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Article

Supporting Student Learning in Computer Science Education via the Adaptive Learning Environment ALMA

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Abstract: This study presents the ALMA environment (Adaptive Learning Models from texts and Activities). ALMA supports the processes of learning and assessment via: (1) texts differing in local and global cohesion for students with low, medium, and high background knowledge; (2) activities corresponding to different levels of comprehension which prompt the student to practically implement different text-reading strategies, with the recommended activity sequence adapted to the student's learning style; (3) an overall framework for informing, guiding, and supporting students in performing the activities; and; (4) individualized support and guidance according to student specific characteristics. ALMA also, supports students in distance learning or in blended learning in which students are submitted to face-to-face learning supported by computer technology. The adaptive techniques provided via ALMA are: (a) adaptive presentation and (b) adaptive navigation. Digital learning material, in accordance with the text comprehension model described by Kintsch, was introduced into the ALMA environment. This material can be exploited in either distance or blended learning.

Keywords: adaptive learning environment; background-knowledge; blended learning; distance learning; learning style; text comprehension

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1. Introduction

There is a growing literature of studies focusing on assisting comprehension through personalized learning environments. In the early 1990s, the system Point & Query (P & Q), a hypertext/hypermedia system, was developed [1]. Students learned entirely by asking questions and interpreting answers to questions. On average, a learner ends up asking 120 questions per hour, which is approximately 700 times the rate of questions in the classroom. Evaluations of the P & Q software revealed, however, that it is not sufficient to simply expose the students to a series of questions associated with hot spots in a large landscape of hypertext/hypermedia content because the percentage of the learner's P & Q choices were shallow questions [1]. The original P & Q software was developed for the subject matter of woodwind instruments and was suitable for high school and college students [2].

AutoTutor is a computer tutor that attempts to stimulate the dialogue moves of a human tutor [3–5]. AutoTutor holds a conversation in natural language that coaches the student in constructing a good explanation in an answer, that corrects misconceptions, and that answers student questions. AutoTutor delivers its dialogue moves with an animated conversational agent that has a text-to-speech engine, facial expressions, gestures, and pointing. One goal of the tutor is to coach the student in covering the list of 10 expectations. A second goal is to correct misconceptions that are manifested in the students' talk by simply correcting the errors as soon as they are manifested. A third goal is to adaptively respond to the student by giving short feedback on the quality of student contributions (positive, negative, or neutral) and by answering the student's questions. A fourth goal is to manage the dialogue in a fashion that appears coherent and accommodates unusual speech acts by learners. AutoTutor has been evaluated on learning gains in several experiments on the topics of computer literacy [2] and conceptual physics [6]. The results of these studies have been quite positive [2].

MetaTutor is a hypermedia learning environment that is designed to detect, model, trace, and foster students' self-regulated learning about human body systems such as the circulatory, digestive, and nervous systems [7,8].Theoretically, it is based on cognitive models of self-regulated learning [9–12]. The underlying assumption of MetaTutor is that students should regulate key cognitive and metacognitive processes in order to learn about complex and challenging science topics [2].

SimStudents, an integrated learner model for history and equation problem solving, uses an ACT-R based cognitive model [13]. Other systems include the Empirical Assessment of Comprehension [14] and the model of comprehension and recall that is based on Trabasso and Van den Broek's model [15]. In this model, the reader, in order to understand the text, has to find the causal path that links the text from the beginning to the end. Recently, various approaches have been proposed [16], which involve learners in negotiating dialogues, as well as learner models that encourage inspection and modification of the model.

W-ReTuDis (Web-Reflective Tutorial Dialogue System) is a web-based open learner modeling system designed to support tutorial dialogue through reflective learning. It models human diagnosis of learner's cognitive learning and cognitive text comprehension. The learner model is open for inspection, discussion, and negotiation. The system promotes learners' personalized reflection through tutorial dialogue, helps learners to be aware of their reasoning, and leads them toward scientific thought. The system offers a two-level open interactive environment: learner level and tutor level. In learner level, the learner participates in the construction of his/her learner model through dialogue activities, which promote reflective learning. In tutor level, the tutor based on the learner model makes decisions concerning the appropriate activity, reflective dialogue, and dialogue strategy for the learner. The evaluation results are encouraging for the system's educational impact on the learners [17].

iSTART (Interactive Strategy Training for Active Reading and Thinking) is a web-based tutoring program that uses animated agents to teach reading strategies to young adolescent (Grades 8–12) and college-aged students [18]. The program is based on a live intervention called Self-Explanation Reading Training (SERT) that teaches metacognitive reading strategies in the context of self-explanation [19]. SERT was motivated in the context of self-explanation. SERT was motivated too by empirical findings that students who self-explain text develop a deeper understanding of the concepts covered in text, combined with a large body of research showing the importance of reading strategies such as comprehension monitoring, making inferences, and elaboration. SERT was designed to improve self-explanation by teaching reading strategies and in turn to facilitate the learning of reading strategies in the context of self-explanation. SERT has been found to successfully improve students' comprehension and course performance at both the college and high school levels. iSTART was designed to deliver an automated version of SERT that could be more widely available and could adapt training to the needs of the student. The research has shown that SERT is most beneficial for students with the least knowledge about the domain as well as the students who are less strategic or less skilled readers.

Our review of these initiatives reveal that the existing learning environments support students' text comprehension via activities which are linked with educational material in the web (Point & Query), via texts (MetaTutor), via texts, questions and dialogue between the tutor and the students (ReTuDis), via teaching guiding reading strategies (i-START). Nevertheless, the above learning environments do not support the following:

- The adaptation of learning environment to students' background-knowledge;
- The adaptation of learning environment to students' learning preferences;
- Students' text comprehension with texts of different cohesion; and,
- Students' support and assessment with activities which activate students' application of various reading strategies such as paraphrasing, bridging, elaboration.

In this line of research, the learning environment ALMA (Adaptive Learning Models from texts and Activities) was designed and developed. Its design was motivated by the results of previous studies in the field of text comprehension. Gasparinatou and Grigoriadou investigated the role of text cohesion and learners' background knowledge in the comprehension of texts in the domain of computer science [20–22]. The results showed that high-knowledge readers benefit from a minimally cohesive text, in contrast to low-knowledge readers who learn better from a maximally cohesive text. These empirical findings motivated the design and the development of ALMA. ALMA supports students' text comprehension via texts and activities. It supports learning via: (1) texts with various local and global cohesion for students with low, median, and high background-knowledge; (2) activities which correspond to different levels of comprehension and activate the student to apply different reading strategies while the proposed learning sequence of activities is adapted to students' learning style; (3) feedback during the performing of activities in order to inform, guide, and support students in order to discover their mistakes in order to make any corrections; and (4) individual support and guidance according to students' special characteristics.

ALMA can be exploited both in distance and in blended learning where students are supported with both face-to-face and computer based teaching. The adaptation techniques which are provided via ALMA are: (1) Adaptive presentation: the learning environment proposes the student to read the text version which is more appropriate for him according to his background-knowledge; and (2) adaptive navigation: the environment helps students to find paths in the hyperspace of the educational material via the adaptation of the page links to the characteristics of the learner model. In this context, ALMA contributes in the development of principles for the design of learning environments which support text comprehension and provide both individual help and guidance. Furthermore, ALMA contributes in the performance of a prototype adaptive learning environment which supports text comprehension and follows these special principles.

