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Instructional and Interface Design in an Adaptive Educational Hypermedia System

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SUMMARY
The paper focuses on the instructional and interface design adopted in the Adaptive Educational Hypermedia System INSPIRE-INtelligent System for Personalized Instruction in a Remote Environment. INSPIRE dynamically generates lessons accommodating diversity in learners' knowledge background, preferences and progress, and supports end-learner modifiability. The design of the interface supports the notion of the system as a coach on the learning process. The way the interface is embodied in the instructional strategy adopted in INSPIRE is described. An experimental study of the system is presented, which assesses students' attitudes towards the proposed design.

KEYWORDS: Adaptive Educational Hypermedia Systems, Usability, Utility, Adaptation.

INTRODUCTION

Adaptive Educational Hypermedia Systems (AEHSs) [1] possess the ability to make intelligent decisions about the interactions that take place during learning and to support end-learner modifiability, introducing novel forms of co-operation and communication between tutors, learners, developers and computers. Considering the *usefulness* of these systems, two different dimensions should be considered, utility and usability [5]. In general an educational system has high *utility*, if learners learn by using it. Thus, it is important to consider a system's instructional design and adaptation within the framework of current learning theories and models, and thoroughly plan the sharing of the task of adaptation between the learner and the system [6]. On the other hand, the *usability* of an AEHS, i.e. how well learners use system's functionality, should be considered through the known principles of interface design but in the framework of the proposed instructional design, leading to the pedagogical usability design [8]. The interface is the embodiment of the instructional strategy [2]. As a mediator between the system and the learner its contribution is critical to the twin goals of learning effectiveness and learning efficiency.

In this paper, we present the instructional design approach adopted in a recently developed AEHS named INSPIRE as well as the way it reflects to the interface of the system. The paper is organised as follows. In the next Section, i.e. Section 2, the main functionality of the system is presented as well as several interface design issues that outline it. In Section 3 the way that the interface is adapted in order to provide learners with personalized support in their navigation and study, is presented. In Section 4 the opportunities offered to the learner to undertake the instructional control are exhibited. In Section 5 experimental results evaluating the quality of the instructional material incorporated in the system and the usability aspects of the interface are reported. The paper ends with concluding remarks and further research.

INTERFACE DESIGN ISSUES

INSPIRE, based on the learning goals of the learner, generates a sequence of lessons, i.e. plans the lesson contents and delivers the appropriate educational material, supporting learners to the accomplishment of their goals. Furthermore, it provides learners with the option to intervene, to express their opinion about their own characteristics or about the lesson contents, and this way to provide learners with instructional control over the system. As the interface outlines the functionality of the system, it should accentuate the above learner-centred design, keeping learners "informed" about the *adaptivity* and *adaptability* options and providing them with control over the system. To this end, multiple interaction metaphors are offered to the learner. In case the prevailing interaction metaphor is that of direct manipulation by the learner, where the learner undertakes the instructional control and the system behaves rather passively, offering to the learner the necessary tools to maintain the initiative and control of the interaction. In another interaction metaphor the system takes the instructional control adapting its response to the learner and providing lessons tailored to his/her knowledge level and learning style.

Following the principle that a conceived interface design of an educational system should make everything but performing the learning tasks as transparent as possible [2], a functional analysis [9] was performed on what tasks/functions are performed by the learner in a distance learning setting. This way several aspects of the interface were clarified. Thus, the learners are provided with the appropriate *communication tools*, with *navigation aids* on the domain knowledge aiming to protect them from

the "lost in hyperspace" and "cognitive overhead" problems, usually identified in hypermedia [6], with the appropriate *learning resources* and *the option* to personalise the whole interaction.

INSPIRE's main screen is divided into three areas (see figure 1):

- The *Navigation Area*, which includes the contents of the lessons in a hypertext form as links. A structural navigation form of links [17] has been adopted to outline the structure of the domain knowledge and to support learner-controlled navigation;
- The *Content Area*, where the pages, that the learner selects to study, appear. Associative links [17] within the content of these pages are used, that point out to different types of educational material, such as exercises, examples, activities, etc. This way a general overview of the page contents is provided as well as long information is split into multiple pages (see next Section for more details on the Content Area). In order to sustain optimal legibility, we used black text on white background (so-called positive-text) [17];
- The *Toolbar*, which includes several tools that offer learners *easy access to* communication means (e-mail, forums, chat), to their personal notes, to their favourite pages, to a glossary of terms or *the option* to intervene to the dynamic process of lesson generation, undertaking the instructional control. Thus, the adopted design provides learners with a complete view of the structure of the domain knowledge, with direct access to learning resources and to the systems' functionality.

