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Courseware Adaptation to Learning Styles and Knowledge Level

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1. Introduction

According to initial design of adaptive e-learning, content of an adaptive course should be suitable for students with different profiles (Brusilovsky, 1996). These profiles may contain information about goals, preferences, knowledge level, learning style, rendering psychological profile, and more. Typically, the learning content is developed for some groups of students that have similar values of one or several parameters of the student's profile. For more groups of students an adaptive course is designed, the more personalized it is.

Adaptive Hypermedia Systems (AHS) use models and techniques for adaptive content delivery. They are widely used for technology enhanced learning together with applications for adaptive e-learning, intelligent tutoring, adaptable multimedia delivery and adaptive computer games. AHS are entirely oriented to individual learner profiles. In the context of e-learning area, AHS deliver hypertext and hypermedia content which is in line with particular set of parameters of individual learner profile or group of learners (Dagger et al, 2005). Adaptive content delivery must be executed in accordance with a pedagogical strategy. Thus, in order to assure high quality of an adaptive course it has to embody sufficient number of teaching strategies. Such strategies are supposed to be appropriate for different types of students diversified according learning style, level of knowledge, shown performance, preferences and specific goals, learning history or learners needs, etc. (Bontchev, Vassileva, 2009). Strategies are realized by techniques for achieving adaptation such as adaptive navigation, adaptive content selection and link annotations (Conlan, 2003). Another less frequently used method for the realization of adaptive content delivery is by using automatically generated curriculums for each student according to his/her profile or through definition of education storyboards, applying appropriate instruction strategies and methods. Except adaptation techniques, AHS must choose parameters of the student profile which are to be used for controlling adaptation process and to be consistent with the applied teaching strategies. Some researchers emphasize the content adaptation to current learner skills and level of knowledge (Karagiannidis and Sampson, 2002), while others include as well other parameters such as learning history, learners' needs, learning styles of given style family, goals and preferences (Velsen, 2008).

The present chapter is focused on courseware adaptation to both learning styles and learner's performance as two very important metrics of the learner model. Within the scope of ADOPTA (ADaptive technnOlogy-enhanced Platform for eduTAinment) project, there was

developed a software platform for adaptive content delivery based on a conceptual model supporting adaptivity to learning styles and learners performance, i.e. shown knowledge level (Bontchev and Vassileva, 2011). After presenting an overview of the conceptual model and platform architecture, the chapter discusses approaches for construction of course storyboards adaptive to learning styles and knowledge level of individual learners. It provides a description of a methodology for adaptive course storyboard design and management and, next, shows how this methodology may be used for practical development of an adaptive course in XML technologies. Finally, the chapter considers some practical results collected during pilot experiments with the platform using the adaptive course within a field trial with bachelor students in Software Engineering at Sofia University, Bulgaria. The results concern assessment of efficiency of adaptivity and are summarized from survey conducted after finishing the adaptive course.

2. Background

The main issues treated by modern research in the field of traditional and adaptive e-learning, may be summarized as follows:

- creation and reuse of learning objects (Collis and Strijker, 2004) thanks to metadata that provides information about a learning resource (Friesen, 2005);
- support of content adaptation to different learning styles (Vassileva and Bontchev, 2011);
- development of adaptive learning courses, which use various pedagogical approaches to different students with different learning style, level of knowledge and preferences (Vassileva, 2010).

2.1 Learning objects and metadata

Learning objects (LOs) represent a popular paradigm for creating teaching materials. Instead organizing teaching into lessons and courses that meet predetermined objectives, LOs paradigm provides educational content divided into smaller independent units that can be used both separately and combined statically or dynamically with others.

Generally, the term LO may be used in different meanings, shapes and with different granularity. IEEE Learning Technology Standards Committee (LTSC) defines learning object as any object, digital or not, which can be used for education or training (IEEE LTSC, 2004). LOs have several main properties as follows:

- modularity - LOs may be used both separately and together with other aggregate;
- interoperability - in order LOs to be portable between different environments and platforms, they are packaged according to the Sharable Content Object Reference Model (SCORM) standard (Rey-López et al, 2002);
- reusability - facilitates authors of content, who can use learning objects in different contexts and for different purposes;
- accessibility - LO should be accessed anywhere, anytime and can be used in different networks. For this purpose, each LO should be annotated with appropriate metadata.

Metadata provide specific information about a resource such as description of its context, characteristics, common usage and features. Metadata can describe an object regardless of its

level of aggregation such as a collection of resources, a resource or component of a larger object. The purpose of using of metadata is to improve and facilitate retrieval of information. Furthermore, they can support interoperability, integration of an object and its identification.

There are three main types of metadata (NISO, 2004):

- *narrative* or *descriptive metadata* that describe resources in such a way that they can be more easily detection and identification. They include items such as title, creator or author, publishers, language;
- *structural metadata* that define in what way and how complex objects are placed together, such as how learning objects are included in a page;
- *administrative metadata that provide information* for assisting resource management. For example, where, when, in what format and size a file is created.

The most popular and used metadata standards practically used in the field of e-learning are two - Dublin Core (DCMI, 2009) and IEEE Learning Object Metadata (LOM) (IEEE LTSC, 2004).

2.2 Approaches for creating adaptive courses

While developing adaptive course, there are two main points which must be taken into account. The first of them is the choice of appropriate teaching strategies that will be realized within in the course. The second one is the selection of a method for constructing an adaptive course. The choice of pedagogical strategies is based on the objectives set out in the course such as to make it suitable for learners with different levels of knowledge of students, different way of adoption of information, different ways of understanding, different goals, preferences, etc. (Paramythis and Loidl-Reisinger, 2003). Approaches to construct adaptive courses can be basically divided into three groups (Vassileva, 2010), which are based on:

- *a network of concepts* – concepts are linked to connections reflecting the rules under which the learner can move from one concept to another. In the simplest case this is the sequence in which they should be visited by students (Weber et al, 2001). There are two chief disadvantages of this approach: first at all, it is difficult to add more than one rule to a relationship. The second drawback is that a representation in the form of network of the learning process hampers its monitoring;
- *creation of several traditional courses* - learning content in each is different from others and it is appropriate for a group of learners. The disadvantage of this method is that if you add a new group or condition for adaptation you will need to create a new course or revise the contents of all courses;
- other way to create adaptive *course is by setting rules for transition from one concept or page to another one* (Grimón, 2009). These rules can be implemented in two main ways – either they can be programmed in the course itself or, otherwise, to be described in a particular format that is understandable to the system delivering adaptive content. The first approach requires programming skills by the author and intensive labour. The second one allows more freedom of the author and the ability to add transition rules and criteria for selecting the most appropriate content.

