Introducing Cognition in Web-Based, Learning Management Systems for Vocabulary Teaching

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Abstract

Nowadays, connectivity is practically imposed for everyone, as it is used for professional interactions, information retrieval, or just for entertainment. Thus, the importance of communicating, along with the need of people to interact through various foreign languages, increases rapidly, so as to enable ubiquitous connectivity and continuous updating. The increase of the vocabulary in a foreign language is often provided as a service in the context of web-based systems and can be significantly facilitated through considering the various ways that knowledge can be perceived and interpreted by each person. The goal of this paper is to consider such factors in designing a “cognitive, web-based, foreign language learning management system”. The system proposed is capable of monitoring the user’s activity and adapting accordingly, so as to improve the learning process as a whole. This is achieved by exploiting Bayesian Networks’ concepts, in order to monitor past preferences, acquire knowledge and estimate the likelihood of future preferences. The paper presents the related work in the field and the influences in the current work, the system’s basic requirements and structure, the methodology for introducing cognition in such a system and indicative simulation results that showcase the system’s effectiveness.

Keywords: Bayesian Networks, cognition, knowledge acquisition, user profile, vocabulary learning

1. Introduction

Currently, the need for communication and access to information becomes necessary on a daily basis in peoples’ routine. At the same time, knowledge travels so fast, that people are searching for the most suitable way to keep up with the latest trends on their fields of interest. In this respect, learning a foreign language rapidly and effectively can play a significant role in everyday interactions. At the same time, the continuous advances in telecommunications, reflected on the expansion of the utilization of electronic devices, make users even more accustomed to the functionalities network services offer.

In this context, web-based language teaching systems are a really useful tool, which can provide users with the potential to quickly and effectively learn a foreign language, regardless of spatial and time constraints. It is essential for this system to be available through the internet, as it aims to encourage user’s communication with other users, to update the content in real time, to store historical data, as also detailed in Section 3.2 of the paper. Therefore, the system produces the respective statistics and is able to make more efficient content management in the future sessions of the students. In other words, the proposed mechanism complements the existing e-learning platforms and is targeted to improve the platform's response to the user's needs. Furthermore, the system is in position, in case user preferences change, to instantly transform the material in the appropriate way, taking into consideration both past/ stored preferences and also current ones. After all, the main idea is that the user is able to access the platform ubiquitously, not only through a single computer. For instance, the user will have the ability to access a course through a laptop or a smart phone. In this way, learning becomes more effective.

The structure of the paper is as follows. The next section presents the related work in this field, as well as this paper's perspective to the field and authors' contribution (Section 2). Section 3 provides the motivation for this work, both regarding the theoretical approach of vocabulary teaching and the learning styles and strategies that influence teaching. Section 4 discusses on the idea of a cognitive, web-based, vocabulary teaching system, describing the "cognitive, web-based, foreign language learning management system" (web-FLAME) system in detail. Section 5 presents the methodology followed so as to add cognition in a vocabulary system, as well as indicative results that showcase the efficiency of the proposed system. The last section (Section 6) includes some concluding remarks and outline of future work.

2. Related Work and Adopted Characteristics

This section presents the related work that has already been done in the field, as well as the way the system has been influenced by it, adopting certain characteristics. During the last two decades, several research attempts have led to the design and development of various electronic environments that aim at facilitating learning, through specialized forms of teaching (Alomyan, 2006; Brusilovsky, 2001; Dager, 2003; Dolog et al., 2004; Hsu, 2008; Juvina & Oostendorp, 2004; Ong & Hawryszkiewycz, 2003), namely e-learning environments. Moreover, recent research findings have paved the way towards new models and new learning theories that are associated with multimedia, in conjunction with the consideration of various, previously ignored factors in learning, with the goal to result in a deeper understanding of the way multimedia influence learning (Nam & Smith, 2007; Samaras et al., 2006).

In the light of the above, several approaches have been centered on the personalization of e-learning systems, so as to increase the efficiency of their interactions with the user and consequently achieve better results in the learning process. This is achieved by using monitoring and evaluation methods during the learning procedure. For instance, a student modeling server may be used (Brusilovsky et al., 2005), taking explicitly or implicitly input by the user through the Detection Mechanism (Garzotto & Cristea, 2004) or an adaptation filter, which removes the implied unnecessary information for the user (Zakaria et al., 2003). Another method is used in (Juvina & Oostendorp, 2004), where it is supported that web navigation can be modeled by studying individual differences and behavioral metrics, using Latent Semantic Analysis (LSA) (Latent Semantic Analysis (LSA), 2011). The DEPTHS system (Jeremić et al., 2009) is a system using design patterns, incorporating semantic annotation service and context-aware learning services, so as to facilitate and enrich users learning experience and performance. The GRAPPLE system (Oneto, 2009) serves as a platform for Learning Management Systems to be integrated and, despite the fact that it integrates personalization and adaptation features, it does not emphasize on the detailed interactions with users. Moodle (Moodle, 2011), on the other hand, is an Open Source Course Management System, which encourages collaboration between students, it is rather flexible regarding the organization of the courses, yet personalization and adaptation are still basic. Furthermore, personalization in vocabulary learning management systems has also been researched. More specifically, in (Gamper & Knapp, 2002) psycholinguistic methods are applied along with adaptive hypermedia, yet the system does not take direct feedback from users. This means that the system only can make "assumptions" on the user's preferences, which can thus be verified by applying the adapted content. The VocaTest system (Kazi, 2005) is based on indirect user feedback as well, which takes into consideration the user's scores in test, in order to assume the preferences. In more recent researches as (Jung & Graff, 2008) and (Yoshimoto et al., 2009), a more modern approach is followed, the one of the strategy of creating Games, in order to help user absorb the new vocabulary introduced. Yet, in these cases too, the policy of the systems is based on assumptions and not on applied mathematics/algorithms.

