ADAPTATION AND DISABILITY ASPECTS IN A VIRTUAL LEARNING ENVIRONMENT

CARACTERÍSTICAS DE ADAPTACIÓN Y DISCAPACIDAD A TENER EN CUENTA EN ENTORNOS VIRTUALES DE APRENDIZAJE

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Abstract: This paper discusses the main aspects that drive the design of intelligent tutoring system based virtual learning environments. Most of these virtual learning systems focus on tutor activity and use artificial intelligence techniques. Information about the interaction with these systems is used to create a model that, given the preferences and learning styles of a student, performs an information retrieval process to adapt content delivery to the student, according to his/her particular characteristics (learning style, behavior, performance, and whether the student has a disability or not).

Keywords: Intelligent tutoring systems, Adaptation of information, Disability, Virtual Learning Environments.

Resumen: Este artículo presenta los principales aspectos que se deben tener en cuenta en el diseño de ambientes virtuales de aprendizaje como por ejemplo, los tutores inteligentes. La mayoría de estos sistemas virtuales de aprendizaje se concentran en la actividad del tutor y se utilizan técnicas de inteligencia artificial. Los sistemas que se relacionan a continuación permitieron la generación de un modelo que, dadas las preferencias y estilos de aprendizaje de un estudiante, realiza un proceso de recuperación de información con el fin de adaptar el despliegue y la manera en la que se muestra el contenido a un estudiante dadas las características particulares del mismo (estilos de aprendizaje, comportamiento y desempeño en el sistema y si tiene una discapacidad).

Palabras Clave: Sistemas tutoriales inteligentes, Adaptación de información, Discapacidad, Ambientes virtuales de aprendizaje.

1. INTRODUCTION

The Colombian General Education Law grants citizens the right to education [1]. To effectively enforce this right, Colombian law establishes criteria, rules, and procedures to deliver educational services to citizens.

One particular aspect of this law is the education of people with disabilities, particularly, sensory disabilities, such as visual or hearing impairment, which decrease learning opportunities of students. In this regard, the Law no longer requires special places for these students to be provided. Instead, district schools must provide an integrated environment for all students, to provide equal access to education, regardless of the student's condition [1]. In practice, this change implies that all of the students must be integrated into a regular school regardless of any disability.

People with sensory disabilities introduce new challenges to educational institutions, since they must have the resources and the know-how to integrate these various types of students. Students with sensory disabilities require special pedagogical strategies to insure that they assimilate all of the information provided in the classroom. For instance, hearing impaired students require that teachers learn pedagogical strategies to visually convey all of the information in the classroom, such as sign languages and frequent use of figures and written text. Analogously, blind people need teachers to convey the information by audible means.

The problem is that many teachers lack adequate training in addressing the needs of this population or the time to transform learning materials and strategies to meet the needs of these students. As a result, the classroom environment is often not appropriate for these students and they tend to leave educational institutions with low achievements or even completely drop out from the school system [7]. One possible way to address this problem is through the use of special software and hardware technology. Most of the existing work in this area focuses on motor or sensor disabilities, utilizing electronic devices and human-computer interfaces to improve communication with students and facilitate learning [23].

Other technologies, such as virtual learning systems [11], hypermedia [14], and intelligent tutor systems [15], also have the potential to reduce the achievement gap between students with disabilities and regular students. Most of the works in this area focus on cognitive disabilities [24] and they do not adapt to learning styles associated with sensory disabilities. Although these systems may convey a lot of information to the student, that information is not adequately filtered to satisfy the specific necessities and learning strategies of sensory-impaired students. To address the above problems, it is necessary to have a system that can adapt to the learning style of people with sensory disabilities. To create such system requires: the identification of characteristics and learning styles of people with sensory disabilities; the definition of an adaptation model; the design of techniques and algorithms to retrieve information to perform adaptation and personalization; the definition of a pedagogical model that supports this system; and its validation through a case study with people that have sensory disabilities.