2.3 Impact of learning styles

Learning styles are determined by emotional, psychological, physical and sociologically dependant characteristics of an individual. They define ways of extracting, learning and

generalization of knowledge and competences by learner and, thus, are very important when trying to improving the performance of given learner (Lindsay, 1999).

Various families of learning styles have been developed during last decades. There may be encountered four basic types of approaches for identifying different learning styles (Sadler-Smith, 1997):

- learning styles presenting personal cognitive characteristics about dependence or independence in given area;
- styles dealing with specific learning preferences;
- approaches combining elements of cognitive and personal learning preferences;
- styles determined by ways of processing information - based on the cyclical model of (Kolb, 1984) for converger, diverger, accommodator, and assimilator styles and, as well, on the Honey and Mumford model (Honey and Mumford, 1992).

The Honey and Mumford's model is based on the theory of Kolb according to which learning process has two bipolar dimensions - perception (y axis in fig. 1) and processing of information (x axis). Thus, four styles can be formed by this two-dimensional coordinate system, where one of them is often dominant to the other styles. The model includes the following four predefined learning styles: *activist* (fond of new ideas and experiments and looking for challenges of practical tasks rather than listening to lessons), *reflector* (preferring to observe subjects from different perspectives and to reflect about their characters), *theorist* (opposite to activist, looking for formalization, concepts and logical theories) and *pragmatist* (opposite to reflector, prefers to apply theoretical ideas into practice). Fig. 1 represents graphically relations between learning styles of Kolb (in internal circle) and Honey and Mumford found in (Munoz-Seca and Silva Santiago, 2003). The activist matches Kolb's styles of accommodator and diverger and feeds from concrete experience, while the theorist corresponds to converger and assimilator and benefits from abstract conceptualization. The
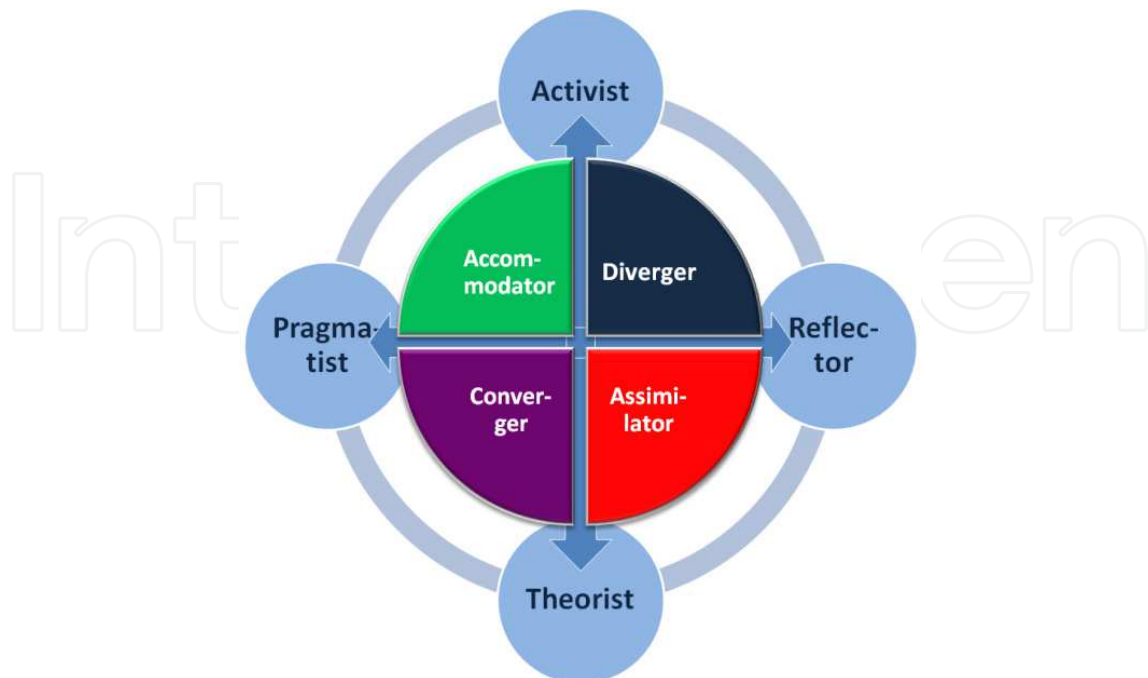

Fig. 1. Learning styles of Kolb versus styles of Honey and Mumford

pragmatist corresponds to accommodator and converger and looks for active experimentation, while the reflector is stacked to diverger and assimilators and prefers reflective observation.

The learning styles of Honey and Mumford are widely used within pedagogical strategies for adaptive learning. Therefore, the learning stylistic character is polymorphic as far as it is represented by levels of affiliation to several learning styles. These levels are determined by a specific style test performed before starting adaptive learning.

2.4 Existing adaptive e-learning platforms

In recent years, the field of adaptive e-learning systems marks significant progress with the emergence of many new applications, realizing and reflecting new trends in this area, and improvement of old ones. Some adaptive e-learning platforms enabling to define different teaching strategies in one course are as follows:

- InterBook (Brusilovsky et al, 1996) – its aim is to deliver to learners educational content in form of adaptive electronic textbooks. This electronic textbooks consist of specially annotated HTML pages and the InterBook provides tools for their creation and presentation. In InterBook learning content is organized into a network of concepts. Each HTML page of an electronic textbook is associated with a set of concepts. For each concept, InterBook stores individual level of knowledge of the learners and based on it dynamically generates links between pages. In this way adaptation is only to knowledge of learners;
- NetCoach (Weber et al, 2001) – similarly to above system knowledge of each course are organized in a network of concepts. Links between them are two types. The first type shows what additional concepts are needed to acquire a certain term. The second type indicates that a concept is assumed to be acquired by a student if he/she has already learned several other. The NetCoach implements adaptation to learner knowledge and goals, but it does not support adaptation to learning styles;
- PERSO (Chorfi and Jemni, 2004) – it is an adaptive e-learning system based on processing and natural language recognition. It uses sophisticated techniques to understand the information entered by students and their requirements and on this bases the system constructs a curriculum. PERSO does not support standards for learning content and course packaging and adaptation to learning styles;
- AHA! (De Bra et al, 2006) - educational content is stored in fragments, pages and concepts. Pages are represented as XML files. The pages contain information about different concepts and their relationships. Moreover, pages are composed of fragments, for each of which are defined conditions. These conditions specify whether a fragment will be visible to a learner. In this system, as in InterBook adaptation is implemented again only to knowledge of students.