This paper builds on the aforementioned research findings and aims at providing novel techniques for increasing the personalization levels of e-learning foreign language systems, leading to a subsequent increase in their efficiency. In particular, the paper proposes a web-based system, which has the ability to adapt the vocabulary material to each user's unique learning style and pace.

The detection mechanism as introduced in the abovementioned past researches is adopted, renamed as "User

Monitoring" and evolved in order to be more proactive. Therefore, this system takes into consideration personal user preferences and historic activity, both directly and indirectly. This is achieved through acquiring knowledge from previous interactions with the user and mapping personal preferences to the specific learning style, for enhancing the user's vocabulary as part of learning a foreign language. This gradual transformation of past interactions to knowledge and experience endows the system with *cognitive* capabilities (Thomas, 2006). The advantage of the resulting system lies in the increase of the probability of successfully adapting to the user's learning preferences and consequently facilitating the learning process. The simplest components were taken into account, comprising the system's architecture.

The learning functionality is influenced by Bayesian networks. More specifically, for the technical approach and application of this work, the concepts of Bayesian Networks (Pearl, 1988; Santos, 1999; García et al., 2007; Tedesco et al., 2006; Sbatella, 2004; Koutsorodi, 2006; Koutsorodi, 2007) which constitute robust techniques for modeling and solving stochastic problems, and therefore, are main technologies for the development of cognitive systems. The Bayesian principles were taken into consideration and then adapted to the e-learning platform requirements. In this way, an equation considers both the previous and the current preferences and attributes certain values to them (through parameters, as described in Section 5.3). Thereafter, this mechanism adds certain weights to these values, producing the likelihood of user's preferences. A simulated experiment of three different scenarios is finally presented, in order to showcase the functionality and effectiveness of the mechanism. All in all, through the use of Bayesian Networks the behavior of the e-learning platform and its response to user's activities and preferences are improved.

3. Motivation

Providing personalized teaching in a conventional classroom, able to cover at the same time different learning styles, is practically impossible. This is justified through the fact that the first and most difficult issue that teaching has to deal with is the large number of words that will have to be not only taught, but also absorbed and fully adopted by the users, so as to be used creatively as speakers and be comprehended as listeners. The quantity of the words that will have to be taught to the students is reversely proportional to the time available. It is well known that based on the available time for teaching the vocabulary, the percentage that could be systematically and thoroughly taught in the classroom is relatively small. This means that the systematic exercise of the students in strategies that enable them to learn and improve their own knowledge and vocabulary seems to be mandatory (Nation, 2001; Schmitt & McCarthy, 1997). Moreover, taking into consideration user's personal learning style, as well as the heterogeneous nature of different user groups (as discussed in section 3.2), the need for the students to recognize, choose and use the learning strategies that respond and suit their personal learning style arises.

In Section 3.1 the idea of vocabulary teaching on a theoretical basis is elaborated, emphasizing on the importance of the creation of such a learning package. Of course, in this context, the learning styles and strategies (Section 3.2) have a very significant role, aiding in the personalization of the learning experience.

3.1 Vocabulary Teaching

The extremely rapid progress of the linguistic science during the last three decades, and its consequent development of multiple pertinent inter-science linguistic fields, gradually led to the reveal of the huge importance and value of the vocabulary. Only recently did the vocabulary start conquering the position it deserves in the field of the linguistic teaching and especially in the context of a second or a foreign language. According to the views of the language acquisition theories, linguistic activity is based primarily on the vocabulary; language is a procedure to rather give the words a grammatical structure, than a procedure to "vocabularise" the grammatical structures (Lewis, 1993). Therefore, this means that modern trends accept the fact that the main field of Linguistics is the vocabulary and that the field of grammar settles and conforms to the "vocabulary" structures, which are of primary importance (Mitsis, 2004). Of course, it has to be underlined that it is impossible to create a correct sentence in a language without knowledge of the appropriate words and their meaning.

Yet, vocabulary teaching is associated with a series of difficulties, mainly related to the lack of time for the sufficient teaching of the specific learning field, as well as with the obvious weakness of teaching in a personalized way. This means that it is rather difficult, as teaching is structured in the traditional way, to adapt the teaching material to the special characteristics and learning approach of each user. On the one hand, the use of an integrated teaching methodology and stable reactions in the teaching material significantly limits the amount of the teaching material. This means that the traditional teaching methodology cannot offer personalized experience to the user, in order to respond to the requirements.

3.2 Learning Styles and Strategies

According to the findings of applied Linguistics in the field of the second or foreign language, each user approaches the linguistic material with special ways and techniques, which imposes the use of personalized teaching. These special ways are obviously related to basic characteristics of the personality of each user, amongst which the "learning style" prevails.

The term "*learning style*" refers to the stable way, in which a subject responds to a learning environment and interacts with the learning material. In other words, it is defined as *the general approach that a particular user has towards the learning of the second communication code*, such as the use of senses (vision or auditory), the concentration on the set or subset of a section, the impulsive or stochastic reaction to the linguistic material (Cohen, 2003; Felder & Henriques, 1995; Mitsis, 1998; Oxford, 2003), or being a converger, diverger, assimilator, accommodator learner, as Kolb (1984) defined. The learning style, as a basic characteristic of each user's personality and as a general type of learning material approach, does not appear as a whole in the procedure of learning a second language. Instead, it is realized using a series of techniques and procedures, known as "learning strategies".