The contribution of this paper is two-fold. First, this paper surveys related work to identify the key aspects for the design of an intelligent tutor system that can adapt to specific student characteristics (particularly sensory disabilities). Second, this paper uses the above information to propose a model for an *Adaptive Learning System* (*ALS*). The *ALS* model includes adaptation of information as a first-class construct, with a focus on conveying information to students with sensory disabilities.

The remainder of the paper details these contributions. Section 2 explains the main concepts of virtual learning, focusing on virtual learning object standards and intelligent tutors. Section 3 surveys and discusses the main pedagogical aspects associated with virtual learning environments. Section 4 describes the *ALS* model. Section 5 validates the *ALS* model through a case study. Section 6 concludes the results of this research.

2. VIRTUAL LEARNING AND STANDARDS

E-learning platforms are software and servers to administer course content and communication between students and teachers in a virtual learning environment. Essential elements of these platforms are: *Learning Management Systems* (*LMS*), the components that administer the student learning process; and, *virtual learning objects* (*VLO*), the main mechanisms to provide content to students [9].

Course content in these platforms must adhere to certain standards, which provide the following benefits: (a) Normalize and formally describe course content functionality., (b) Standardize content creation in a virtual learning environment, (c) Save development costs, (d) Reuse content, (e) Abstract content developers from technological aspects of the e-learning platform, allowing them to focus on making quality content [2].

The Shareable Content Object Reference Model (*SCORM*) integrates several standards for virtual learning objects to facilitate interoperability among e-learning platforms [21]. To adhere with *SCORM*, a virtual learning object must comply with the following: be displayable in a browser, use specific meta-data to describe itself, and be organized and packaged according to specific standards [3]. *SCORM* describes two types of content: assets that reference static content, such as images, static web pages, multimedia, among others; and, Shareable Object Content (*SCO*), which are *VLO* that can communicate with the learning management system and have dynamic behavior [4].

SCORM has three main components. The *content aggregation model* (*CAM*) specifies how to describe and package *VLO*. The *runtime environment* (*RTE*) describes the communication protocol between *SCO* and the *LMS*, and also the data elements used in the communication between the student and the *VLO*. *Sequencing and navigation* (*SN*) specifies the order of navigation events when accessing SCORM content [5].

According to a study of the University of Castilla [6], *SCORM* use is steadily increasing in e-learning platforms and *SIVEDUC* (Spanish acronym for virtual education system) implements an important portion of *SCORM*. Table 1 compares different works that utilize *SCORM*. This table shows that the main use of *SCORM* is content design in e-learning courses.

Table 1. Comparison between works that use *SCORM*.

System	Pedagogic Activity	1. Advantages 2. Disadvantages
[7]	Activity tracking, resource display	1. Main learning tasks can be accomplished 2. Limited amount of resources
[8]	Content design based in Mind Maps	1. Mind map *VLO* shows graphical information to students 2.Incomplete implementation of *SCORM* in the Dokeos platform and Moodle
[9]	Content design based in simulations	1. Simulations improve student perception of the concepts 2. Simulations are hard to execute in a *SCORM* environment
[10]	VLO reuse in content design	1. *SCORM* saves time in content generation 2. *VLO* that did not comply with *SCORM* are harder to use.
[11]	Content design	1. Adaptation features to personalize content display 2. Lack of a system to determine student preferences or learning styles

3. INTELLIGENT TUTORS

Intelligent tutors are artificial intelligence systems to support the educational process. The first intelligent tutor system was developed by Jaime Carbonell [12]. This system assisted students to learn South American geography. The main difference with traditional systems was its ability to generate individual responses to students, based on a semantic network that represented domain knowledge. The main aspects of intelligent tutors are a student model and the use of Artificial Intelligence techniques.