Main drawbacks of considered systems are basically two - lack of effective support of adaptation to learning styles and lack of a convenient graphical interface with which a course instructor can monitor how the course will proceed for different learners (most systems provide a scheme of relationships between concepts and learning objects, however, it makes not clear how to conduct the training process).

ADOPTA platform covers the shortcomings mentioned above (Bontchev and Vassileva, 2009). It provides several tools with rich, comfortable and effective interface for creating adaptive courses and it supports learning styles of all kinds (the ADOPTA system is not

oriented to a specific family of learning styles). ADOPTA is consistent with a specific conceptual adaptability model of AHS (Vassileva and Bontchev, 2009) called triangular model. The next part of the chapter is devoted to description of this model and of software architecture of the ADOPTA platform.

3. Overview of the ADOPTA conceptual model and platform

The ADOPTA platform supports adaptive e-learning content delivery according to contemporary requirements of AHS such as interoperability based on exchange of educational materials and activities, reusability of LOs and, most important, construction of e-learning courses with adaptation to user learning styles and user knowledge level (Velsen, 2008). The software architecture of the platform is oriented to the ADOPTA conceptual model of adaptive hypermedia, so next sub-sections briefly presents this model.

3.1 Principal conceptual model

The ADOPTA platform is compliant to a special triangular conceptual model of AHS conceived as an extension of the AHAM reference model (De Bra et al, 1999). The AHS triangular model is described in details in (Vassileva et al, 2009) and uses a metadata-driven design approach separating narrative course storyboard from educational content and adaptation control engine (ACE). Fig. 2 represents a mind map of this triangular model which refines the AHAM reference model by dividing in three the separate models describing learner, domain, and adaptation. It follows a brief description of both structure and semantic of these sub-models.
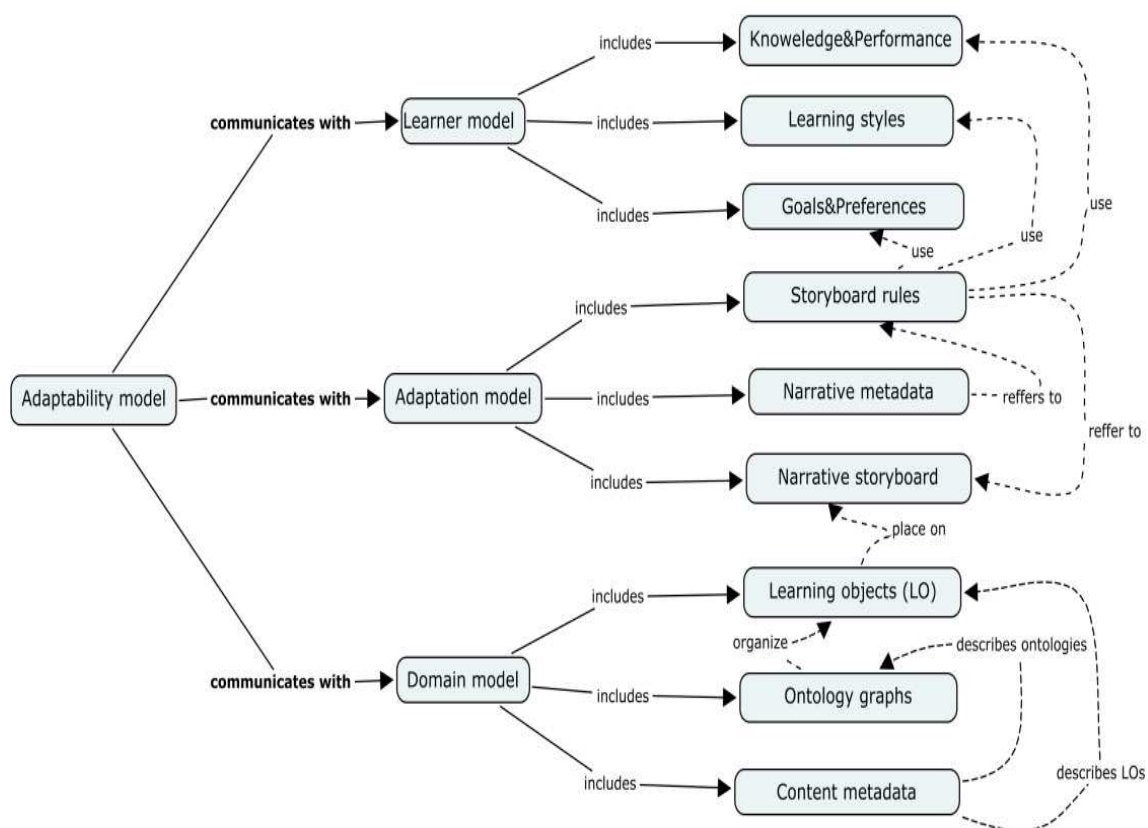

Fig. 2. Mind map representation of the ADOPTA model (Bontchev et al, 2009)

3.1.1 Learner model

The chief specifics of the learner model conclude in separation of a sub-model of goals and preferences from another sub-model of shown knowledge and performance, as the first sub-model is appropriate to be used for personalization while the second one is suitable for adaptive content selection. The model of learning style (such as activist, reflector, pragmatist and theorist) is detached as another sub-model as far as it determines the adaptive navigation throughout the narrative storyboard. Learning character is polymorphic and includes affiliation to several learning styles which is set before starting adaptive e-learning by dedicated pre-tests. On other side, learner's knowledge level may be assessed many times during adaptive learning process in order to adapt content through adaptive content selection.