By "*learning strategies*" one refers to *a series of purposive techniques, actions and reactions on the teaching material* (for instance, the combination of the teaching word using the respective image, mimic, definition, grouping words according to a thematic field, synonyms, antonyms etc), *that aim at achieving the goals of the teaching procedure in a quicker and more effective manner* (Chamot, 2005; Cohen, 2003; R. Dunn & K. Dunn, 1978; Mitsis, 1998; Nation, 2001; Schmitt & McCarthy, 1997; Sprenger, 2003). For the learning strategies to be effective, they have to be chosen so as to be compatible with each user's learning style, which means that they will have to respond to the general way that the user approaches the learning procedure and reacts to the learning environment. Moreover, learning strategies are not realized as a whole in the classroom either, but they appear in the form of particular teaching activities, that are related with the content and the goals of the teaching section in a targeted audience. For instance, the strategy of learning new words using the procedure of "problem solution" will be realized as an exercise within a specific section that will be taught to a particular class and involves a certain set of words.

Following Mariani's taxonomy (Mariani, 1996), which begins from some general factors and results in the more specialized and particular ones, the factors that are involved in the learning procedure and more particularly in the learning vocabulary as a second or foreign language are depicted in Figure 1. Obviously, these factors are not only interconnected, but also overlapping. Therefore, the teaching procedure, in order to be effective, will have to correlate them and deal with them as a whole (Cohen, 2003; Mariani, 1996). This means that even a very simple activity in the field of vocabulary learning will have to be an application of the respective strategy, which, in turn, belongs to the learning style of each student. For instance, presenting a vase in a classroom, having a sign "Vase" on it, is the application of the strategy known as "Word-Object Combination". This strategy belongs to the context of a specific learning style that requires using user's senses, and more specifically the sense of vision. This activity appeals to a special group of users, those who approach the knowledge through vision and are known as "visual learners".

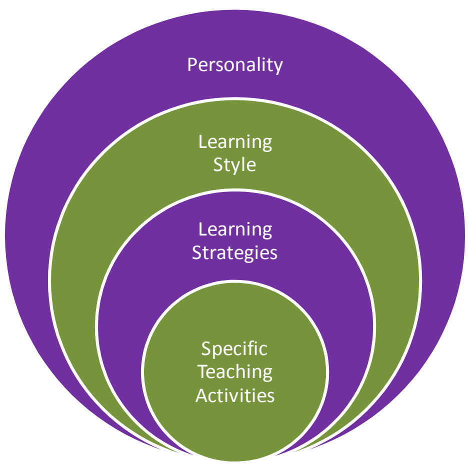


Figure 1. Mariani's (Mariani, 1996) taxonomy in Personalized Learning

It has to be noted that in the context of this work the way the system responds to the overall user's behavior is examined. Focus is put not only on the learning styles that affect each user's learning procedure, but also on every aspect of needs that make the users learn more efficiently.

4. The Idea of a Cognitive, Web-based, Vocabulary Teaching System (Web-FLAME)

Taking into account the theoretical basis discussed in Section 3, it is essential to consider the development of a novel teaching methodology, which will have to incorporate the essentials of vocabulary learning, along with the potential to adapt to user's specific needs, making learning more effective and quick. A web-based platform for achieving the above could also be of use, so as to accelerate and facilitate ubiquitous learning. Moreover, the system needs to be able to proactively adapt to the user's profile, provide the appropriate material, be able to evaluate the performance and guide the user appropriately towards improving the performance (Kritikou et al., 2008). This could increase the quality of the electronically delivered knowledge, contributing, in turn, in time and effort saving. Consequently, the proposed methodology seems to be realistic and appropriate for sufficiently complementing and serving vocabulary teaching. In this respect, this work moves in the direction of creating a cognitive, web-based, foreign language learning management system (web-FLAME).

This section makes a detailed analysis of the web-FLAME system, a system able to adapt to users' personal preferences, so as to more efficiently learn the vocabulary of a second/foreign language. More specifically, Section 4.1 presents the components and the architecture of the system, while Section 4.2 discusses on the user interaction with the system.

4.1 Architecture and System Components

The architecture adopted here is based on simplicity. This means that it is rather important to have simple and clear components in the architecture, each having a very distinct role. Moreover, the components may communicate with each other at any time, in order to give the user the best learning experience. For instance, in case the system detects unusual behavior from the user, it automatically adapts to the new circumstances, in order to satisfy the changed needs.

In general, four main components make up the web-FLAME system, namely the "*User Profile Model*", the "*Content Model*", the "*User Interface*" and the "*User Monitoring*", as depicted in Figure 2. Each of these components has an irreplaceable role in this system, making its presence mandatory for the system's functionality (Alomyan, 2004; Garzotto & Cristea, 2004; Kritikou et al., 2008; Zakaria, 2003).

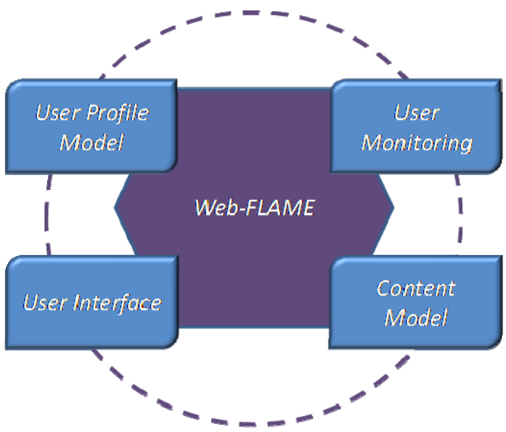


Figure 2. Web-FLAME components

The *User Profile Model* component stores all user-related data, i.e. the users' profiles, including personal information, preferences, monitored user actions and user performance related data. Its main objective is to tailor the learners' information space, by presenting learning material according to each group's cognitive level/progress, socio-cultural attributes, goals, plans, tasks, preferences, and beliefs (Brusilovsky, 2001; Conati & Zhao, 2004; Kalaydjiev & Angelova, 2002). This is achieved by providing a set of simple questions in the beginning of the first course (as a part of a questionnaire). Of course, the questions are optional for the user to answer. In case the user would not like to take the questions, the system places the user in a more general group and thereafter, in cooperation with the User Monitoring component, specifies the unique needs of this user.