The first objective of this paper is to present the learning environment ALMA (Adaptive Learning Models from texts and Activities) which is based on Kintsch's Construction-Integration model for text comprehension [23] and also on Kolb's Learning Style Inventory (LSI) [24]. ALMA supports students with four text-versions of the same content but with different cohesion. It also supports students with a series of activities. Both texts and activities help students to reach deep comprehension. The second objective of this paper is to present the assessment of ALMA environment by the students who interacted with it.

2. The Construction-Integration Model

Adaptive Learning Models from texts and Activities environment (ALMA) is based on Kintsch's Construction-Integration model for text comprehension [23]. This model proposes that reading primarily involves the surface, text-based, and situation model levels of comprehension. Most relevant for our research are the text-based and situation model levels. A good text-based understanding relies on a coherent and well-structured representation of the text, whereas a good situation model relies on different processes, primarily on the active use of long term-memory or world knowledge during reading. Links between text-based and background-knowledge must be activated in the reader's mental representation of the text. Motivated readers encountering a gap in the text will attempt to fill it, and doing so requires accessing information from their background-knowledge, which in turn results in the text information being integrated with long-term memory. This gap-filling process can only be successful if readers possess the necessary background-knowledge.

The degree to which the concepts, ideas, and relations with a text are explicit has been referred to as text cohesion, whereas the effect of text cohesion on readers' comprehension has been referred to as text coherence [25,26]. Text coherence refers to the extent to which a reader is able to understand the relations between ideas in a text and this is generally dependent on whether these relations are explicit in the text.

Texts have local and global structure. Microstructure refers to local text properties and macro-structure to the global organization of text. Micro-structure is generally cued by the text via explicit indicators of relations between concepts and ideas (e.g., connectives, argument overlap, and pronominal reference). Micro-structure can also be constructed on the basis of the learner's knowledge when there are details or relations left unstated in the text. A text's macro-structure can be cued directly by the text via topic headers and sentences. Thus, for a good situational understanding, a single text cannot be optimal for every reader: low-knowledge readers benefit more from an easier, cohesive text, whereas high-knowledge readers should be allowed to infer with harder, less cohesive texts. McNamara *et al.*, examined students' comprehension of four versions of a biology text, orthogonally varying local and global cohesion. They found that readers with low and high background-knowledge benefit from a cohesive and a minimally cohesive text respectively [26]. Gasparinatou and Grigoriadou, investigated the role of text cohesion and learners' background-knowledge in the comprehension of texts in the domain of computer science [20,21]. The results are in agreement with the results of McNamara *et al.*, and motivated the design and the development of ALMA [26].

3. Kolb's Learning Style Inventory (LSI)

According to Kolb, "Learning is the process whereby knowledge is created through the transformation of experience [24]. Knowledge results from the combination of grasping experience and transforming it". He proposes that experiential learning has six characteristic features: (1) Learning is best conceived as a process, not in terms of outcomes; (2) Learning is a continuous process grounded in experience; and (3) Learning requires the resolution of conflicts between dialectically opposed modes of adaptation to the world. For Kolb, learning is by its very nature full of tension, because new knowledge is constructed by learners choosing the particular type of abilities they need. Effective learners need four kinds of ability to learn. From concrete experiences (CE), reflective observations (RO), abstract conceptualizations (AC), and active experimentations (AE). These four capacities are structures along two independent axes, with the concrete experiencing of events at one end of the first axis and abstract conceptualization at the other. The second axis has active experimentation at one end and reflective observation at the other. Conflicts are resolved by choosing one of these adaptive modes, and over time, we develop preferred ways of choosing; (4) Learning is a holistic process of adaptation to the world; (5) Learning involves transactions between the person and the environment; and (6) Learning is the process of creating knowledge which is the result of the transaction between social knowledge and personal knowledge. Kolb describes the process of experiential learning as a four-stage cycle. This involves the four adaptive learning modes mentioned above—CE, RO, AC, and AE—and the transactions and the resolutions among them. The tension in the abstract-concrete dimension is between relying on conceptual interpretation (what Kolb calls "comprehension") or on immediate experience (apprehension) in order to grasp hold of experience. The tension in the active-reflective dimension is between relying on internal reflection (intention) or external manipulation (extension) in order to transform experience [27].

Kolb defines four different types of knowledge and four corresponding learning styles. The main characteristics of the four styles are summarized below:

1. Type 1: the converging style (abstract, active) relies primarily on abstract conceptualization and active experimentation; is good at problem solving, decision making, and the practical application of ideas; does best in situations like conventional intelligence tests; is controlled in the expression of emotion and prefers dealing with technical problems rather than interpersonal issues.
2. Type 2: the diverging style (concrete, reflective) emphasizes concrete experience and reflective observation; is imaginative and aware of meanings and values; views concrete situations from

many perspectives; adapts by observation rather than by action; interested in people and tends to be feeling-oriented.

3. Type 3: the assimilating style (abstract, reflective) prefers abstract conceptualization and reflective observation; likes to reason inductively and to create theoretical models; is more concerned with ideas and abstract concepts than with people; thinks it is more important that ideas be logically sound than practical.
4. Type 4: the accommodating style (concrete, active) emphasizes concrete experience and active experimentation; likes doing things, carrying out plans and getting involved in new experiences; good at adapting to changing circumstances; solves problems in an intuitive, trial-and-error manner; at ease with people but sometimes seen as impatient and "pushy" [27].

4. An Outline of the ALMA Environment

ALMA actively engages students in the learning process (Figure 1). Learners differ in their experiences, their expectations, their skills, interests, preferences, and their cognitive or learning style. The basic principle of individualized learning is that a simple teaching strategy is not sufficient for all students. Therefore, the students will be better able to achieve their learning goals more effectively when the pedagogical processes are adapted to their individual differences [28]. According to Kolb: "Students with different learning styles respond differently to different teaching approaches and therefore the teaching strategies need to match their learning style" [24]. The benefits that arise when designing courses considering the learning styles of learners are: (a) the response of learners in the educational material and (b) the improvement of their performance. According to Sampson and Karagiannidis, the criteria for selecting the learning style model, apart from the theoretical and empirical justification, is that the selected model: (a) must hold an evaluation tool; (b) describes teaching strategies related to each category of learning style; and (c) is appropriate for the content and its cost [29]. Moreover, Merill suggests that, in teaching systems (in person or based on technology) in which a learning style model is adopted, it is necessary to choose appropriate teaching strategies for the cognitive objective of teaching and secondarily, based on these strategies, we can choose the most appropriate for each learning style [30]. According to Ferraro, the learning style may be more effective for the trainees where the technology fits with the principles of instructional design, wherein the application of the teaching criteria is essential for the selection of the most appropriate learning style model [31].

ALMA takes into account readers' learning preferences in order to propose them to start from activities that match their learning preferences and continue with less "learning preferences matched" activities in order to develop new capabilities [24]. To achieve this goal, it suggests that the student performs the "Learning-Style Inventory (LSI© 1993 David A. Kolb, Experience-Based Learning Systems, Inc: Boston, MA, USA)". The Learning-Style Inventory describes the way a student learns and how he/she deals with ideas and day-to-day situations in his/her life. It includes 12 sentences with a choice of endings. Consequently, ALMA is adapted to students' learning style resulting in personalized learning.

Figure 1. ALMA environment.