INTERFACE ADAPTATION BASED ON AN INSTRUCTIONAL DESIGN MODEL

The general design of the system's interface, as described in the previous Section, supports learner's freedom of movement. Furthermore, the system, aiming to enhance the learning experiences of the learner, has the ability to personalise the Navigation and the Content Areas. On each generated lesson, the presentation of the educational material in the Content Area is adapted to the learners' learning style [10] and a navigation route in the domain is proposed in the Navigational Area based on their knowledge level [12]. This functionality is mainly implemented through the appropriate visual cues and the interface adaptation as follows:

- The system supports learner's navigation and orientation in the domain by annotating the links in the lesson contents, following learner's progress;
- Different presentations of the educational material are provided, determining different instructional strategies depending on the learner's learning style;

The adaptive behaviour of INSPIRE is mainly guided by the learner model which reflects some features of the learner. The learner model that describes the learner (general information, learning style) and his/her "current state" (knowledge level on the different concepts, performance on assessment tests, etc.) is stored in the system and updated during the interaction. A benefit of this design is that every time a learner enters the system, INSPIRE is able to let him/her continue the lesson from the point where s/he left off the last time.

The Navigation Area. The instructional material of each lesson, provided for a particular learning goal, is organised around the outcome concepts, i.e. the most important concepts of the goal [13]. With each outcome concept specific *learning outcomes* are associated as well as its prerequisites and related concepts. The structure of the generated lesson is visualised in the Navigation Area of figure 1. The lesson contents are organised hierarchically into: (*i*) the learning goal, (*ii*) the selected outcome concepts, followed by a link to their prerequisites (icon on the right of the outcome's name), and (*iii*) the educational material. The educational material of the outcome concepts is further organised in three different levels of performance according to the instructional design theory [11]. Different icons annotate all the previous levels of knowledge abstraction.

Furthermore, the system adaptively annotates the lesson contents through colour cues, supporting learners to find an optimal path through the lesson. The knowledge-based adaptive annotation technique has been adopted [4]. Additional information about the current knowledge level of the learner on the different concepts augments their appearance in the Navigation Area. Thus, the outcome concepts are associated with the appropriate icons that represent the learner's progress. Using a real world analogy, like the filling of a measuring cup as a metaphor denoting learner's progress, we aim to support learner's expectations about the interface and to increase cognitive directness [9]. Concerning the navigational support provided through the educational material, a "flashlight" metaphor is adopted: the system colours the icons next to the links of the pages (in the Navigational Area) that the learner is proposed to study next. To this end, two state icons, i.e. coloured or black and white, are associated with the links of the educational material pages of the outcome and prerequisite concepts; wherever coloured icons appear next to a page, this page is recommended, i.e. ready to be studied but still not learned, while black and white icons appear next to the rest of the links. This information results from the learner's knowledge level on the outcome and the prerequisite concepts.

Also, a history-based mechanism has been developed so that as each page is visited from the Navigation Area, a check mark appears next to the link (see figure 1 – Navi-

gational Area). This way, learners are able to clearly see which pages of educational material they have already seen and which remain to be visited. Therefore, their sense of structure and location in the material is significantly strengthened [17].

The Content Area. According to the proposed instructional design, learners with different learning styles view different presentations of the educational material. Each page of the educational material is constituted of multiple representations of the outcome concepts, named *knowledge modules*, such as expository and inquisitory presentations, examples, exercises, activities based on computer simulations, exploration of resources and group works. These knowledge modules are presented as different areas in the educational material pages, annotated with different icons. These areas, depending on the learning style of the learner, are, either embedded in the page, or appear as associative links [17], or they do not appear at all. According to the proposed approach, all types of learners are provided with the same knowledge modules. However, the method and order of their presentation is adapted, implementing multiple instructional strategies that focus on different perspectives of the concept. According to [15] the order and the manner in which topics are treated can produce very different learning experiences.