3.1.2 Domain model

The domain model is composed of domain ontology, multimedia learning content granulized in LOs according to the SCORM standard, LO's metadata as defined by IEEE LOM (Learning Object Metadata) and, as well, ontology metadata. The ontology represents semantic references such as of type *IS_A* (i.e., a term is of subtype of another term) and of type *HAS_A* (a term has a relationship with another term or concept) between terms of given knowledge domain and is built during content composition process by content author. It is used for browsing, filtering and searching of LOs when the instructor disposes appropriate LOs onto course pages of a storyboard graph of the course in order to be delivered to the learner adaptively according his/her learning style and knowledge level.

LOs are annotated by LOM metadata with three main purposes:

- instructors use LOM annotations in order to dispose LOs onto pages of given path within the storyboard appropriate for a learning character with specific polymorphic style. As well, they take into account LO's complexity level and may dispose onto one page several LOs about a concepts and having different levels of complexity;
- the adaptation control engine selects for the page going to be delivered to the learner LO with appropriate complexity according his/her result shown at last intermediate assessment;
- export/import facilities assure interoperability with other e-learning systems thanks to LOM annotations of LOs been exported/imported.

3.1.3 Adaptation model

The adaptation model (AM) is responsible for the design of adaptive e-learning courses. In each of these courses is included a set of pedagogical strategies and each of them is suitable for students with a learning character. Adaptive courses contain learning objects with different complexity and the instructor of the course determines what level of student knowledge is appropriate to visit the relevant content. Furthermore, AM defines rules for selecting the most appropriate teaching strategy for a student accordance with his/her learner model. AM consists of three sub-models - narrative storyboard, storyboard rules and narrative metadata. The narrative storyboard sub-model includes a description of a storyboard graph for each course. Storyboard graphs are represented in form of directed graph, which has two types of nodes - control points (CP) and narrative pages. Narrative

pages consist of a list of LOs but CPs include questions assessing students' knowledge. Between two CPs the course instructor can define paths named work paths (WP) that consist of interconnected narrative pages. Each WP refers to a pedagogical strategy and it has a weight which indicates the suitability for a learning character. The storyboard rules sub-model includes the logic of choice for passing through a narrative graph and for determining which LOs are visible to a learner. The narrative metadata sub-model contains metadata for storyboard rules such as annotations of links between narrative pages, thresholds in CPs, which determine level of assessment performance for continuing to next CP or for returning back to the previous CP.

3.1.4 Adaptation control engine

The adaptation control engine (ACE) communicates with each of the three main models (learner model, domain model, and adaptation model) in order to generate and deliver the most appropriate learning content to the learner. The main task of the ACE is to select the most suitable WP of the narrative storyboard graph for a learner as taking into consideration his/her learning styles and shown by him/her knowledge and performance. For a learner the best WP is calculated using the following formula:

$$\max_{(k)} \left\{ \frac{\sum_i W_{WPk}(c_i) * Wc_i(l)}{\|W_{WPk}(c)\| * \|Wc(l)\|} \right\} \tag{1}$$

where – k is number of WPs from the current CP to the next; c_i is one of learning styles; $W_{WPk}(c_i)$ is the weight of the k-th path WP_k for c_i and $W_{Ci}(l)$ is level in which a learner l belongs to the learning style c_i and this value is determined by test at the beginning of each course (Vassileva, 2010).

Other basic functions of the ACE are following:

- selecting the appropriate LOs in narrative pages;
- selecting the appropriate test questions in CPs;
- calculating test results of answers;
- updating weights of WPs based on these results.

The formula for updating the weight of WP, after solving test in CP $k+1$, is following:

$$W_{WPk}(c_i) = W'_{WPk}(c_i) + \frac{W''_{WPk}(c_i) + (R - P) * Wc_i(l)}{N} \tag{2}$$

where – $W_{WPk}(c_i)$ is the new weight of WP_k for c_i; WP_k is k-th WP from CP k to CP $k+1$; c_i is one of learning styles; $W'_{WPk}(c_i)$ is initial value of weight for path WP_k for c_i; $W''_{WPk}(c_i)$ is the difference from the value of current weight and initially set weight WP_k for c_i; R is test result of a learner l for CP $k+1$; P is adjustment parameter with default value equal to the threshold defined for CP $k+1$. The goal of P is to restrict the increase of the value of $W_{WPk}(c_i)$ in case of unsatisfactory test results; $W_{Ci}(l)$ is level in which a learner belongs to the learning style c_i; N is the number of students passed until the moment through the path WP_k. Thus, it will avoid

the incorrect situation, where weights of the WPs which have passed more students through are higher (Vassileva, 2010).

Thus, for a particular user, the best path is calculated and stored for the learner as current work path. When learner asks for the next page, adaptive engine may hide objects with specific complexity level that are not important for this user. As many users may pass through this path, ACE has to remember user tracks. The learner may abandon the work path determined by ACE (by clicking on a link leading to another page outside of the path), the ACE continues tracking traversed pages and provides return back to the calculated path by adding the link "Return to the WP" to each page. In the end of the path, the learner reaches the next control page, where ACE generates a test including some of the questions linked within the ontology to LOs delivered to the learner by showing pages of the storyboard graph. As far as these delivered LOs are with complexity level suitable for the individual learner, the questions related to these LOs will be appropriate to this learner, as well.

As well, ACE stores some statistics of learner feedbacks to determine which pages are useful for which kind of users. This gives the adaptation engine ability to learn from their skills and perform better estimations for paths for further learners.