The classification of students according to their predominant learning style, follows the model proposed by Kolb, for the following reasons:

1. It is supported by the empirical studies of Svinicki and Dixon, and Harb *et al.*, concerning the application of Kolb's learning cycle in classrooms [32,33];
2. It is supported by the empirical study of Sein and Robey, in the domain of Computer Science [34];
3. Such an approach focuses on adult preferences on specific types of activities and educational material and thus it is considered suitable for an adaptive web based educational environment where students are usually adults with a common interest in the subject of the courses they follow;
4. The approach fits a student-centered teaching by providing useful guidance for the correlation of sequence of the specific type of educational material on the students' preferences, in order to achieve specific learning objectives;
5. It is supported by the questionnaire Learning Style Inventory (LSI) of Kolb, which consists of 12 multiple choice questions, the use of which is easy for trainees;
6. It is low cost and it is available for research purposes; and
7. It focuses on the behavior and on the beliefs of students in the workplace and so it has a great potential in the field of distance education.

The design of ALMA is also based on Kintsch's Construction-Integration Model. According to Kintsch, text comprehension always requires the student to apply knowledge: lexical, syntactic, semantic, and domain knowledge, personal experience, and so on. Ideally, a text should contain the new information a student needs to know plus just enough of the old information to allow the reader to link the new information with what is already known. Texts that contain too much of what the student already knows are boring to read and, indeed, confusing (e.g., legal and insurance documents that leave nothing to be taken for granted). Consequently, too much coherence and explication may not necessarily be a good thing [23]. Gasparinatou and Grigoriadou investigated the role of text cohesion and learners' background knowledge in the comprehension of texts in the domain of computer science. The results showed that high-knowledge readers benefit from a minimally cohesive text, in contrast to low-knowledge readers who learn better from a maximally cohesive text. Furthermore, the students perform activities which correspond to different levels of comprehension and activate them to apply different reading strategies while the proposed learning sequence of activities is adapted to students' learning preferences [20,22].

ALMA also, takes into account readers' background-knowledge in order to propose the appropriate text version from four versions of a text with the same content but different cohesion at the local and global level. As soon as the student selects the learning goal, ALMA suggests that the student performs a background knowledge assessment test, with scores characterized as "high", "median", and "low". ALMA motivates high knowledge students to read the minimally cohesive text at both local and global levels (lg), median knowledge students to read the text with maximum local and minimum global cohesion (Lg) or with minimum local and maximum global cohesion (Lg) and low knowledge students to read the maximally cohesive text (LG). Thus, ALMA offers individualized support via the technique of adaptive presentation. ALMA, also allows the student to choose the preferred version of text and records the time spent reading it (Figure 2).

Figure 2. ALMA suggests the appropriate text to the student according to his background-knowledge.

4.1. Educational Material Texts

For each learning goal, four text versions are developed through the authoring tool of ALMA (ALMA_auth) which provides the author with the option of developing and uploading the educational material. The author firstly develops the original text lg (the text with the minimal local and global cohesion). By varying the cohesion of the original text, according to rules described below, the author develops four texts with the same content but with different cohesion.

The following three types of rules are used to maximize local cohesion [26,35]:

- Replacing pronouns with noun phrases when the referent was potentially ambiguous (e.g., in the phrase: “Having determined a packet’s next destination the network layer append this address to it as an intermediate address and hands it to the link layer.”, we replace both “it” with “the packet.”)
- Adding descriptive elaborations that link unfamiliar concepts with familiar ones (e.g., “the network topology determines the way in which the nodes are connected,” is elaborated to “the network topology determines the way in which the nodes are connected, which means, the data paths and consequently the possible ways of interconnecting any two network nodes”).
- Adding sentence connectives (however, therefore, because, so that) to specify the relationship between sentences or ideas.
- The following two types of rules were used to maximize global cohesion [26,35]:
- Adding topic headers (e.g., ring topology, access control methods in the medium).
- Adding macro propositions serving to link each paragraph to the rest of the text and the overall topic (e.g., “subsequently, the main topologies referring to wired local networks, and their main advantages and disadvantages, will be examined in more detail”).

4.2. Educational Material-Activities

ALMA supports and assesses students’ comprehension through a series of activities such as: text recall, summaries, text-based, bridging inference, elaborative inference, problem solving, case studies, active experimentation, and sorting tasks.

Text recall helps students remember the basic ideas in the text by translating it into more familiar words. The students are also encouraged to go beyond the basic sentence-focused processing by linking the content of the sentences to other information, either from the text or from the students’ background knowledge. The empirical findings have shown that students who are able to recall the text and go beyond the basic sentence-focused processing are more successful at solving problems, more likely to generate inferences, construct more coherent mental models, and develop a deeper understanding of the concepts covered in the text [36] (e.g., “Describe in your own words the operation of network based on client-server model”).

Summaries also encourage students to go beyond the text and like text recall can be perfectly good indicators of well-developed situation models [23] (e.g., “Describe briefly the ways in which networks are interconnected”).

Text-based questions, as they demand only a specific detail from the text, measure text memory (e.g., “Which device is used to connect two incompatible networks?”). Bridging-inference questions motivate students to make bridging inferences which improve comprehension by linking the current sentence to the material previously covered in the text [37]. Such inferences allow the reader to form a more cohesive global representation of the text content [23] (e.g., "Compare the advantages and disadvantages between networks based on client-server model and on peer-to-peer model"). Elaborative-inference questions motivate students to associate the current sentence with their own related background knowledge. The most important is that students are encouraged to engage in logical or analogical reasoning process to relate the content of the sentence with domain-general knowledge or any experiences related to the subject matter, particularly when they do not have sufficient knowledge about the topic of the text. Research has established that both domain knowledge and elaborations based on more general knowledge are associated with improving learning and comprehension [38]. Elaborations essentially ensure that the information in the text is linked to information that the reader already knows. These connections to background knowledge result in a more coherent and stable representation of the text content [23,26] (e.g., "Could the internet function properly if we replaced the routers with bridges?"). In order to answer this question, the student has to link the information in the text according to which: "Compatible networks are interconnected with a bridge whereas incompatible networks are interconnected with a router" with the information from background knowledge according to which "the Internet consists of incompatible networks". Problem-solving questions motivate students to use the information acquired from the text productively in novel environments. This requires that the text information be integrated with the students' background knowledge and become a part of it, so that it can support comprehension and problem solving in new situations [23] (e.g., "In the following figure, the nodes 01 and 02 consist the network 1 whereas the nodes 03, 04, 05, and 06 consist the network 2. The two networks are interconnected with a bridge. Let us assume that the node 03 intends to send a message to node 02. Describe the process which will be followed") (Figure 3).