In summary, the User Profile Model has to infer the following information: (a) the users' preferences concerning the content of each linguistic course; and (b) the users' preferences regarding the structure of the user interface/platform. Furthermore, it has to store the following information:

- the users' profiles, i.e. personal information about each user;
- information about each user group, i.e. which members it consists of, what are its main characteristics (e.g., group of novice or expert users);
- log files about each user's behavior during his/ her navigation through the system;
- the answers each user provided to the set of questions and tests, when entering the system for the first time;
- the scores in the exercises and evaluation tests, when completing a course, as well as the feedback provided by the administrator of the course, for each user.

The *Content Model* component stores information about the material that is to be delivered to users. The Content Model stores the learning segments (learning courses) in XML format and, when notified, provides the appropriate information to the User Interface component, utilizing the instructions sent by the User Model, about each user group's preferences.

The *User Interface* is the component that exploits information from the User Profile Model, in which the users' preferences are stored, and the Content Model, in which each course's structure is stored, and forms the final content to be delivered to the user. This content is formed in pages using Java Servlets (De et al., 2003), and comprises the material to be finally presented to the user.

Finally, the architecture is completed with the *User Monitoring* component. This component monitors each user's behavior during the navigation in the e-learning system, detecting the user's interest on certain subjects, or weaknesses of understanding in some others. The data collected in the User Monitoring component are transferred to the User Profile Model, in order to serve as input for the adaptation of the user profile.

All in all, the components described above aim at rendering the system easy to navigate, interesting and attractive to the user, as well as adaptable to particular characteristics and learning style preferences, imposed by each user group.

4.2 User Interaction with the System

As previously mentioned, the design, development and appropriate exploitation of an electronic teaching system is essential in order to develop an interactive and efficient web based vocabulary teaching system. This teaching model, having the necessary structure and information (through the initial questionnaire and the evaluation process of user's behavior, as will be analyzed in the sequel), groups the user in an appropriate set, based on the learning style, offering guidance within the learning material through certain activities and strategies, which completely adapt to it.

Specifically, in the beginning of user's navigation in the system, the user may optionally provide answers to a certain set of questions. This is shown in Figure 3. These answers will help the system form the user's initial profile, adding him in a group of users, having the same learning style and the same level of knowledge. The questionnaires that are dealing with the initial learning style detection will be formed based on learning style's categorization that is closer to the school routine and teaching reality (Felder & Henriques, 1995; Mariani, 1996; Mitsis, 1998; Oxford, 2003). After the initial categorization of the user, the user officially enters the course. In this context, the learning material is accessed, studying the course, referring to the respective further studying incentives, solving the exercises and generally following the suggested learning itinerary by the system. In case the user chooses not to take the questionnaire, the system classifies the user in the novice group and the procedure continues by monitoring the user's behavior throughout the navigation in the system.

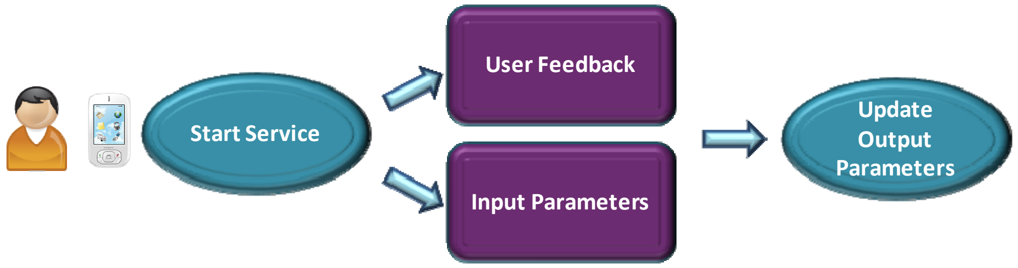


Figure 3. User's navigation within the system

The originally formed learning material starts at this point to adapt to the user's special preferences and learning pace. This means that the learning material included in the system is scaled in levels of difficulty and at the same time is structured in a way so as to provide to each level the strategies that realize different learning styles. Moreover, the user's activity is evaluated so as to detect potential weaknesses and problems encountered, and record the respective performance and behavior. The aim is the adaptation of the learning material, consequently leading to the overall improvement of the user's performance.

At the same time, the system monitors the learning pace, the amount of the material and the specific needs of the users, in the context of the certain learning style, making the process personalized. Such an environment is considered to serve as incentive for the user, to make a bigger effort during the learning process, as the user will feel more confident in the learning environment. It is assumed that the users that are presented content in accordance to their learning style, are going to learn quicker and more effectively the words (Dunn & Dunn, 1978). Therefore, they can achieve more sufficient and creative learning of the material, compared to the traditional vocabulary teaching method used today.

Finally, the system evaluates the user's progress, by providing the user with a quick test to assess the amount of information absorbed. The test corresponds to a course completed by the user, containing quick questions that do not overload the user which can be answered with a "Yes" or a "No". This means that even technology agnostic users are able to answer such questions easily, with the minimum interaction possible.

Conclusively, the proposed vocabulary teaching system has the following characteristics, which are extremely difficult and time consuming to be incorporated in the traditional teaching process.

- Personalization
- Adaptability to users unique characteristics
- Interactivity between the system and the user
- Variety in the levels of difficulty the way of presenting the learning material

4.3 User Profile Parameters Classification

As mentioned above, user preferences might be changing over time, along with progressively studying the offered courses, enhancing knowledge and viewing versatile aspects of a subject. This means that web-FLAME should revise certain aspects of the offered learning procedure, in order to better meet the user's evolved needs. Each of these aspects is influenced by one or more factors that reflect the user's behavior within the system, namely the user profile parameters. This means that the user's behavior can be monitored through parameters concerning the navigation in the system and certain points of user's behavior and, by being kept in log files, this information can be updated accordingly.