3.1 Student Model

The student model denotes the student behavior and creates a qualitative representation of his/her cognitive and affective knowledge. This model exposes student performance (e.g. time to perform a task), observes errors and reasons that explain why the student developed certain activities or made specific decisions. This model also includes knowledge representation, *i.e*. data structures to interpret data to predict behavior. A student-model module in an intelligent tutor system is a code component that stores: domain knowledge, knowledge about the student, and the learning process.

To develop the student model, two aspects must be considered. The first aspect is the representation of the knowledge the student must acquire. The student model can represent diverse types of knowledge: topics, erroneous concepts, errors, affective characteristics, experience, and stereotypes. This representation can be made using artificial intelligence techniques [12]. Most intelligent tutors focus on a top-down approach to build the knowledge model in order to achieve intelligent behavior. The second aspect is the way to update the knowledge about the student to adequately infer what the student knows and what does not know. There are several techniques to infer student knowledge, such as comparing the student answers and those provided by experts, or comparing between the sequence of actions performed by the student to solve a problem, and the actions performed by experts. Table 2 shows an example of the way student knowledge can be symbolically represented, the Category, and the Approaches, how reasoning can be automated to get the required information .

Table 2. Knowledge representation- student model [12].

Knowledge	**Category**	**Approaches**
Concepts	Facts, procedures, norms, skills, objectives, plans, and tasks.	Overlapping plans procedures, Bayesian networks, declarative knowledge
Erroneous Concepts	Erroneous concepts and lack of knowledge	Collecting errors, error libraries, and wrong norms.
Causes that affect student performance	Commitment, boredom, frustration, focusing degree	Bayesian reinforcement learning

Knowledge	Category	Approaches
Student experience	Student history, attitude, discourse, plans, objective, and user context	Retrieving student declarations, identifying patterns in student actions
Stereotypes	General knowledge about the student skills and features. Initial student model	Build various models for different students

3.2. Artificial Intelligence techniques utilized in intelligent tutors

The main techniques utilized to develop intelligent tutors are: *a)* cognitive intelligence or artificial science, including tracking methods and constraint-based methods [17]; and, *b) AI* techniques, including formal logic [16], expert systems [19], plan recognition, and Bayesian networks [15]. These techniques are not exclusive and several of them can be combined to design an intelligent tutor [13].

Cognitive science techniques are mainly utilized to update the student model and to represent knowledge. These techniques are used to develop *tracking* tutors, which track the learning process using similar methods to those utilized in information processing. Constraint-based methods are used to develop *performance-based tutors*, which assume the opposite: that learning cannot be completely stored and only student errors can be identified by the information system. Both methods have yielded successful learning results [13].

The above methods are associated with different attention levels. Tracking tutors focus on procedures executed by students and procedures being learned by students. Performance-based tutors ignore the learning path of the student, focusing only on the pedagogical goal that the student must reach. *AI* techniques can be used to update the student model, to reason about the student knowledge. The main *AI* techniques used are formal logic, expert systems, planning methods, and Bayesian network prediction. The focus of these techniques is to improve model-reasoning performance.

Formal logic uses the symbolic representation of objects and relations as a set of rules and facts and uses them to deduct new information [14]. Different logical systems offer various ways to represent information.

Expert systems differ from formal logic in that expert systems keep a *knowledge base*, organized and up-to-date knowledge about the problem that is used to verify the execution of the model. Expert systems can be used to teach students classification and problem-solving skills. Many expert systems are based on condition-action rules and their representational capability is restricted to the student model. In other words, one solution to a set of rules can represent a unique path in the domain, but multiple paths cannot be represented by rules. Rule finding and execution is computationally expensive. Also, student knowledge is hard to evaluate using this technique [14].

Planning and plan recognition models enable tutors to reason about the steps students must follow to perform a certain activity. A student model that is based on plan recognition usually includes a set of trees that represent plans. The root node of a tree is the goal. Intermediate nodes are sub-goals. Leafs correspond either to actions or probabilistic events. The plan recognition process, analyzes the trees bottom-up until reaching the goal [14].