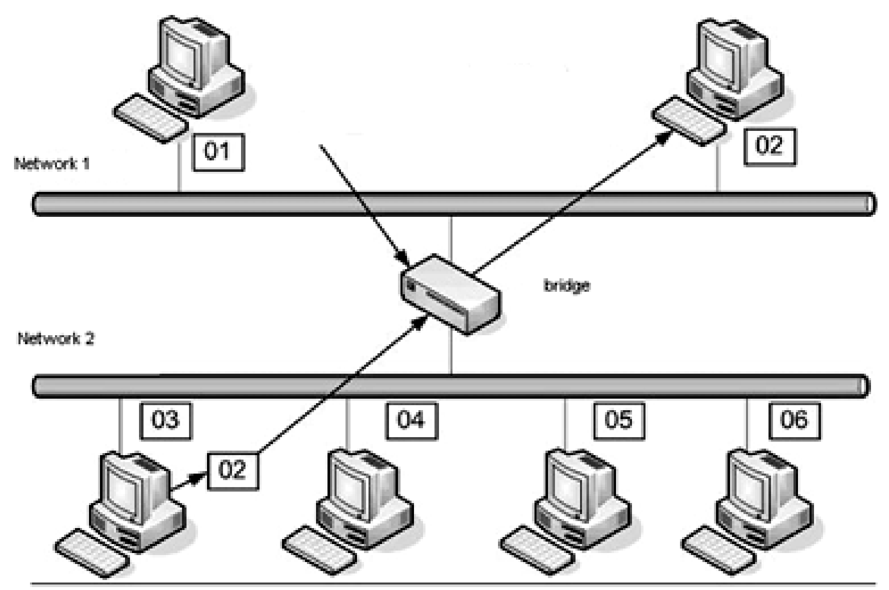

Figure 3. Delivery of a message between the nodes of two networks which are interconnected with a bridge.

Sorting task has great potential as a simple task and can be used both as a method of assessment and as a mode of instruction. Students are asked to sort a set of key words contained and not contained in the text, in certain groups. They are encouraged to do this task twice, once before reading the text and once more after reading the text. The sorting data are used to determine how strongly reading the text affected students' conceptual structure concerning the information in the text. We are interested in the degree to which the information presented in the text influences their sorting. Sorting task is an alternative method for assessing situation model understanding. (e.g., "Sort each of the following concepts: client server, administrator, in one of the following categories: client-server model, peer-to-peer model, distributed systems") [23].

Active experimentation activities motivate students to undertake an active role and, through experimentation, to construct their own internal representations for the concept they are studying [39,40] (e.g., Students are given the diagram of a home network (Figure 4) and they are asked if the network operates properly. Next, they are asked to design the same network by themselves via a software tool (e.g., Network Notepad) and check via the software if their original answer was correct).

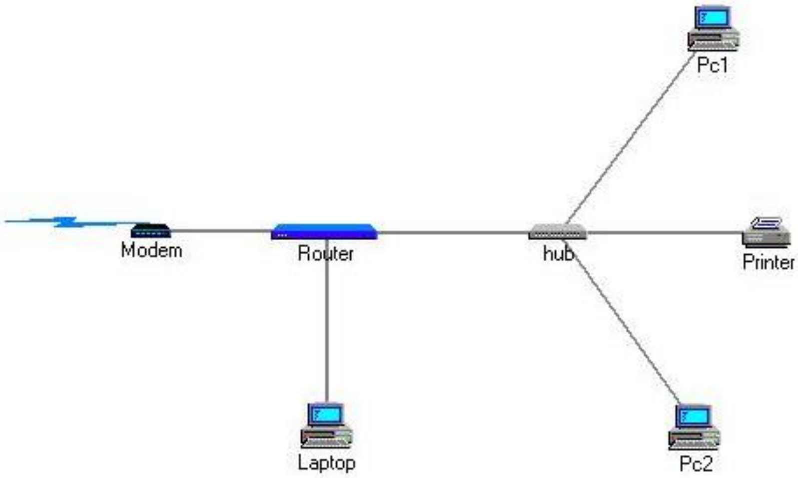

Figure 4. A home network.

Case studies motivate students to engage in the solution of an authentic and thus interesting problem. They are asked to analyze it and propose solutions. The problem is described in detail and is followed by a series of questions aiming to guide the students in the problem solving procedure (e.g., Students are given to study the process of mission and reception of a message. Then they are given the solution and clarifications about the solution of the problem. Afterwards, they are given a similar problem (e.g., concerning the web-based game, *World of Warcraft*. The game exploits the internet and specifically the client-server model and it permits students to play in a virtual environment possessing an agent. There are also other users in this environment with whom the students are able to chat when they are on line or send them a message. Next, students are asked to describe the process which will be followed in order for a user to connect with the specific network and to communicate with another user when the other user is: (a) online and (b) offline (Figure 5).

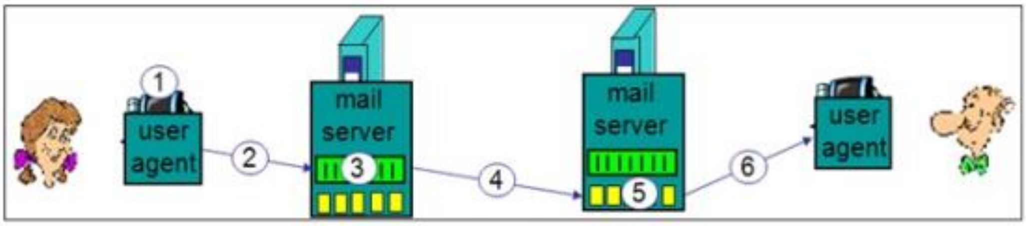

Figure 5. The route of data in the network.

Moreover ALMA supports multiple Informative, Tutoring and Reflective Feedback Components, aiming to stimulate learners to reflect on their beliefs, to guide and tutor them towards the achievement of specific learning outcomes and to inform them about their performance [41] (e.g., "Your answer is correct!" or "Your answer is not correct! You may have to read again carefully the paragraph concerning the peer-to-peer model").

5. Adaptive Techniques Provided via ALMA

5.1. Adaptive Navigation

As we mentioned before, ALMA actively engages students in the learning process. It takes into account readers' learning preferences in order to propose them to start from activities that match their learning preferences and continue with less "learning preferences matched" activities in order to develop new capabilities [24]. For example, the activity-based view of the content provided for converging learning style suggests that the learner should start with the activity of active experimentation (Figure 6). If the learner needs help, he can study the theory or case activity. Afterwards he can do the other activities for further practicing.

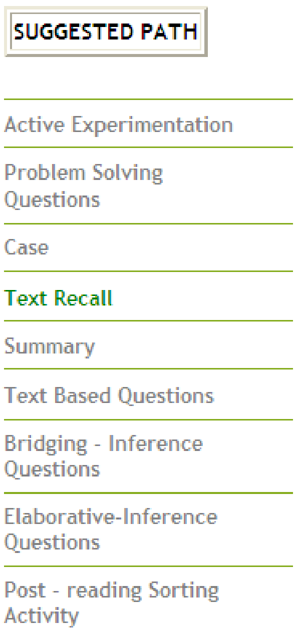

Figure 6. Learning sequence for student with converging learning style.

The activity-based view of the content provided to diverging learning style suggests that the learner should start by studying a case activity, continuing with the theory and then trying to complete the other activities. The activity based view of the content provided to assimilating learning style suggests that the learner should start by reading the theory, continuing with a case activity and then completing the other activities. The activity-based view of the content provided to accommodating learning style, suggests that the learner should start with a problem-solving activity. The learner continues with a case activity and an activity of active experimentation. Afterwards, he completes the other activities. Thus, ALMA offers individualized guidance according to student specific characteristics using the technique of adaptive navigation.

5.2. Adaptive Presentation

As soon as the student selects the learning goal, ALMA suggests that the student performs a background knowledge assessment test, with scores characterized as “high”, “median”, and “low”. ALMA motivates high knowledge students to read the minimally cohesive text at both local and global levels (lg), median knowledge students to read the text with maximum local and minimum global cohesion (Lg) or with minimum local and maximum global cohesion (lG) and low knowledge students to read the maximally cohesive text (LG). Thus, ALMA offers individualized support via the technique of adaptive presentation. ALMA, also allows the student to choose the preferred version of text and records the time spent reading it (Figure 2).