User profile parameters can be classified following (Ahmad et al., 2004; Juvina & Oostendorp, 2004a), so as to facilitate their evaluation. Therefore, it is assumed that a user's e-learning profile consists of two types of parameters: the influential factors, which will be called 'input parameters', and the user and learning procedure preferences, which will be referred to as 'output parameters'. In what follows, two output parameters and three input parameters are presented and analyzed in details. More complex models may incorporate a higher number of parameters, yet the nature of the analysis does not change.

4.3.1 Input Parameters

Though it may seem easy, it is in practice rather difficult to properly set the values of the output parameters. In most cases, even the user is not in position to realistically estimate the educational level, the level of familiarity on a subject, the learning style or the expected outcomes of taking a specific course. Therefore, setting a number of input (evaluation) parameters is necessary, in order to aid the system to evaluate the user's preferences, as progressing with the study of the provided material. Those parameters include the *Course Duration*, the *Test Duration* and the *Performance*.

More precisely, *Course Duration* refers to the time that a user spends for completing a didactic unit/course. This time is measured and then compared by the system to a set of (pre-estimated) threshold values, which depend on the particular course. The result is the classification of the user's time in one of the following four classes: low, medium, high, or very high. The value of *Course Duration* subsequently affects the determination of the target parameters' values. The *Test Duration* parameter is similar in nature, with the difference that it is related to the time that a user spends to complete a test.

What is also measured and taken into account in the process of user preferences prediction is the *Performance* parameter. By keeping the user's test scores, the system can estimate how well the user has comprehended the concepts of the course. This parameter is assumed to have four possible values: ‘A’, ‘B’, ‘C’, or ‘D’.

The dependencies between input and output parameters are depicted in Figure 4.

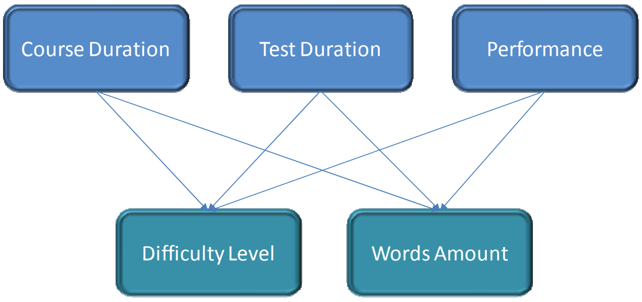


Figure 4. Dependencies between input and output parameters

Therefore, the web-FLAME system groups certain parameter values, so as to evaluate the user, as shown in Table 1. In case the system has inferred after the initial short questionnaire that the user is Novice, it presents the corresponding information and adapts itself accordingly, using the information by Table 2.

Table 1. Input parameters and user groups

	Course Duration	Test Duration	Performance
Novice	High	High	D
Intermediate	Medium	Medium	B/ C
Expert	Low	Low	A

Table 2. Output parameters and user groups

	Difficulty Level	Number of Words
Expert	High/ Medium	High/ Medium
Intermediate	Medium	Medium
Novice	Low	Low

Thereafter, the user takes the course and the system monitors the user’s navigation and behavior. This is done by measuring the evaluation parameters, as discussed previously. Comparing the values of these parameters with the data of Table 2, the system can conclude whether the parameters’ group will have to be changed or not. This is also combined with the feedback that the user has provided the system with. For instance, in case the user provides the system with low evaluation, despite the high scores and good performance, the system concludes that it needs to rearrange the content to fit the appropriate learning style of the user.

The next subsection describes the knowledge acquisition and adaptation methodology.

4.3.2 Output Parameters

The output parameters are practically the parameters that affect the user’s performance, but cannot be easily measured. Yet, as it is essential for the system to be aware of their value, they are composed by other measurable parameters (input parameters, discussed in the previous section) and they can thus be inferred through them. The exact procedure is presented in detail in section 5.

The output parameters include *Difficulty Level and Number of Words*. By keeping these parameters updated, the system is able to provide the user with the appropriate content, in the most suitable way. The values of these parameters are modified according to the user’s behavior in each didactic unit.

Difficulty Level is influenced by the level of the user’s knowledge on the subject, being a *novice*, *intermediate* or *expert*. As the user takes more and more courses, the level of knowledge changes, from novice to intermediate, or from intermediate to expert, and consequently asks for more complex content, with more detailed information on the subject and more advanced resources to explore. *Difficulty Level* may be attributed to one of the following three values: low, medium, or high.

Number of Words refers to the amount of information the user wishes to explore in the course to study. Low, medium, or high are the values that *Number of Words* can be set to. For instance, Low corresponds to a small amount of words defined and presented in each course, so as to be easily absorbed by the novice user. Medium and high are formed respectively including for instance fifteen (15) and twenty-five (25) words in the course.

5. Web-FLAME Implementation

5.1 Methodology for Knowledge Acquisition and Adaptation to User Preferences

The process of developing knowledge regarding user preferences comprises two phases. The initial phase is the collection of information on the user. For the initial phase, the approach proposed in this section is to monitor the user's behaviour, collect feedback from him/ her and calculate rankings of Number of Words and Difficulty Level combinations. The next phase is the approximation of future user preferences based on the gathered feedback, using Bayesian statistics principles, in order to improve the behaviour of the e-learning platform towards the user.

Concepts from Bayesian statistics are applied in order to estimate the probability of the Difficulty Level and Number of Words for a specific content provided. This can be done through updating instantaneous estimations by taking into account existing information on the user (Kritikou et al., 2008; Stavroulaki et al., 2009).

The first step of the application of this methodology is to create the Conditional Probability Table (CPT) for each Output Parameter (Table 3). Practically, the CPT Table serves as an input to the instantaneous estimated probabilities of utility volume, which is the second step of this methodology. As the user is being delivered with a specific content, the instantaneous estimations are changing, depicted by and depending on the monitored behaviour of the user within the system. This means that the instantaneous probability estimations are changing in time and act as input to the estimation of the adapted probability.