Bayesian networks or belief networks are directed acyclic graphs that provide a practical and compact way to represent uncertain knowledge. Bayesian networks are useful when there is uncertainty in the student cognitive development, since other methods (formal logic, expert systems, and plan recognition) fail to adequately understand the student [15].

Table 3 compares different *AI*-based intelligent tutor systems. This table shows the system name, the aspect modified by the *AI* technique, the *AI* technique utilized, the adaptation features, and the disadvantages of each technique.

Table 3. Comparison systems - artificial intelligence in virtual learning.

System	Aspect / AI Technique	Adaptation technique / Disadvantages
[16]	Dynamic student profile, information processing techniques / Formal logic, heuristic models, mathematical modeling	Student learning tracking to adapt activities / It does not consider preferences or disabilities
[17]	Student model, learning style / Formal logic, prediction systems reasoning	Activity adaptation depending on learning style / It does not consider preferences or disabilities

System	Aspect / AI Technique	Adaptation technique / Disadvantages
[18]	Student model, domain model, pedagogic model / Intelligent agents	Learning style / It does not consider preferences or disabilities
[19]	Student model / Mathematical model, neural networks	Activity adaptation to track student learning / It does not consider preferences or disabilities
[20]	Student model / Information retrieval algorithms	Content display / It does not consider preferences or disabilities
[15]	Student model / Bayesian networks	Activity adaptation to track student learning / It does not consider preferences or disabilities

All of the above intelligent tutor systems modify the student model. The most common *AI* techniques are formal logic and intelligent agents. Adaptation is performed when generating and displaying contents. However, most initiatives do not consider students with disabilities.

4. PEDAGOGICAL ASPECTS IN VIRTUAL LEARNING ENVIRONMENTS

When designing a virtual learning environment, learning theories and pedagogical models should consider the following aspects: problem domain, student learning style, and student proficiency level.

Problem domain influences the choice of educational strategy. For instance, learning algebra has strong theoretical and abstraction requirements. To better learn concepts in this domain, a systemic approach is necessary (*e.g*., theory, cognitive learning). More pragmatic domains that are focused in problem-solving or heuristic solutions are better addressed educing a constructivist approach (*e.g*. cognitive learning or social interaction). Some domains can be better addressed controlling the student environment. Other domains that require higher-level processing and integration of multiple tasks (*e.g*. software engineering) can be better taught using social learning (*e.g*. localized learning) [12].

Cognitive learning theory has been used by intelligent tutors to efficiently transfer knowledge to students, focusing on mental processes. Cognitive theory treats simple to complex aspects using an internal knowledge structure and three information stages: a) *transformation* that involves receiving sensorial information; b) *short-term memory* (*STM*) that records sensorial information; c) *long-term memory* (*LTM*) that stores the information from *STM* for longer periods [12].

In a virtual learning environment, some pedagogic material is "imposed" through *LTM* and manipulated by the system to achieve higher processing levels, linking old information with new. It is important to consider some characteristics, such as: *a)* Significant events, significant information is easier to learn and remember; *b)* Serial and positional effects (*e.g*., elements at the beginning or end of a list are easier to remember); *c)* Pragmatic effects, practical actions improve information retention; *d)* Transference effects, applying previous knowledge on a current task improves cognitive processes; *e)* Interference effects, when previous learning is interfered by current information. In addition, there is the *Adaptative Control Thinking* (*ACT*), a cognitive learning theory based in decision-making and uncertainty. This theory simulates the interaction between declarative knowledge, factual information, such as multiplying tables and procedural knowledge, how to use knowledge to solve problems. Both characteristics apply to long-term memory. Declarative knowledge, stored in long-term memory, can be modeled using semantic networks [12].

5. PROPOSED MODEL

Considering all of the above information, this paper proposes the *adaptive learning system* (*ALS*), a model that can adapt course contents, considering student disabilities.