6. The Learner Model

The learner model in ALMA, keeps information about:(1) learners’ background knowledge level and learning style; and (2) learners’ behavior during interaction with the environment in terms of the learning sequence chosen, time spent on reading the text, time spent on an activity, *etc*. The learner model is dynamically updated during interaction with the system in order to keep track of the learner’s present status. During interaction, learners may access their model and view the information kept concerning their progress and interaction behavior (Figure 7). The model which supports the PESY ALMA, is the overlay model [42]. The overlay model is based on the representation of the knowledge of the student as an overlap of the field of knowledge. For each section of the learning objective, the learner model maintains a price which is an estimate of the level of knowledge of the trainee. The learner model is updated dynamically during interaction in order to always maintain the current status of trainee. The Adaptive Environment ALMA reserves the model of each student working in the environment and updates it throughout the interaction. The learner model:

- provides general information about the student such as user name, gender, learning style, background knowledge, knowledge level, and other characteristics of the learner;
- it includes data on the interaction of the learner with the learning content, relating to the course in relation to the didactic design of the environment and the opportunities it offers;
- it is updated dynamically during the interaction, in order to always maintain the current status of student; and
- the learner has the ability to access his model.

As we can see, in Figure 7, the student is informed by the model for his learning style, his background knowledge, the text which ALMA suggests to study according to his background knowledge, the performance in the activities, the performance of his colleagues *etc.* In particular, the characteristics that the system maintains for each student are:

- Name
- Sex
- Username
- Password
- Learning style
- Current learning target
- Performance in the background knowledge questionnaire
- The text or texts versions that have been read
- The performance in each activity (quantitative characterization)
- The average performance of other learners in activity
- The number of activities which the student elaborated
- The average number of activities which were elaborated by other students
- The feedback requested
- The browsing history

The fact that the learner is informed for the average performance of his colleagues through his model is very important because the student feels part of a group of students who have a common goal while healthy competition is cultivated. The learner model is a useful tool for teachers because: (1) it facilitates the assessment of the behavior and the performance of students during the performance of activities; and (2) it provides individualized feedback, where it is necessary, through ALMA_auth tool. Moreover, the study and the evaluation of learners' preferences with respect to the supplied material, provides a useful information for the assessment of texts, activities, and provided feedback units. Learner characteristics retained in the model, such as background knowledge and learning style are a source of adaptation to the environment.

7. Alma Authoring Tool (ALMA_Auth)

ALMA also includes the authoring tool (ALMA_auth). This tool provides the author with the option of developing and uploading the educational material. The ALMA_auth firstly gives the possibility to teacher to upload the educational material which satisfies the rules described above (see Sections 4.1 and 4.2) and secondly defines the adaptive techniques (adaptive navigation and adaptive presentation). Thus, it is a precious tool for the teacher to develop and to upload the learning material for the ALMA environment (Figure 8).

Specifically, the knowledge field of the environment is informed through ALMA_auth tool and the teacher introduces: (1) the texts and activities; (2) the correct answer in each activity; and (3) the units of feedback. For each learning target, ALMA_auth supports the author to write four versions of a text with different local and global cohesion according to the rules discussed in Section 4. Furthermore, the authoring tool supports the author in the development of activities that support learning, by activating the student to apply the reading strategies of paraphrasing, bridging and elaboration. The activities follow the specifications mentioned in Section 4. In addition, for each activity, ALMA_auth supports the author in developing three units of feedback according to the specifications mentioned in Section 4.

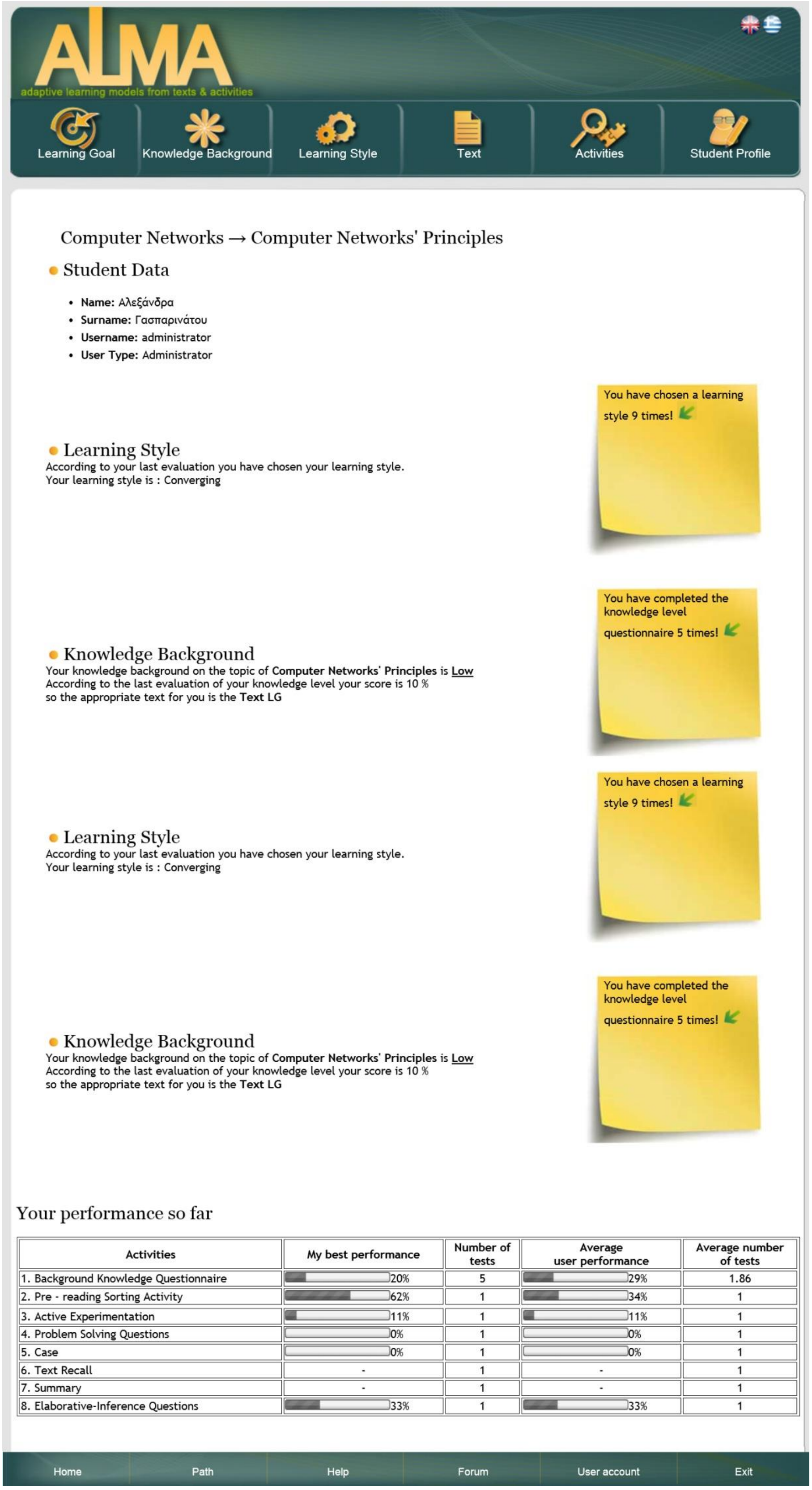

Figure 7. Learner Model.