Table 3. CPT for "Difficulty Level" output parameter

Parent Node(s)			LevelDifficulty			
CourseDuration	TestDuration	Performance	High	Medium	Low	bar charts
High	High	A	0,1	0,35	0,55	
		B	0,25	0,35	0,4	
		C	0,05	0,35	0,6	
	Medium	A	0,3	0,35	0,35	
		B	0,2	0,45	0,35	
		C	0,15	0,3	0,55	
	Low	A	0,5	0,3	0,2	
		B	0,35	0,35	0,3	
		C	0,1	0,3	0,6	
Medium	High	A	0,1	0,35	0,55	
		B	0,15	0,6	0,25	
		C	0,05	0,4	0,55	
	Medium	A	0,25	0,45	0,3	
		B	0,25	0,55	0,2	
		C	0,1	0,5	0,4	
	Low	A	0,55	0,35	0,1	
		B	0,15	0,45	0,4	
		C	0,1	0,25	0,65	
Low	High	A	0,15	0,55	0,3	
		B	0,25	0,3	0,45	
		C	0,15	0,35	0,5	
	Medium	A	0,6	0,3	0,1	
		B	0,2	0,45	0,35	
		C	0,25	0,45	0,3	
	Low	A	0,5	0,3	0,2	
		B	0,3	0,45	0,25	
		C	0,2	0,25	0,55	

The third step of this procedure is the calculation of adapted probabilities. The calculation of these probabilities is based on the following formula (Kritikou et al., 2008):

$$p_{adapted,n} = w_{hist} \cdot p_{adapted,n-1} + w_{instant} \cdot (1 - |p_{adapted,n-1} - p_{instant,n}|) \cdot p_{instant,n} \quad (1)$$

Where:

- $|x|$: represents the absolute value of x
- n: denotes the current instant
- $p_{adapted,n}$: represents the adapted probability estimation at moment n
- $p_{adapted,n-1}$: represents the adapted probability's previous value
- $p_{instant,n}$: stands for the current instantaneous estimation
- w_{hist} and $w_{instant}$: reflect the weights attributed to the historical estimation and the current instantaneous estimation, respectively. Their value is in the interval (0, 1) and the formula $w_{hist} + w_{instant} = 1$ is always true.

5.2 Indicative Results

This section aims at evaluating web-FLAME through indicative results. Three scenarios are used for the evaluation. The first scenario presents a regular case, the second scenario aims at showing how web-FLAME reacts to an unexpected monitored behavior and the third scenario describes the role of weights in the overall process.

5.2.1 Scenario 1 - Regular Case

In this scenario, we examine web-FLAME's behavior in a generic situation. The value of the ratio $w_{hist}/w_{instant}$ has been set equal to 1, meaning that $w_{hist} = w_{instant} = 0.5$. As discussed in Section 5.1, the first step of the application of the methodology is to create the Conditional Probability Table (CPT) for each Output Parameter (Table 3). This Table is produced with the use of the MSBNx Bayesian Network editor and toolkit (MSBNx, 2009), based on the "network" of Figure 4. Initially (step 1), as depicted in Figure 5(b), where the vertical axis represents the value of the probability ([0,1]) and the horizontal axis the progress of the phases of the course, all the possible values of each target parameter are considered equally probable (uniform distribution). Hence, a vocabulary course with random difficulty level and amount of words is generated and delivered at this step. At the end of this course, the model's monitoring mechanism reports the following evidence: *Course Duration = High, Test Duration = Medium, Performance = A*, as depicted in Figure 5(a). This set of evidence serves as input for the formation of the next course, i.e. the course of step 2. At the beginning of step 2, this evidence is utilized in order to produce a set of instantaneous probability estimations concerning the target parameters. This is carried out with the use of Equation (2), as described in Section 4, after setting *CD=High*, *TD=Medium* and *R=A*. Subsequently, the instantaneous estimations of this step (step 2), in conjunction with the adapted probability estimations of the previous step (step 1), are utilized for the computation of the adapted probability estimations (Figure 5(c)) of the current step (step 2). Based on the adapted probability estimations, we come to the conclusion that, at step 2, *Low* is the most probable value for *Difficulty Level* and *Low* for *Number of Words*. Thus, the course of step 2 should comply with these suggestions, in order to best fit the user's preferences. The same method is followed for inferring the most probable values of the target parameters throughout the rest of the steps.

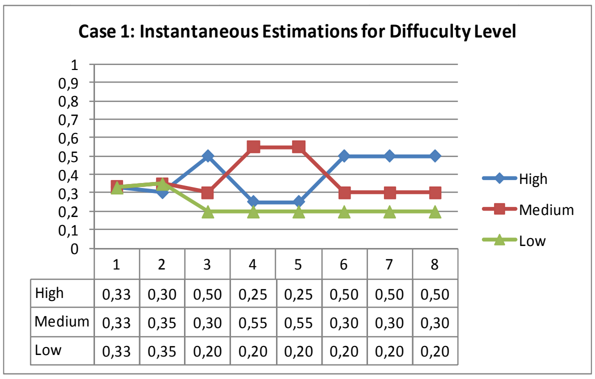
As may be observed from the curves in Figure 5, the adapted estimations normalize the sharp fluctuations of the instantaneous estimations by adapting to the evidence at a slower pace. This has the clear advantage of exploiting not only the most recent evidential data, but also knowledge about the past, by attributing the appropriate weight to each probability estimation figure.

As a further indicative example of this behavior, let us observe the estimation results for the *Difficulty Level* parameter, at steps 5 and 6, in Figure 5(b). At step 6, we may observe that the adapted estimation indicates *Medium* as the most probable value. However, at step 6, a radical change is detected at the evidential data. According to the instantaneous estimations, *High* is the most probable value at step 6. However, the adapted estimation takes into account the historical knowledge, by moderating this oscillation, and suggests again *Medium* as the most probable value; this time, of course, the probability of value *Medium* has significantly been decreased.