Figure 1 describes *ALS*. *ALS* combines an adaptation model and an application model. The adaptation model includes the student profile that is dynamically updated and includes characteristics such as learning style, student behavior when interacting with the system, and disabilities. In this context, a disability is a student condition that reduces the chances to learn in a learning environment. To determine whether a student has a disability or not, one can utilize medical history, social service assessments and records of the interactions between the student and the system. Artificial intelligence (*AI*) techniques, such as Bayesian networks or fuzzy logic can be used to interpret the above data and find students with disabilities.

The application model comprises the course structure, including activities and virtual learning objects (*VLO*) of all of the repositories that are accessible from the learning system. The application utilizes *AI* techniques, such as intelligent agent or formal logic, to provide services adapted to the student profile.

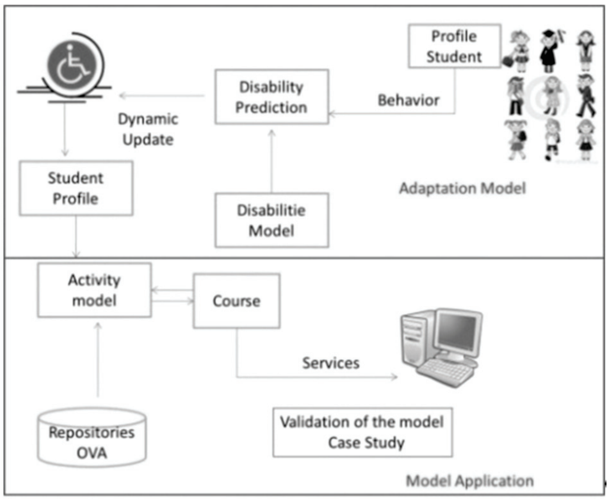

Figure 1. The *ALS* Model

The following sections describe the main components of the student profile, the disability model, and the validation of this model in a case study.

5.1 The Student Profile

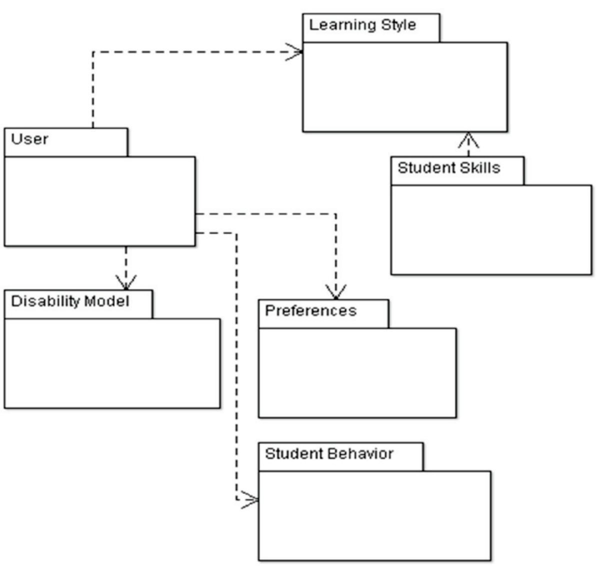

Figure 2. The Student Profile

The *student profile*, also known as *student model*, stores the student's personal information, represents his/her behavior, and defines a qualitative representation of the student's cognitive and affective aspects, such as learning style and skills. Figure 2 describes the components of the student profile. The *learning style* stores characteristics that determine types of learning and the way the student perceives information (*e.g.* visual and verbal).

Figure 3 details learning style attributes. Learning style theories have an identification code, name, author, and description.