3.2 Platform architecture

As an adaptive e-learning platform, ADOPTA includes an authoring tool, an instructor tool, an adaptation control engine and a set of administration tools, all communicating through a common data repository. Fig. 3 represents the principal architecture of the ADOPTA platform. The work process of mastering and delivery of adaptive courseware defines five working roles:
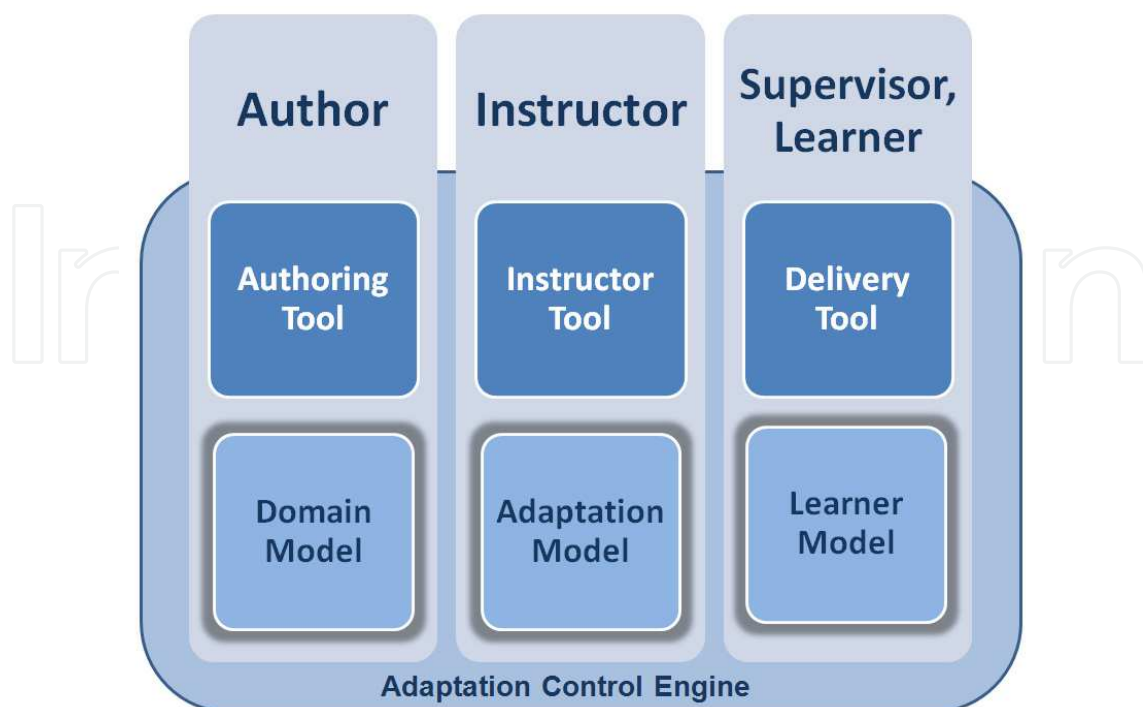

Fig. 3. Principal architecture of the ADOPTA platform

- Author – responsible for design of annotated LOs organized within ontology, by means of the authoring tool;
- Instructor – uses the instructor tool to design a course as a narrative storyboard for courseware delivery with adaptation to learning styles and knowledge, respectively by defining work paths disposing LOs onto pages appropriate for style and knowledge level; as well, the instructor should define paths weights, link annotations and assessment grade thresholds in control pages, as explained in the next chapter;
- Supervisor – responsible for tuning and controlling the adaptation engine, e.g. starting and stopping adaptation behaviour for a given student group, tracking progress of every learner, etc.;
- Learner – solves test for determining his/her learning character (polymorphic learning style) and, next, follows the chosen course by receiving adaptive content from the delivery tool and solving assessment tests at control points
- Administrator (not shown in fig. 3) – controls all the users by means of administrative tools.

As presented in the figure, the tools for authoring learning contents, adaptive instructional design and adaptive content delivery are based respectively on the models describing domain, adaptation and learner, as explained before. The adaptation control engine uses all these three models in order to perform a successful control over the adaptation process.

4. Field trial

An adaptive e-learning platform should be evaluated regarding its functional and quality properties, within a field trial under practical working conditions. In order to evaluate experimentally the ADOPTA platform described in the previous section, the field trial involved design of an adaptive course and its delivery to four-year students of the bachelor program in Software engineering at Sofia University, Bulgaria. The present section explains in detail the methodology used for creation of the field trial and, next, some issues about the design and delivery of the adaptive course.

4.1 Methodology for design and management of adaptive courses in ADOPTA

ADOPTA uses a special methodology for creating e-learning courseware allowing various instructional strategies for adaptive design using non-linear course storyboards. The methodology strongly depends on the strict separation and independence between the three main sub-models within the conceptual model and on the mechanisms used for course delivery with adaptation to learning style and student knowledge level.

Fig. 4 depicts basic methodology steps to be followed when designing adaptive courses. Several key issues should be discussed here:

- Creation of annotated LOs is supposed to be executed by using the ADOPTA authoring tool, however, any other authoring environment compliant to the SCORM (Rey-López, 2002) and IEEE LOM (Learning Object Metadata) standards (IEEE LTSC, 2004). ADOPTA authoring tool allows interoperability with other systems by means of facilities for export and import of LOs. Organization and annotation of LOs is of key importance because it facilitates their usage while designing and maintaining the

storyboard graph of an adaptive course. For example, LOs annotations about their appropriateness for specific polymorphic learning character (comprising of a combination of learning styles) and given complexity level are to be used for creating a storyboard graph providing adaptivity toward learning styles and knowledge level. While IEEE LOM is used for annotating LOs by setting and inheriting appropriate metadata from types to sub-types within the ontology, the ontology itself is to be annotating using OMV (Ontology Metadata Vocabulary) (Hartmann et al, 2005);

Steps for designing an adaptive course:

▶ creation of annotated LOs organized within ontology

▶ construction of course storyboard graph

▶ setting paths' weights appropriate for learning styles

▶ selecting and grouping LOs best suited for given learning style and student knowledge level

▶ distributing each group of LOs onto pages of a work path in the storyboard graph

▶ setting inter-page links' annotations and thresholds at control points

Fig. 4. Methodology for adaptive course design

- Construction of storyboard graph has to imply development of sufficient working (learning) paths covering different polymorphic learning characters, i.e. different combinations of style levels for reflector, theorist, activist and pragmatist. It is not realistic to cover all the possible combinations of such style levels, however, even after developing paths for the four quadrants of fig. 1 the adaptation control engine will be able to select the path mostly suitable for predominant styles of given individual learner character. During the next step, the instructor should define a set of weights for each of these paths, where the set comprises four values showing appropriateness of the path for each learning style;

- Disposal of LOs appropriate for given learning character (combination of learning styles) should be performed after following a pedagogical strategy. The methodology does not fix or restrict such a strategy, thus, instructors are free to select upon their preference;

- Setting appropriate annotations of inter-page links makes possible the adaptation control engine to display them in order to inform the learner about all other possible opportunities for navigation from given course page, different from the next page for

the path determined for delivery by the engine. Thus, the engine does not restrict the learner to follow exactly the path selected as best path for the learner; he/she may leave this path and return to it latter or, otherwise, reach the next control point via another path. In any case, the engine will track all the pages traversed by the learner, in order to select at the next control point questions about LOs delivered at these pages. Note, there are also other details about tuning of the adaptation control, such setting tuning rules for selection of LOs with complexity level appropriate for learner assessment grade shown in the previous control page.