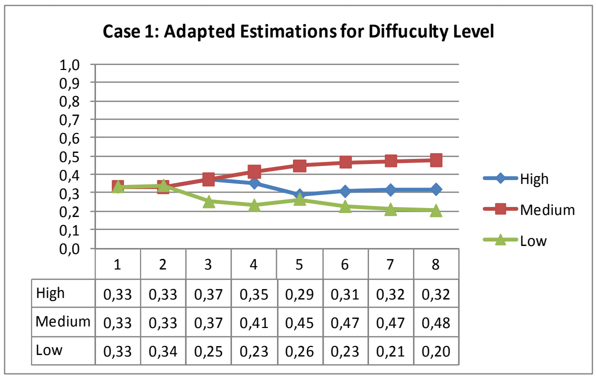
This gradual adaptation to the evidence allows the system to avoid temporary and impulsive oscillations.

Evidence Table		
Course Duration	Test Duration	Performance
High	Medium	A
High	Low	A
Medium	Medium	B
Medium	Medium	B
Low	Low	A
Low	Low	A
Low	Low	A

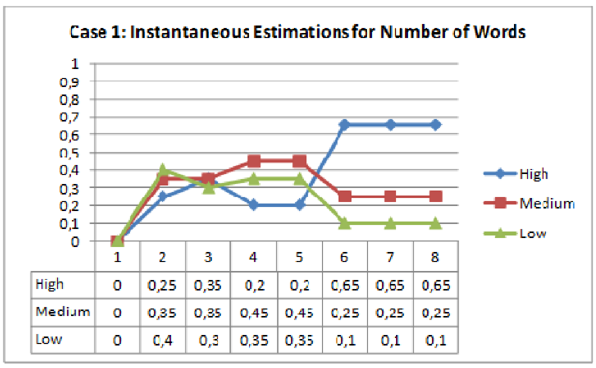
(a)



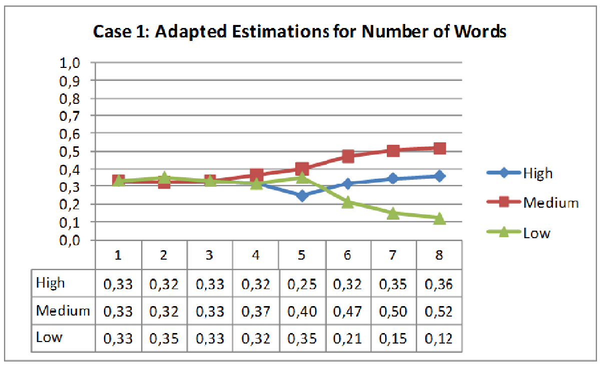
(b)



(c)



(d)



(e)

Figure 5. Case 1. (a) Evidence Table; (b) Instantaneous probabilities estimations for Difficulty Level (c) Adapted probabilities estimations for Difficulty Level (d) Instantaneous probabilities estimations for Number of Words (e) Adapted probabilities estimations for Number of Words

5.2.2 Scenario 2 - Managing an Unexpected Monitored Behavior

In this scenario, we examine the avoidance of vacillations through a more specific example. As depicted in Figure 6(a), we assume that the user's performance is very high during the steps 1-3, then that there is a sudden radical deterioration at step 4, while at step 5 the user continues to have a very high performance, taking much time to complete a course (Course Duration = High) and little time to finish the test (Test Duration = Low). In this use case scenario, at step 4, the system monitors a rather unusual and unexpected behavior on the user's part. In this case, it would not be wise and safe for the system to come to the conclusion that the user has suddenly become a novice in the vocabulary field. In other words, using more "technical terms", the system should avoid providing the user with content of very low difficulty at this point. This means that the system should not respond hastily and take desultory measures. On the contrary, a more modest method will have to be followed.

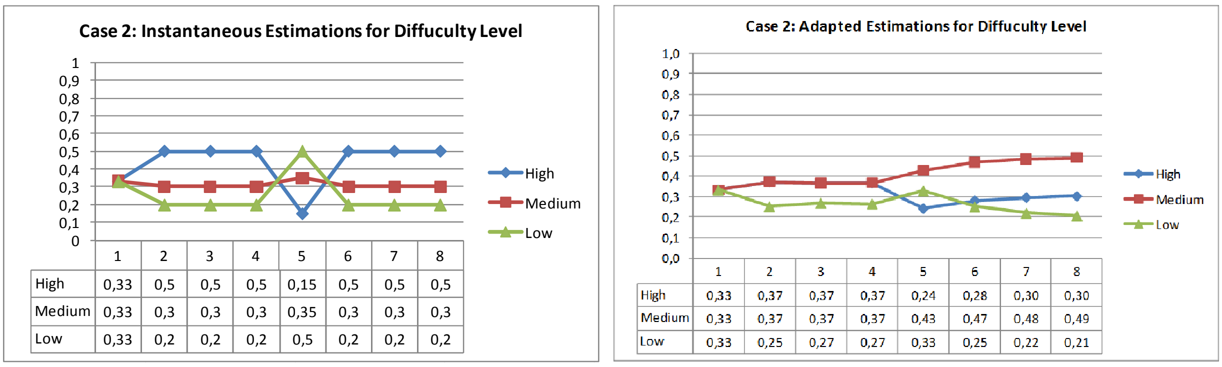
Indeed, going through the estimation results for the *Difficulty Level* parameter, this is exactly what is achieved by the proposed system. More specifically, at step 4, as may be observed in Figure 6(a), the user performs unexpectedly low. Yet, applying the Bayesian methodology presented in section 5.1, the instantaneous estimations of Figure 6(b) evolve in the adapted, with the Bayesian methodology, estimations of Figure 6(c).

