagnetism Learning

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Abstract

In this paper we describe the Web-based adaptive educational hypermedia system called MATHEMA. In general, the MATHEMA is a learning system that dynamically generates courses in electromagnetism according to students' learning goal, knowledge level, performance, learning style, abstract or concrete dimension of learning style, preference for visual and/or verbal feedback, preference for the kind of navigation, and preference of using or not the navigation guidance. The MATHEMA supports the following adaptive and intelligent techniques: curriculum sequencing, adaptive presentation, adaptive navigation support, interactive problem solving support, and adaptive group formation and peer help. Also, the MATHEMA supports meta-adaptation in the navigation of learners.

1: Introduction

Adaptive Educational Hypermedia (AEH) systems can be considered as the solution to the problems of traditional online educational hypermedia systems. These problems are due to the static content, the "lost in hypermedia" syndrome and the "one-size-fits-all" approach. AEH systems build a model of the individual learner, and apply it for adaptation to that learner. The adaptation is based on the learner specific characteristics such as goals, knowledge level, background or prior knowledge, interests, preferences, stereotypes, cognitive preferences and learning style that are stored into the learner model [1].

In Web-based AEH systems, several adaptive and intelligent techniques have been applied to introduce adaptation such as: curriculum sequencing, adaptive presentation, adaptive navigation support, interactive problem solving support, intelligent analysis of student solutions, example-based problem solving support, and adaptive collaboration support or adaptive group formation and peer help.

Indicatively, we refer the following relevant AEH systems: Arthur [3] uses the Mastery Learning Theory and supports the curriculum sequencing technique. KBS-Hyperbook [7] uses activities developed according to Project-based Learning Theory and supports the curriculum sequencing and navigation techniques. INSPIRE [9] uses the Elaboration Theory and Component Display Theory and supports the curriculum sequencing, adaptive presentation, and navigation support techniques as well as it uses the Honey and Mumford’s learning style model for adaptive presentation.

2: Design principles of the MATHEMA

DiSessa [2] suggests that Physics is best taught through experiments, labs, demonstrations and visualizations which help the students to understand physical phenomena conceptually. According to [10], educators should consider to stimulate the basic purposes of schooling curiosity, exploration, problem solving, and communication. Based on [2] and [10] suggestions, we design the MATHEMA by adopting Kolb’s Experiential Learning Theory (ELT) [5].

Kolb’s ELT is a holistic theory of learning and proposes a constructivist theory of learning whereby social knowledge is created and recreated in the personal knowledge of the learner through the combination of grasping and transforming experience. Kolb’s ELT is also a theory of cognitive learning styles that proposes the following four learning styles: Diverging, Assimilating, Converging, and Accommodating. These learning styles are identified by Kolb’s Learning Style Inventory (LSI) questionnaire [6].

Taking all the above into consideration, we adopt the following didactic approaches in the MATHEMA: questions, demonstrations, presentation of theory and examples, exercise solving, and problem solving activity through experimentations with simulations, explorations, guided discovery, and collaboration.

In the MATHEMA, we implemented the following techniques: curriculum sequencing, adaptive presentation, adaptive navigation support, interactive problem solving support, and adaptive group formation and peer help.

Curriculum sequencing: The main concepts of learning goal in the MATHEMA are progressively presented following the internal structure of the concepts.

Adaptive presentation: Taking into consideration the
researches of [4] and [11] as well as our research [8], we consider that the most appropriate didactic strategies that match to each of students’ learning style for adaptive presentation are: (I) Diverging: (a) Questions, Demonstrations; (b) Presentation of Theory and Examples; (c) Exercise Solving; (d) Activity - (II) Assimilating: (a) Presentation of Theory and Examples; (b) Exercise Solving; (c) Activity; (d) Questions, Demonstrations - (III) Converging: (a) Exercise Solving; (b) Activity; (c) Questions, Demonstrations; (d) Presentation of Theory and Examples - (IV) Accommodating: (a) Activity; (b) Questions, Demonstrations; (c) Presentation of Theory and Examples; (d) Exercise Solving.

Adaptive navigation support: In adaptive navigation support the MATHEMA helps the students avoid the lost in hypermedia syndrome by offering them the following techniques: direct guidance, link annotation, link hiding, and link sorting

Meta-adaptation in the MATHEMA: At the first time that the student logs in the system, it adapts the direct guidance, link annotation, and link hiding to the student according to his/her Web experience. Whenever the student has fulfilled the requirements for meta-adaptation (n successful assesses in the assessment tests), then the meta-adaptive mechanism will appear information with the advantages and disadvantages for all four navigation techniques on the screen and the student is able to select a different navigation technique.

Interactive problem solving support: The general framework of the problem-solving activity includes six steps as follows:

Step 1: Activation of prior knowledge (use of formulas from previous knowledge and the formulas of the subject matter that the students are studying with the aim of extracting formulas for calculating certain Physics quantities (or dimensions)).

Step 2: Recognizing of restrictions on the values of parameters of the extracting formulas in Step 1 through a guided dialog with the system.

Step 3: Application of extracting formulas in Step 1 and prediction of the kind of motion.

Step 4: Working with the simulation.

Step 5: Collaboration in pairs of students.

Step 6: Checking of results through a guided dialog with the system.

The aim of the guided dialog in Step 2 of the activity is to help the students to set restrictions on the values of parameters of extracting formulas in Step 1. The aim of the guided dialog in Step 6 of the activity is to detect the possible misconceptions or learning difficulties of the students in order to help them overcome.

Adaptive group formation and peer help: The system creates a priority list of possible candidate mates for a certain student, taking into account the abstract or concrete dimension of his/her learning style and his/her candidate mates’ learning style and total performance as well.

3: Discussion and Future Work

In this paper, we describe the design principles of our AEH system MATHEMA as well as the adaptive and intelligent techniques that it supports.

So far, our AEH system has supported curriculum sequencing, adaptive presentation, adaptive navigation support, interactive problem solving support, and adaptive group formation and peer help techniques as well as meta-adaptation in the navigation.

In the future, it is a real challenge for us to incorporate intelligent analysis of student solution, and example-based problem solving support in the MATHEMA.

References