Some steps of the methodology described here may be used for management of the storyboard during the adaptive delivery, as well. For example, changing the weights of the working paths in a graph and/or the threshold's values at the control points may be executed during run time while tracking learning process and assessment results.

Designing curriculum and shaping the course are two aspects of an iterative and incremental process that are consistent with the learner model. Once content is created by the author, it must be linked appropriately in the course by the instructor and adapted according to the goals, knowledge, learning style, etc. These two aspects have a great influence on the efficiency of adaptive e-learning methods. The process of creating LOs of the curriculum refers to the subject domain, while the process of designing a course storyboard is determined by the applied adaptation model.

4.2 Design of a field trial using ADOPTA

One of the main objectives of the experimental field trial consisted in evaluation of courseware delivery using ADOPTA offering adaptation to both learning style and student knowledge level. Thus, the field trial was focused on realization of adaptive course in XML technologies using the ADOPTA platform which is a joint effort of content authors, course instructors and learners' supervisors. The process workflow involved the steps of the methodology for adaptive course design shown in fig. 4. Authoring of content about XML technologies domain supposes creation of LOs of various types such as narrative LO (lesson), exercise, project, essay, problem solving, games and others, in order to be used next by instructors when designing course storyboard graphs by means of the instructor tool. Fig. 5 gives a distribution of learning objects types to learning styles of Honey and Mumford found by the authors during a decade of practical experiments in e-learning (Bontchev and Vassileva, 2009). LOs of type game, essay, project, problem-solving, comparative analysis and observation task can also be used to assess learner's knowledge as well as classic tests. LOs for assessment are given in the figure as yellow ellipses and may be used for self, peer and teacher assessment as presented in the legend. Finally, the LOs are to be annotated and organized within domain ontology as described in (Bontchev and Vassileva, 2011).

Construction of adaptive course storyboard may be based either on using strongly connected storyboard graphs or on parallel branches (Vassileva and Bontchev, 2011). The approach using parallel branches has two main streamlines (i.e., work paths) – one with educational content intended for theorists and another designed for opposite learning style - activists. As shown in fig. 6, each of these two main WPs is divided at several places symmetrically of two other paths which merge again. Thus, design in parallel branches produces two sets of WPs - one containing all the WPs for activists and other containing all WPs for theorists. Therefore, it is

possible for predominant activists or theorists to add also LOs appropriate for pragmatists or reflectors (according distribution of types of LOs shown in fig. 5).
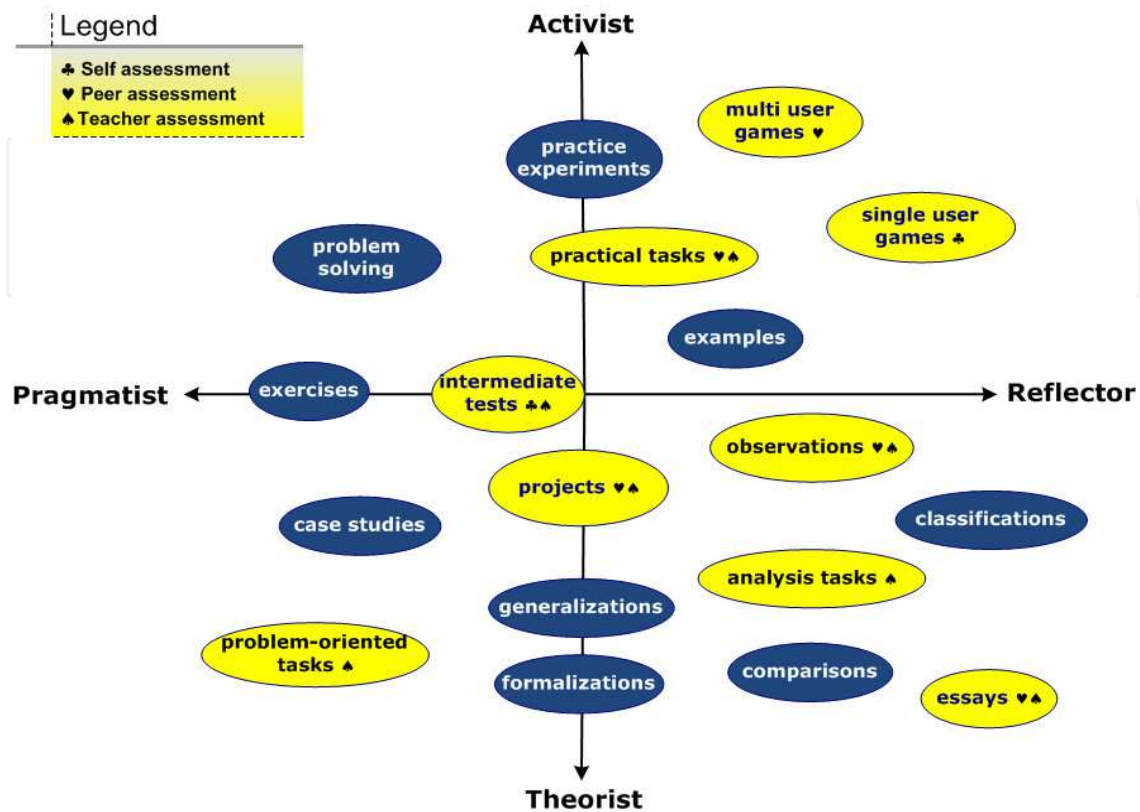