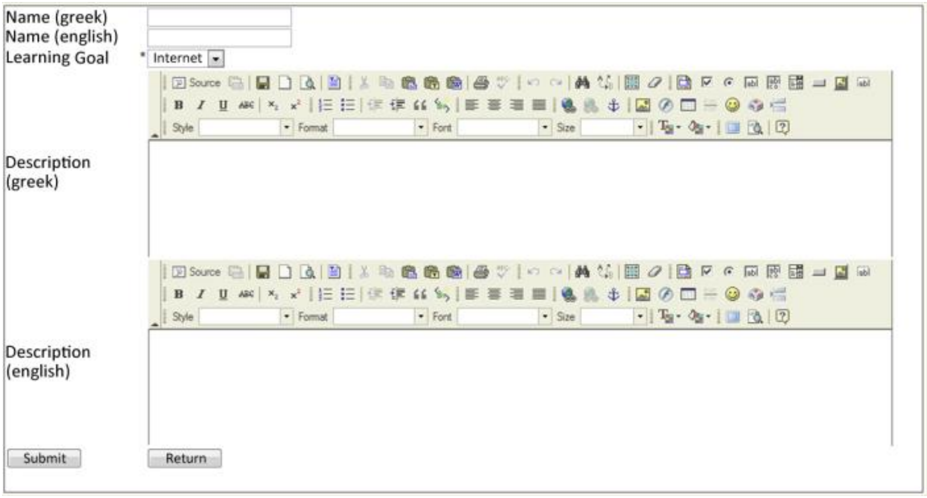

Figure 8. The author creates the learning goal via ALMA_auth.

8. Alma Forum

Finally, ALMA includes a forum where students have the possibility to collaborate with each other and also with the teacher (Figure 9).

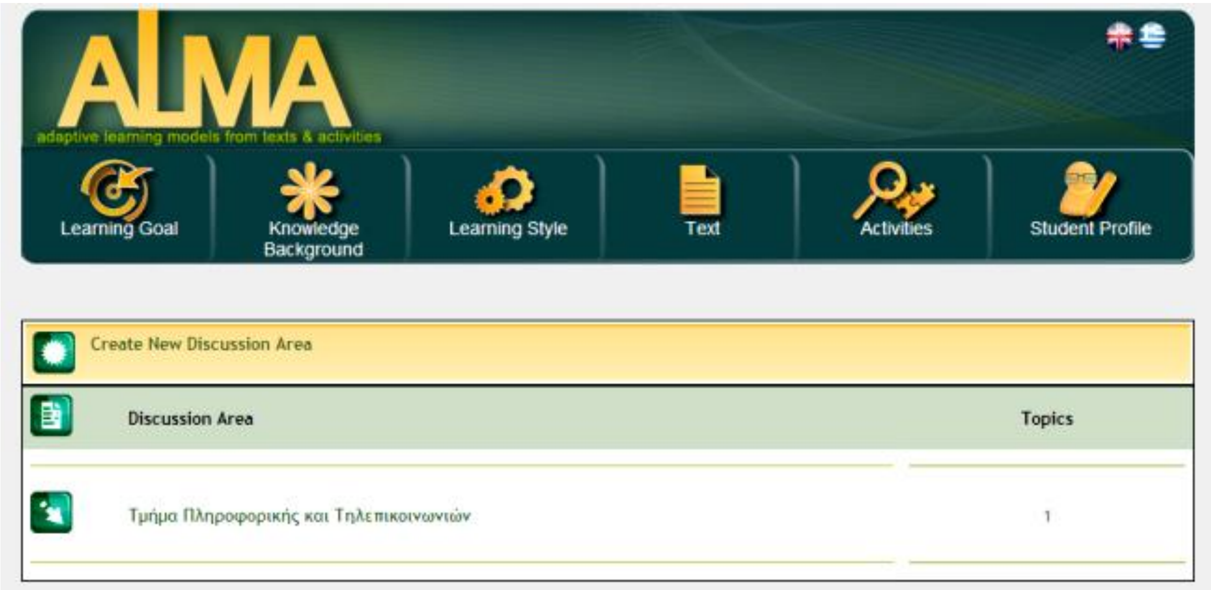

Figure 9. ALMA forum.

9. The Assessment of ALMA Environment

9.1. The Empirical Study

The aim of the empirical study was to investigate how the learning design of ALMA, can support the learning process of students, with a wide range of backgrounds and different learning preferences, in the context of introductory computer science courses. The study was conducted during the winter semester of the academic year 2009–2010 in the context of the undergraduate course “Introduction to Informatics and Telecommunications.” The course objective is to give students a strong background knowledge in the computer science topics: data storage, data manipulation, operating systems, networking and Internet, and algorithms and programming languages. Specifically, the main research questions were: (1) Do the students agree with the proposed by ALMA text version according to their background knowledge? (2) Do the students agree with the learning sequence proposed by ALMA according to their learning style?

9.2. Participants

The study sample consisted of 77 first-year students who were taking the course “Introduction to Informatics and Telecommunications” at the Department of Informatics and Telecommunications of the National and Kapodistrian University of Athens, Greece. Their participation was in the context of an activity having the following objectives: (1) to study the learning goal “Computer Networks’ Principles”; (2) to assess the course designed via ALMA.

9.3. Procedure

The empirical study took place for three weeks and consisted of the following phases: (1) presenting the ALMA environment in the classroom, (2) interacting with ALMA and working out activities, which took place for two weeks, and (3) completing a questionnaire on the effectiveness of ALMA in supporting the learning process in such a course. This phase lasted one week. During these three weeks, students cooperated with each other and the instructor via the ALMA forum.

9.4. Materials and Tasks

In order to investigate how to support the learning and teaching process in the context of the course “Introduction to Informatics and Telecommunications”, educational material in the form of text and activities described in unit 4, was developed. Students studied the learning goal “Computer Networks’ Principles”. All tasks were completed remotely.

9.5. Data Collection

In order to answer the research questions, we analyzed: (1) ALMA log files created automatically by the environment. In particular, students’ sequence during interaction with the environment and performance in the activities was identified. This way, we obtained an indication of how ALMA supports students to deepen their knowledge and develop an adequate situational model; (2) the assessment questionnaire completed by the students.

9.6. Data Analysis

9.6.1. Achievement Measures

Having an objective to investigate students’ exploitation of ALMA facilities and particularly to identify the sequences of actions that students performed in order to study the aforementioned topic, we analyzed ALMA log files.

9.6.2. Questionnaire

The evaluation questionnaire, filled by the students, consisted of Likert-scale type and other types of questions asking students to express their opinion on the effectiveness of ALMA in supporting the learning process (indicative question is: "Do you agree to study the proposed by ALMA text version according to your background knowledge?"). Students' answers, in Likert scale type questions, varied from 1 to 5 (1 indicates "I strongly disagree", 5 indicates "I strongly agree"). Additionally the students were given the option to express their opinion about each one of the questions, as well as to make comments and suggestions for the improvement of ALMA. Cronbach's alpha for learning style questionnaire and the assessment questionnaire was 0.70 and 0.81 respectively implying a reasonable level of internal reliability.

9.7. Results

The results showed the following:

9.7.1. Learning Style

Seventeen students (22.1%) had the diverging learning style, 30 (39%) the assimilating learning style, 19 (24.7%) had the converging learning style, and 11 (14.3%) the accommodating learning style.