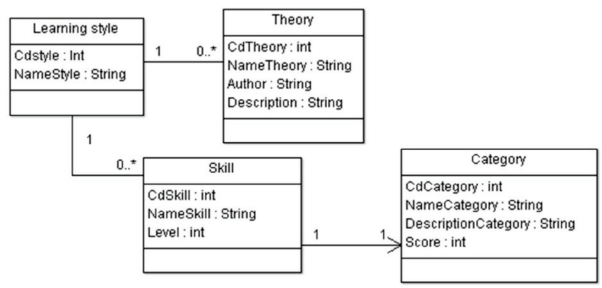

Figure 3. Student Learning Style Attributes

Student skills are associated to a category: cognitive, practical, synthesis, among others. Student disabilities affect student learning chances. Figure 4 describes the main attributes associated with disabilities: name (*e.g.*, autism, visual impairment), category (*e.g.*, cognitive, sensorial), sense (*e.g.*, vision, hearing), disability level (*e.g.*, 1, 2, 3).

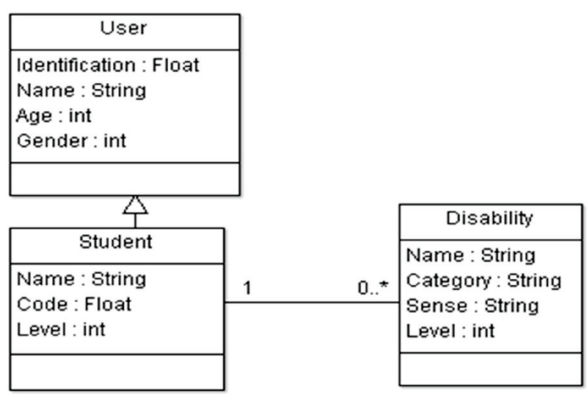

Figure 4. Student Disability Attributes

Preferences store information about the way a student wants to access a particular feature of the system, or which option the student selects among a set. This is the most important part of the adaptation model, since it will determine the way and what kind of information will be presented to the student. Figure 5 details preferences. *Perception preferences* describe the way the student wants to receive the information, *e.g*. if the student likes visual information, the student can choose whether the information is delivered in the form of simulations or conceptual maps. *Navigational preferences* describe the path the student follows when performing different activities in the system and when accessing the information. *Information display preferences* describe the best interface design for a particular student. *Device preferences* describe the student's preferred devices to interact with the system, *e.g.,* mouse, keyboard or other special devices. *Localization preferences* are associated to the place from where the student accesses the information. *Activity preferences* describe the most adequate actions and virtual learning objects to use when teaching a student.

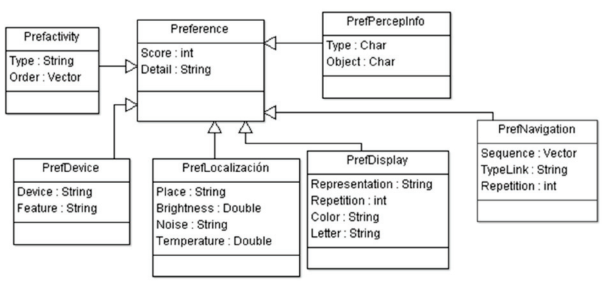

Figure 5. Student Preferences

Figure 6 describes the main characteristics of the *student behavior*. Student behavior is associated to perception, memory, and language and it can be used to determine types and degrees of disability.

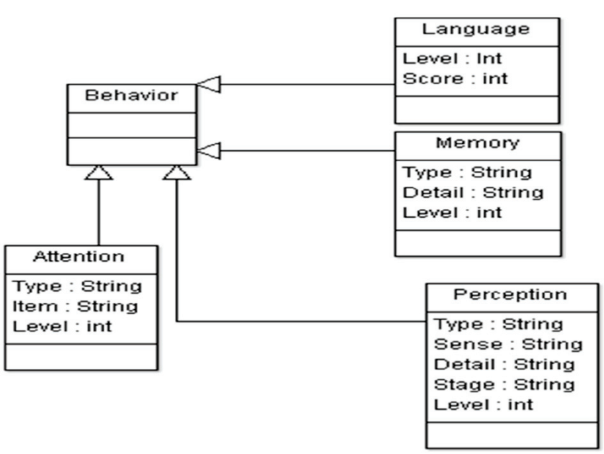

Figure 6. Student Preferences

5.2. Disability Model

The Disability model (Fig. 7) describes the most common disabilities of the student. This model is strongly related with the student profile and can be used to infer the main aspects of the interaction between the student and the system.