LEARNER–CONTROL OVER THE SYSTEM

According to [14] while novices often need more guidance and want to be released from too complex tasks, advanced learners want to have control over the system. Especially in a distance learning setting, the target group is usually characterised by a considerable heterogeneity concerning their background knowledge, experiences, and goals. Thus, providing them with opportunities to take the control over the system's adaptation is critical. In the proposed approach, the system supports end-user modifiability offering opportunities to the learners to intervene in the lesson generation process directly or through updating their model. Towards this direction, the learner model is open to the learners, in order to stimulate them to reflect upon its contents. The externalisation of the learner model, so that the learner is able to access it, interact with it and change it, provides a means of communication between the system and the learner [7]. Externalised models can be provided if the model is maintained in a manner that allows it to be understandable, transferable and usable [7]. This way, the learners can always be informed on system's decisions concerning their knowledge level or learning style and in case of disagreement to update accordingly their model. In more detail, the learners always have the options: (*i*) to select the learning goal they prefer to study, among a predefined set of goals, (*ii*) to intervene to the dynamic lesson generation by reflecting upon their learner model, i.e. define their knowledge level on the presented concepts, learning style, (*iii*) to deactivate system's dynamic lesson generation process and select the lesson contents.

4. EXPERIMENTAL STUDY

An experimental study of INSPIRE has been conducted, as a part of the formative evaluation [9][16] of the system. In the experiment that will be described below, the main aim was to measure the subjective satisfaction [9][16] of learners on the instructional and interface design, as well as to collect real data about the way learners utilise the system. In this experiment 10 undergraduate students and 9 postgraduate students of the department of Informatics and Telecommunications, University of Athens, participated. They had already studied the printed notes of the module "Computer Architecture", and they had recently been examined on the module. The students participated in an experiment, in a laboratory setting, where they studied the knowledge goal "Which is the role of cache memory and its basic operations" in INSPIRE for two hours and submitted an assessment test and completed a questionnaire. During the experiment their actions were being logged. According to our pretest results, they differentiate on the learning experiences they prefer, such as attending presentations or working on activities or experimenting or observing a task/process being performed, etc. and they actually prefer graphics or text as a primary style of document. At the end of the experiment, they submitted the questionnaire of Honey and Mumford in order to evaluate their learning style.

All the students were provided with the same presentation of the educational material. In order to ensure that they will experience the full functionality of the system's instructional design in the experiment time, we provided them with a usage scenario [3], in printed form, listing the various steps they should perform. Several questions, with rating scale answers or open-ended, were embedded in the usage scenario, reflecting likes and dislikes, problems identified, suggestions, etc.

The dimensions that were chosen for the analysis of the questionnaires are: (*i*) the instructional design approach, (*ii*) learner's subjective estimation on the support offered by the system through their study and (*iii*) system's usability.

Figure 1: INSPIRE's main screen. The screen is divided into three areas: (A) Navigation Area, (B) Content Area and (C) Toolbar. In the Navigation Area, the contents of the lesson are provided as links. Note that coloured icons indicate the recommended pages of educational material. Also, a check mark denotes the pages that the learner has already visited. In the Content Area, the page that the learner selected appears. Note that, different knowledge modules comprise a page of educational material: Link to the theory, an activity on a computer simulation, links to application examples, link to an exercise. Finally, in the Toolbar Area, several tools are provided: *Glossary:* link to a glossary of terms, *Notes*: link to an area for keeping notes on each particular page of educational material, *Favourites*: link to the educational material pages the learner has marked as favourites, *Communication tools*, *Help*: information on system's functionality, *Model*: link to the page where the learner can inspect and modify his/her model, *Lesson*: link to the page where the learner can deactivate the dynamic lesson generation process and select the contents of the next lesson.

Rating scales were used to ask learners how well they liked the instructional material design and how useful they found it, concerning the conceptual structure, the educational material structure and the multiple representations provided on the different concepts (multiple knowledge modules). The data gathered are presented in Table 1. An interesting point here is that most of them acknowledged the usage of multiple representations in the educational material through independent links, as a way to minimise the text presented in one screen. They also suggest that by providing the different knowledge modules as links, the system protects them from cognitive overhead and disorientation and at the same time it supports them in organising their study.