The results showcase that although dealing with an unexpected behavior on the user's part, the system, using the adaptation mechanism, is in position to adapt more smoothly and intelligently to the user's preferences. This helps the user adjust better in the course's circumstances and does not cause disorientation, by making abrupt adaptations.

The results are similar for the Number of Words parameter, as well.

Evidence Table		
Course Duration	Test Duration	Performance
High	Low	A
High	Low	A
High	Low	A
Low	High	C
High	Low	A
High	Low	A
High	Low	A

(a)



(b) (c)

Figure 6. Case 2. (a) Evidence Table; (b) Instantaneous probabilities estimations for Difficulty Level; (c) Adapted probabilities estimations for Difficulty Level

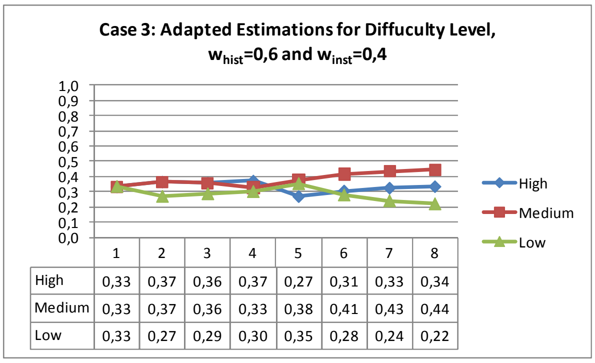
5.2.3 Scenario 3 - The Role of Weights

The goal of this scenario is to showcase the effect of the weights to the adapted estimations. In other words, in this scenario we aim at presenting the way the results are affected in case historical or instantaneous estimations are taken differently into consideration.

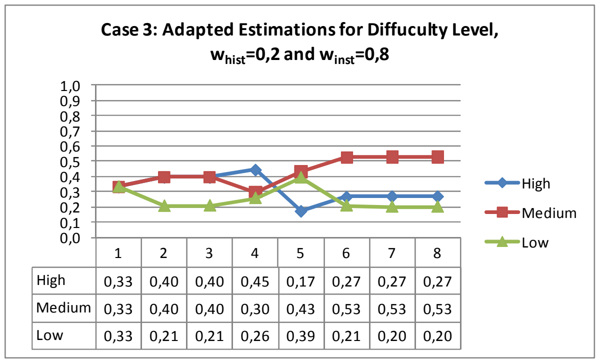
For this scenario, the Evidence Table (Figure 6(a)) of the previous case has been used and different measurements have been taken down, taking into consideration different weight ratios (Figure 7). This means that in the first scenario we have set that w_{hist} is more important than w_{inst} (0,6 to 0,4 the respective weight), in the second scenario w_{inst} is four (4) times the w_{hist}, while in the last scenario w_{hist} is now three (3) times the w_{inst}. This gives us the opportunity to test the system's response in the same case, yet under different circumstances.

As expected, the difference in the weights results in different figures in the adapted estimated probabilities. The biggest the ratio of the weights is, the higher the fluctuations in the results. For instance, in Figure 7(b), where w_{inst} is four (4) times the w_{hist}, it can be observed that the fluctuations are very sharp. Therefore, it is highly necessary to have a mechanism, which will respond effectively according to user preferences and in an even and efficient manner.

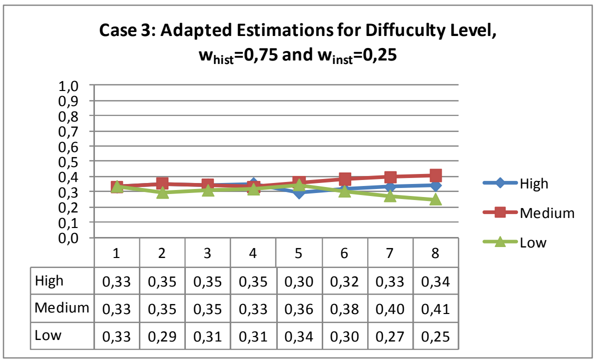
Conclusively, weights play a very significant role in the adaptation procedure. Yet, it is essential to preserve a balance in the weights' ratio, so as to take both parts of the formula into consideration, providing the user a more smoothed out result, adapted gently to user's preferences.



(a)



(b)



(c)

Figure 7. Case 3. Adapted probabilities estimations for Difficulty Level having. (a) whist=0,6 and winst=0,4; (b) whist=0,2 and winst=0,8; (c) whist=0,75 and winst=0,25

6. Conclusions and Future Work

The modern scientific perception in Linguistics emphasizes on the vocabulary teaching, which is considered a critical field in learning a foreign language. Taking into account (a) the importance of the vocabulary and the need for enhancement, (b) the difficulties that emerge when learning new words in the field of a foreign language and (c) the fact that the vocabulary may not be taught sufficiently with the traditional way of teaching, the development and use of a contemporary and more effective methodology was proposed, integrating new technologies.

Specifically, the paper has proposed a cognitive, web-based foreign language learning management system (web-FLAME), which has the ability to acquire knowledge from past interactions with the user and adapt its content and the overall learning process, so as to make it completely tailored to individual user needs. The paper has described the components of the system, as well as the method used for adapting to the (changing) user preferences, based on Bayesian networking concepts. The paper presented results that show that web-FLAME can estimate aspects of learning content which are most suited for a certain user and thus adapt content in such a way as to correspond to specific user needs.

Therefore, the web-FLAME system can increase the quality of the provided web content and, simultaneously, can contribute to time and effort saving, since adaptation to special user preferences and needs is extremely difficult to accomplish in the context of a classroom. The whole process as described responds to vocabulary teaching requirements, as formed today. Indeed, it may be assumed that complementing teaching, and more specifically the e-learning platforms, with the use of a system such as web-FLAME, can accelerate the learning procedure, making it more dynamic and effective. Further development of such a system is definitely going to be useful in the linguistic teaching procedure and more specifically, in the field of teaching a foreign language.

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