9.7.2. Background-Knowledge Questionnaire

Thirteen (16.9%) scored less than 40% (low back-ground-knowledge), 17 (22.1%) scored between 40% and 60% (median), and the remaining 47 (61%) performed more than 60% (high).

9.7.3. Pre-Reading and Post-reading Sorting Activity

We performed one way ANOVA. The results are shown in Table 1.

Table 1. Performance in Sorting Activity.

Activity	N	Mean	SD	SE
Pre-reading sorting activity	77	0.70	0.31	0.03
Post-reading sorting activity	77	0.89	0.17	0.02

According to the results of Table 1, the students performed better in post-reading sorting activity and the difference was statistically significant (p = 0.00). The performance of the students in the pre-reading and the post-reading activity according to their learning style is presented in the Table 2 and it is independent of the learning style ($F(3,73) = 1.910$, $p = 0.135$, pre-reading sorting activity ($F(3,73) = 1.205$, $p = 0.314$, post-reading sorting activity).

Table 2. Performance in Sorting Activity according to Learning Style.

Activity	Learning Style	N	Mean	SD	SE
Pre-reading sorting activity	diverging	17	0.83	0.23	0.05
	assimilating	30	0.68	0.33	0.06
	converging	19	0.60	0.30	0.07
	accommodating	11	0.75	0.35	0.10
Post-reading sorting activity	diverging	17	0.88	0.16	0.04
	assimilating	30	0.91	0.16	0.03
	converging	19	0.86	0.22	0.05
	accommodating	11	0.97	0.07	0.02

The results were expected because there are experimental results that suggest that learners have preferences on the kind of interaction/presentation of information they receive [43–46]. Specifically in a web-based learning environment, data about the usage of the system during interaction is very important as it allows a direct observation of a learner's behaviour [28].

Furthermore, one-way ANOVA showed that the students with low background knowledge were the most improved in terms of post-reading sorting activity followed by students with median background knowledge and lastly the high knowledge readers which were the ones who appeared to be improved the least in post-reading sorting activity. The difference in improvement was statistically significant ($F(2,74) = 12.603$, $p = 0.000$). The results are shown in Table 3.

Table 3. Improvement in post-reading sorting activity according to background knowledge.

Background Knowledge	N	Mean	SD	SE
Low	13	0.51	0.40	0.11
Median	17	0.28	0.29	0.07
High	47	0.08	0.24	0.03
Total	*77*	*0.19*	*0.33*	*0.04*

9.7.4. Performance in Activities

One way ANOVA was conducted. The performance of the students in the rest of the activities according to their background knowledge and their learning style is shown in Tables 4 and 5, respectively.

ANOVA showed that most of the students performed very well in all types of activities. Thus, the students via the learning environment ALMA were able to construct both a good text-based model and a good situation model. The performance in activities was independent from the background knowledge.

The results show that a statistically significant difference was not observed in the performance of the students according to their learning style and they were expected as we mentioned in Section 9.7.3.

Table 4. Performance in Comprehension Activities in relation to background knowledge.

Questions	Background Knowledge	N	Mean	SD	SE	F, p_{sig}
Text-based	low	13	0.88	0.11	0.03	$F(2,74) = 2.310$ $p_{sig} = 0.106$
	median	17	0.83	0.20	0.05	
	high	47	0.91	0.11	0.01	
	total	*77*	*0.88*	*0.14*	*0.01*	
Bridging-inference	low	13	0.87	0.18	0.04	$F(2,74) = 0.336$ $p_{sig} = 0.716$
	median	17	0.84	0.17	0.04	
	high	47	0.93	0.49	0.07	
	total	*77*	*0.90*	*0.40*	*0.04*	
Elaborative-inference	low	13	0.81	0.19	0.05	$F(2,74) = 1.459$ $p_{sig} = 0.239$
	median	17	0.75	0.22	0.05	
	high	47	0.84	0.17	0.02	
	total	*77*	*0.82*	*0.19*	*0.02*	
Problem solving	low	13	0.86	0.16	0.04	$F(2,74) = 1.784$ $p_{sig} = 0.175$
	median	17	0.93	0.44	0.10	
	high	47	0.79	0.20	0.03	
	total	*77*	*0.83*	*0.27*	*0.03*	
Active Experimentation	low	13	0.75	0.18	0.05	$F(2,74) = 0.174$ $p_{sig} = 0.841$
	median	17	0.77	0.18	0.04	
	high	47	0.74	0.15	0.02	
	total	*77*	*0.75*	*0.16*	*0.01*	
Case	low	13	0.83	0.20	0.05	$F(2,74) = 0.038$ $p_{sig} = 0.963$
	median	17	0.83	0.22	0.05	
	high	47	0.84	0.16	0.02	
	total	*77*	*0.84*	*0.18*	*0.02*	

Table 5. Performance in Comprehension Activities in relation to the learning style.

Questiona	Learning style	N	Mean	SD	SE	F, p_{sig}
Text-based	Diverging	17	0.91	0.10	0.02	$F(3,73) = 1.357$ $p_{sig} = 0.263$
	Assimilating	30	0.90	0.11	0.02	
	Converging	19	0.83	0.20	0.04	
	Accomodating	11	0.90	0.10	0.03	
	Total	*77*	*0.88*	*0.13*	*0.01*	
Bridging-inference	Diverging	17	0.87	0.16	0.04	$F(3,73) = 2.116$ $p_{sig} = 0.106$
	Assimilating	30	0.84	0.18	0.03	
	Converging	19	0.85	0.17	0.04	
	Accomodating	11	0.91	0.21	0.08	
	Total	*77*	*0.86*	*0.18*	*0.04*	
Elaborative-inference	Diverging	17	0.84	0.17	0.04	$F(3,73) = 0.212$ $p_{sig} = 0.888$
	Assimilating	30	0.83	0.19	0.03	
	Converging	19	0.81	0.20	0.04	
	Accomodating	11	0.79	0.21	0.06	
	Total	*77*	*0.82*	*0.19*	*0.02*	

Table 5. *Cont.*

Questiona	Learning style	N	Mean	SD	SE	*F*, p_{sig}
Problem Solving	Diverging	17	0.84	0.17	0.04	$F(3,73) = 0.558$ $p_{sig} = 0.644$
	Assimilating	30	0.85	0.31	0.06	
	Converging	19	0.78	0.21	0.05	
	Accomodating	11	0.91	0.39	0.12	
	Total	*77*	*0.84*	*0.27*	*0.03*	
Active Experimentation	Diverging	17	0.74	0.14	0.14	$F(3,73) = 1.143$ $p_{sig} = 0.337$
	Assimilating	30	0.72	0.17	0.17	
	Converging	19	0.75	0.18	0.18	
	Accomodating	11	0.83	0.18	0.18	
	Total	*77*	*0.75*	*0.17*	*0.17*	
Case	Diverging	17	0.86	0.17	0.04	$F(3,73) = 2.137$ $p_{sig} = 0.103$
	Assimilating	30	0.86	0.15	0.03	
	Converging	19	0.75	0.24	0.05	
	Accomodating	11	0.90	0.13	0.04	
	Total	*77*	*0.84*	*0.18*	*0.02*	

9.7.5. Students' opinion about ALMA Environment

The answers of the students in the assessment questionnaire are presented in Table 6.