Fig. 5. Appropriateness of learning objects types to learning styles of Honey and Mumford
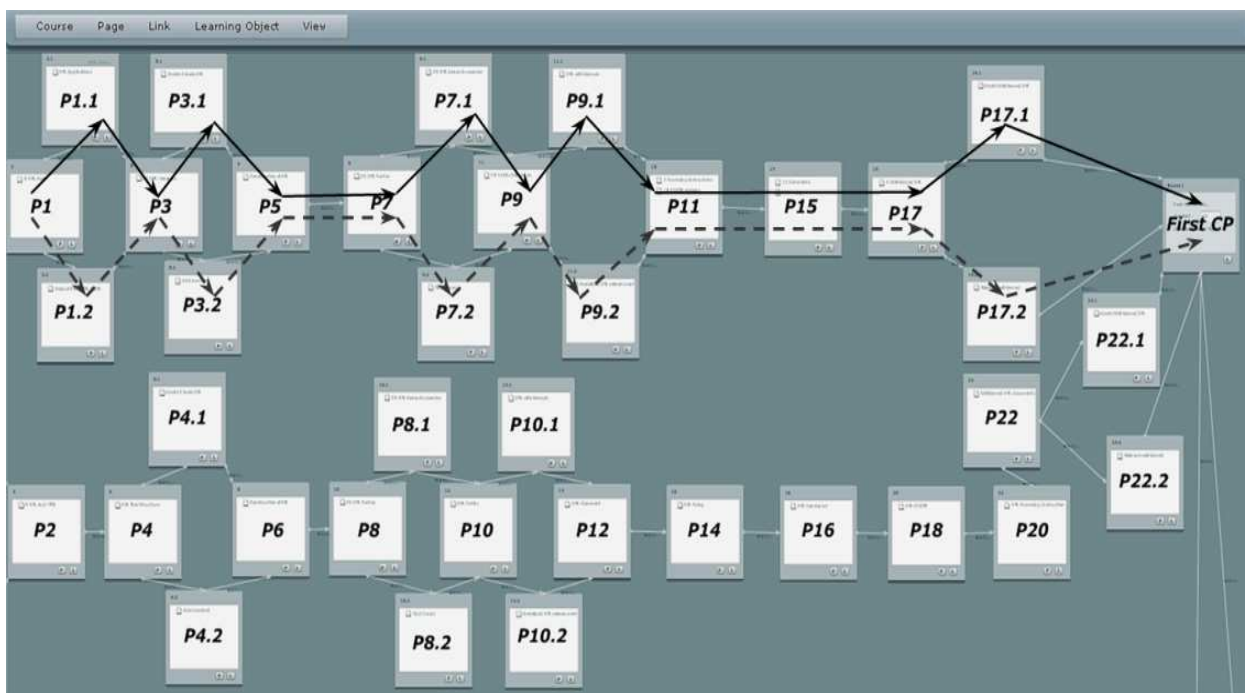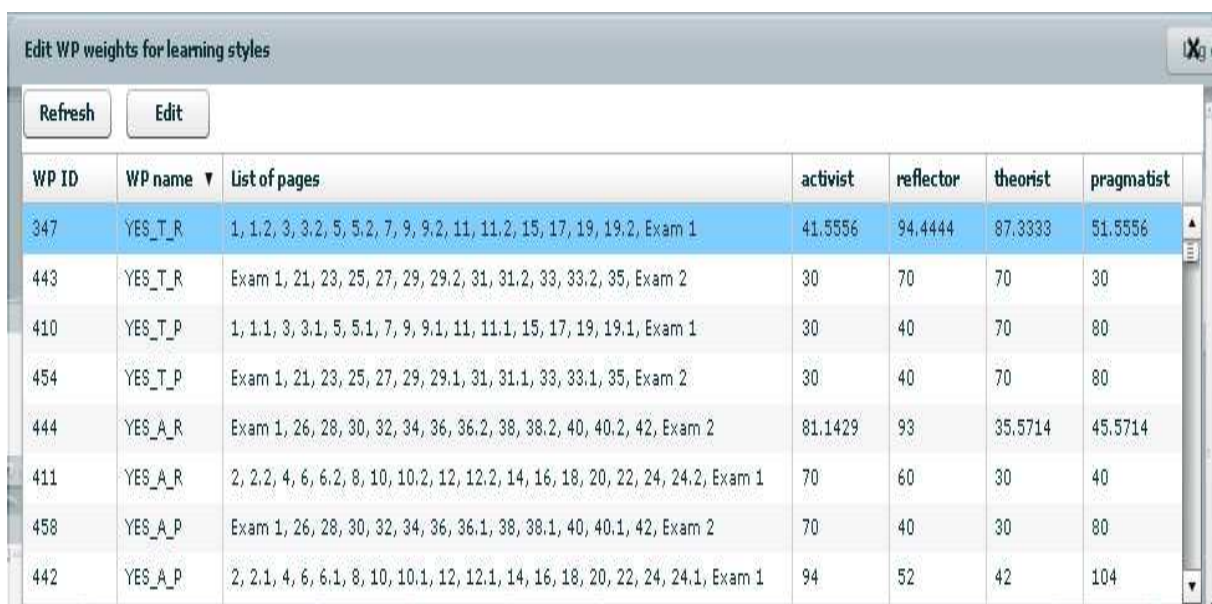

Fig. 6. Partial view of a narrative storyboard graph in the ADOPTA instructor tool (Vassileva and Bontchev, 2011)

After designing and tuning of the storyboard of an adaptive course, the adaptation control engine is able to deliver paths and LOs appropriate respectively to individual learning character and learner's knowledge level. For this purpose, the learner is supposed first to pass the Honey and Mumford survey for assessment of the learning character (styles) and, next, to start the adaptive course. If, at the first control point, the learner assessment grade will surpass the threshold defined at that threshold, then the learner will be able to continue through the path selected by the engine or to navigate to another page making part of another path - by using the annotated link to that page referred as outgoing link. Fig. 7 presents a view of the initialization of the weights of WPs in the Instructor tool, for the developed adaptive course in XML technologies. Each working path consists of a list of pages and has weights for activist, reflector, theorist and pragmatist (when using styles of Honey and Mumford). In contrast with this adaptive navigation, adaptive content selection is possible by placing at each page of the path several LOs with different complexity levels. The adaptation control engine will select LOs with appropriate complexity for given learner depending on his/her last assessment grade received at the previous control point and, as well, according tuning rules for selection of LOs with complexity level appropriate for that grade.