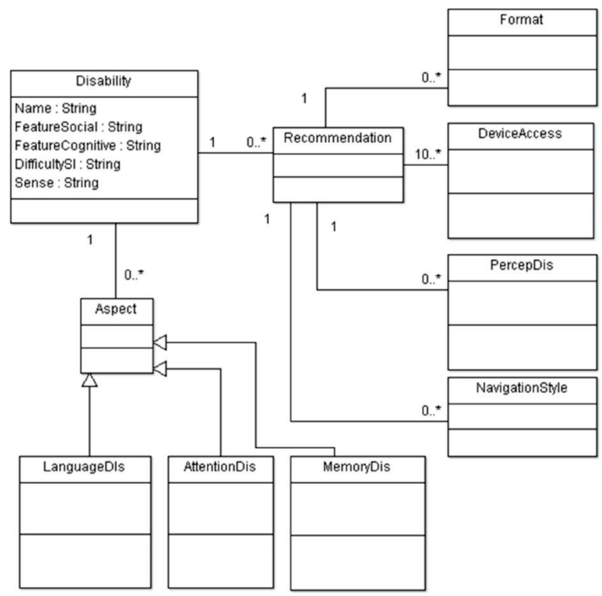

Figure 7. Disability Model

The model comprises several main disability characteristics: access devices (*e.g*., mouse, keyboard), preferred information visualization method (*e.g*., charts, diagrams), and the type of link to navigate between pages (*e.g.,* icons, text). Perception, memory, attention, and language are denoted as levels and they indicate the degree of disability of the student if any. Disability profile knowledge representation comprises: *a)* an identification test, associated with the specific disability; *b)* information about the student's behavior when interacting with the system, which is used to identify student characteristics that are associated with their disability profile; *c)* a Bayesian network that uses the student's medical history to determine the student disability.

5. CASE STUDY

To validate the proposed approach, this paper describes a case study: *ALSHI* (***A***daptative ***L***earning ***S***ystem for ***H***earing ***I***mpaired) [22], an application developed to teach people with hearing impairment.

Figure 8, is an example screen of the application. The system displays content of a natural sciences course: the definition and components of an atom. *ALSHI* utilizes the student profile and his disability profile to adapt information display to students. In the example, the system identified the most adequate virtual learning object for the student, which shows an image of the atom and a video that describes the atom using sign language.

Figure 8. Information display presented to a student with hearing impairment

If the system did not have adaptation characteristics, the system would show the information about the atom as described in Figure 9.

Figure 9. Information display without adaptation

The lack of an adaptation model would show the same information, either to a hearing-impaired student to any other student, without considering their learning style, preferences, or disabilities. To illustrate the different results obtained for different students, Figure 10 shows the same class contents as they are displayed to a student whose learning style is verbal, as was deducted from her profile.

Figure 10. Information display presented to a student with verbal learning style

7. CONCLUSIONS

Educational tools and strategies are essential to assist students' cognitive processes, since they can help to motivate students and improve their performance.

The proposed model in this paper selects virtual learning objects according to the student's preferences, learning styles, and specific characteristics. Content is adapted to the student, which facilitates the adequate selection of *VLOs*, both for people with and without disabilities.

Artificial intelligence techniques, such as Bayesian networks, can predict and determine student specific characteristics, which facilitates content delivery. Intelligent tutor models tend to focus on the student profile. The model proposed in this paper (*ALS*), includes also a disability profile, which identifies the student characteristics when interacting with the information system.

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