Table 6. Questions: Descriptional Statistics.

Questions	Description	N	Mean (SD)	Median	Response Distribution (%)				
					1	2	3	4	5
1	Agreement with the proposed by ALMA text version.	77	4.2 (0.9)	4.0	1.3	3.9	16.9	29.9	48.1
2	The access to the proposed text version is easy.	77	4.3 (1.0)	5	2.6	6.6	3.9	28.9	57.9
3	The proposed by ALMA learning sequence is clear.	77	4.5 (0.7)	5.0	0	1.3	5.2	32.5	61.0
4	Agreement with the proposed by ALMA learning sequence.	77	4.2 (1.0)	5.0	2.6	2.6	16.9	26.0	51.9
5	The completion of the background knowledge questionnaire is easy.	77	3.7 (1.1)	4.0	3.9	11.7	16.9	45.5	22.1
6	The completion of LSI questionnaire is easy.	77	4.1 (0.9)	4	0	4.1	18.9	35.1	41.9
7	The selection of learning style is easy.	N = 33	3.9 (1.2)	4	0	21.2	12.1	18.2	48.5
8	The performing of the pre-reading sorting activity is easy.	77	3.1 (1.2)	3	10.4	14.3	41.6	18.2	15.6

Table 6. *Cont.*

Questions	**Description**	**N**	**Mean (SD)**	**Median**	**Response Distribution (%)**				
					1	**2**	**3**	**4**	**5**
9	The performing of the post-reading sorting activity is easy.	77	4.3 (0.8)	4	1.3	1.3	9.2	39.5	48.7
10	The performing of the text recall activity is easy.	77	3.6 (1.2)	4.0	8.0	10.7	28.0	24.0	29.3
11	The performing of summary activity is easy.	75	3.7 (1.0)	4	4.0	4.0	34.7	33.3	24.0
12	The performing of text-based questions is easy.	77	4.3 (0.8)	4.5	0.0	2.6	10.5	36.8	50.0
13	The performing of the bridging-inference questions is easy.	77	4.0 (0.9)	4	0.0	6.6	18.4	42.1	32.9
14	The performing of elaborative-inference questions is easy.	77	4.0 (0.9)	4	1.3	5.3	18.4	39.5	35.5
15	The performing of problem solving activity is easy.	77	3.7 (1.1)	4	0.0	15.6	29.9	22.1	32.5
16	The performing of Case activity is easy.	77	4.5 (0.9)	5.0	0.0	9.1	2.6	18.2	70.1
17	The performing of Active Experimentation Activity is easy.	77	3.5 (1.3)	4.0	12.5	6.9	19.4	37.5	23.6
18	Satisfaction from the information provided by the Informative Feedback	N = 34	4.0 (0.8)	4.0	0.0	2.9	26.5	41.2	29.4
19	Satisfaction from the information provided by the Tutoring Feedback.	N = 29	3.8 (0.9)	4.0	0.0	10.3	20.7	48.3	20.7
20	The information presented in Learner Model is comprehensible.	N = 77	4.3 (0.7)	4.0	0.0	1.3	10.5	43.4	44.7
21	The information presented in Learner Model is useful.	N = 77	4.3 (0.8)	4.5	1.3	0.0	14.5	34.2	50.0
22	The information provided by ALMA in HELP menu is comprehensible.	N = 77	4.1 (0.8)	4.0	0.0	4.1	15.1	46.6	34.2
23	The information provided by ALMA in HELP menu is useful.	N = 77	4.2 (0.78)	4.0	0.0	1.4	19.2	41.1	38.4

Seventy eight per cent (78%) of the students agreed with the proposed by ALMA text version according to their background-knowledge whereas 77.9% agreed with the learning sequence proposed by ALMA according to their learning style. Eighty six per cent (86%) appreciated that the access to the proposed text was easy whereas 93.5% appreciated that the proposed learning sequence by ALMA is clear.

A significant proportion of students (67.6%) considered the completion of the background-knowledge questionnaire easy whereas 77% considered that the completion of the learning style questionnaire was also easy. As it concerns the completion of the pre-reading sorting activity, only 33.8% considered it easy, whereas a significant proportion (88.2%) considered the completion of the post-reading sorting activity easy.

Furthermore, a significant proportion of students considered the completion of the following activities easy: text-based questions (86.8%), bridging-inference questions (75%), elaborative-inference questions (75%), Case (88.3%).

As it concerns the activity of active experimentation, a proportion of 61.1% considered the completion of this activity easy. Moreover, 54.6% considered that the completion of the activity elaborative-inference questions easy, 53.3% considered that the completion of the text-recall activity easy, whereas 57.3% considered that the completion of summary activity easy.

Moreover, 70.6% of students were satisfied with the Informative Feedback whereas 69% were satisfied with the Tutoring Feedback. An important proportion of 88.1% of students states that the feedback about their knowledge level was comprehensible whereas 84.2% states that the feedback about their knowledge level was useful. A significant proportion, 80.8%, considered the information offered by ALMA in the HELP menu comprehensible, whereas 79.5% considered that the information in HELP menu useful.

Students also answered the following question: "If you would had the option to study the learning goal "Networking and Internet" via: (a) the traditional teaching method; (b) the learning environment ALMA; (c) a combination of the traditional teaching method and the learning environment ALMA, what would you prefer for: (1) your undergraduate studies?; (2) postgraduate studies?"

A percentage of 83.8% and 81.1% of students would prefer to study the above learning goal, via a combination of the traditional teaching method and the learning environment ALMA for their under- and postgraduate studies respectively. A proportion of 14.9% and 12.2% of students would prefer to study the learning goal via ALMA for their under and postgraduate studies respectively and finally only 1.4% and 6.8% would prefer the traditional teaching method for under and postgraduate studies respectively.

10. Conclusion and Future Plans

In conclusion, ALMA could be a valuable tool for supporting the learning process in introductory computer science courses and helping students to deepen their understanding in the undergraduate curricula of Computer Science. Students had a positive opinion about ALMA environment because they were encouraged to use their background knowledge while reading and they believe that ALMA gives them the opportunity to achieve better results in learning from texts in computer science than reading a single text targeted at the level of an average reader. Moreover, students had a positive opinion about the learning sequence proposed by ALMA and they believe that a combination of the traditional teaching method and ALMA environment would be the best for their under- and postgraduate studies.

Consequently, ALMA supports both text comprehension and learning preferences. It differs from the other learning environments in text comprehension, which we mentioned in Section 1, in the following:

- It supports distance learning.
- It offers four versions of a text according to learners' background-knowledge.
- It offers a variety of activities in order to support students' comprehension.
- It suggests a different learning sequence according to learners' learning style.
- It includes an authoring tool (ALMA_auth) which provides the author with the option of developing and uploading the educational material.
- It includes a forum (ALMA_forum) where students have the possibility to collaborate with each other and also with the instructor.

Our future plans include the summative evaluation of ALMA environment by under- and postgraduate students and also by specialists in the assessment of web based learning environments. We further intend to design and develop educational material for other learning goals both in higher and in secondary education.

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Author Contributions

Alexandra Gasparinatou was responsible for designing the study, acquiring and analyzing the data and drafting the manuscript. Maria Grigoriadou was responsible for conception of the study. Both authors contributed to interpreting the results and revising the manuscript for intellectual content and have read and approved the final manuscript.

Conflicts of Interest

The authors declare no conflict of interest.

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