In Table 2 learners' responses about the quality of the educational material supporting the different levels of performance, are summarised. Note that most of them found that the provided material sufficiently covered the provided learning goal. However they stated that more examples would be beneficial. Different learning preferences and studying attitudes were observed. Some of the learners were delighted by the inquisitory presentation of the theory, while others found little use in the questions enriching the text. Some found very helpful the idea of working with activities in computer simulations while others said that examples helped them to understand and use the presented concepts. Analysing their comments, a variety of preferences concerning the order of presentation of the different knowledge modules was observed.

	Not at all	Little	Enough	Very Much
The concepts' organization in outcome concepts followed by their prerequisites in each lesson is logical and well structured	-	-	1 (5)**	9(4)
Structuring the educational material on different levels of performance supports understanding of concepts	-	(1)	6(4)	3(3)
The presentation of multiple knowledge modules on each concept (theory, exercises, examples, activities, etc.) through links facilitate studying	(1)	(1)	3 (3)	5(3)

***Table 1*:** Learner's Estimations on several aspects of the instructional material (courseware) design: the conceptual structure, the educational material structure, the use of multiple representations

	Satisfactory	More theory	More examples	More examples & exercises
Suggest the type of educational material that should be added or removed from the theory presentation (Remember level)	6(4)*	(2)	4(3)	-
Suggest the type of educational material that should complement the application of theory and its use in novel problems (Use level)	6(5)	(2)	3(2)	1

***Table 2*:** Learner's Estimations on Educational Material quality and quantity. Each row contains an open-ended question posed to the learner and the columns their answers.

	Not at all	Little	Enough	Very Much
The proposed design facilitates studying	-	(3)*	-	10 (6)
The proposed design facilitates the navigation through the domain knowledge	-	1 (1)	(1)	9 (7)

***Table 3*:** Learner's estimations on the general system's design

The overall learners' estimation on how much the system supports their study and navigation through the domain is presented in Table 3. Although most comments concerning the system's environment were positive, they pointed out some inconveniences on the icon selection. They also commented that the provided educational material is easier to study and to understand, compared to the printed notes of the module. This is because of the multiplicity of the representations provided, the highly structured presentation and the easy access to prerequisite knowledge.

Concerning system's usability several open-ended questions were posed referring to the login process, system's messages to the learner, the content presentation and the accuracy of icons' notation. All found the login process simple, quick, easy and user friendly as the system guided them with the adequate messages. Also the idea of providing them the option to initialise their learning style was noted as learner-centred. The messages that the system provides were characterised as adequate and comprehensive, nice and user-friendly. An interesting point here is that six of the undergraduate students thought as messages of the system the questions embedded in the educational material in the inquisitory presentations and they comment that this way the formal presentation of information becomes more personalised and user-friendly. Concerning the content presentation, they commented that although studying in front of a computer screen for an extended period of time is very fatiguing, the idea of structuring a page in different areas facilitates studying and at the same time provides them the initiative of selecting the educational material to study next. Concerning the icons associated with the different types of knowledge modules or the different levels of performance or the outcome concepts, students' comments inspired several improvements on the interface of the system.

By a preliminary analysis of the log files, we inspected the learner's navigation routes through the domain and the educational material. The variety of their navigational patterns corroborated the assumption that different instructional strategies should be applied to different learners. All this information will be further used in order to evaluate and further develop the adaptive features of the system focusing on the dynamic adaptation of instructional strategies to different learning styles during the interaction.

* In brackets appears the position of postgraduate students

CONCLUSIONS

Web-based educational systems should be designed to offer learning experiences in a user friendly way. Thus, in order the interaction between the learner and the system to succeed to its educational potential, the issue of the interface design should be considered as a component of the entire system's design. The integration of the interface design into the traditional instructional design process was mainly considered through the case of INSPIRE.

INSPIRE is an AEHS that monitors learner's activity and according to certain instructional design guidelines adapts its interface in order to provide personalised support in learners' navigation and study. It is also adaptable as it allows the learner to take the control over the system. In the proposed approach, the learner model is used as the basis for the personalization of knowledge communication among the system and the learner.

Further research is on progress concerning:

- the way the information stored in the learner model can be further exploited by: (*i*) the system to inform the learner on its decisions, and (*iii*) the tutor for the evaluation of the provided material and for monitoring learners' progress and attitude while studying
- the evaluation of the educational effectiveness of system's adaptation

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