WP ID	WP name ▼	List of pages	activist	reflector	theorist	pragmatist
347	YES_T_R	1, 1.2, 3, 3.2, 5, 5.2, 7, 9, 9.2, 11, 11.2, 15, 17, 19, 19.2, Exam 1	41.5556	94.4444	87.3333	51.5556
443	YES_T_R	Exam 1, 21, 23, 25, 27, 29, 29.2, 31, 31.2, 33, 33.2, 35, Exam 2	30	70	70	30
410	YES_T_P	1, 1.1, 3, 3.1, 5, 5.1, 7, 9, 9.1, 11, 11.1, 15, 17, 19, 19.1, Exam 1	30	40	70	80
454	YES_T_P	Exam 1, 21, 23, 25, 27, 29, 29.1, 31, 31.1, 33, 33.1, 35, Exam 2	30	40	70	80
444	YES_A_R	Exam 1, 26, 28, 30, 32, 34, 36, 36.2, 38, 38.2, 40, 40.2, 42, Exam 2	81.1429	93	35.5714	45.5714
411	YES_A_R	2, 2.2, 4, 6, 6.2, 8, 10, 10.2, 12, 12.2, 14, 16, 18, 20, 22, 24, 24.2, Exam 1	70	60	30	40
458	YES_A_P	Exam 1, 26, 28, 30, 32, 34, 36, 36.1, 38, 38.1, 40, 40.1, 42, Exam 2	70	40	30	80
442	YES_A_P	2, 2.1, 4, 6, 6.1, 8, 10, 10.1, 12, 12.1, 14, 16, 18, 20, 22, 24, 24.1, Exam 1	94	52	42	104

Fig. 7. Initialization of the weights of WPs in the instructor tool

5. Assessment results

The chapter presents results of evaluation of courseware delivery using the ADOPTA platform offering both learning style and knowledge level adaptations. The experimental field trial was conducted by using the adaptive course in XML technologies specially designed for this purpose. 84 four-year students of the bachelor program in Software engineering took participation in practical experiments. These students were divided into two groups with equal number of participants and equilibrated in terms of average student performance demonstrated in previous assessments of the same students. The first, so called control group passed course modules of a traditional, non-adaptive course in XML technologies given by the Moodle platform, while the experimental group took the same

modules using ADOPTA where the course was adapted to individual learning styles and student performance shown at intermediate assessment test. Thus, each student of the experimental group obtained learning materials, which are most suitable for her/his individual learning character and knowledge level between two control points.

Students from both the control and experimental group had passed through the same assessment tests and received grades in percentage from 0 to 100%. The assessment results of both student groups are given in fig. 8 by interpolated curves in order to express better dynamics and changes. The eloquent difference between these two curves shows in a clear way that students of the experimental group (taken the adaptive version of the same course) have demonstrated rather better performance, with average result of 77,89% while average result of the control group is 67,14%. As far as both the student groups consisted of the same number of students (42 for a group) with equal average performance shown in former assessments, we conclude the adaptive delivery of the same course is more effective than the traditional one and, thus, the adaptation to style of learning and student performance makes learning more appealing and productive.
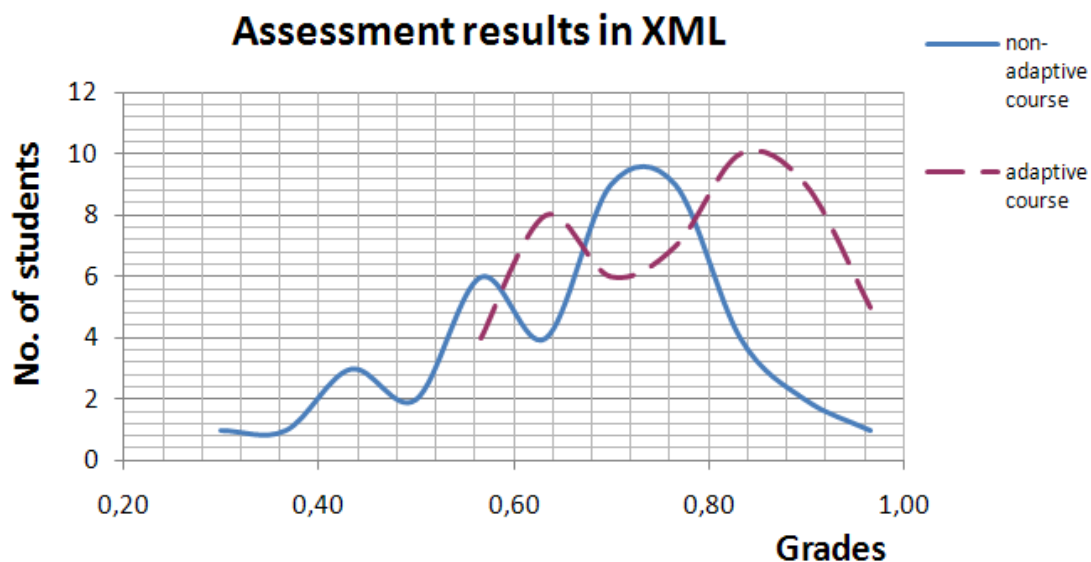

Fig. 8. Assessment results for non-adaptive and adaptive courses in XML technologies

In order to assess the effectiveness of adaptivity to learning styles, a special survey was conducted among the students of the second group after the end of the adaptive course in XML technologies. The questions asked for students' opinions about the quality of adaptive courseware delivery. Fig. 9 presents students' answers using 5 levels Likert scale with the levels: 1=strongly disagree, 2=disagree, 3=not sure, 4=agree, and 5=strongly agree, for the following questions presented in the form of statements:

1. Learning objects delivered within the course fit your learning style presented by values for theorist, pragmatist, reflector and activist).
2. The ADOPTA platform does really adapt the courseware to my learning style.
3. The assignments, exercises, topics for essays and games were interesting and valuable for me.
4. The ADOPTA platform effectively adapts the learning courseware to my knowledge level.
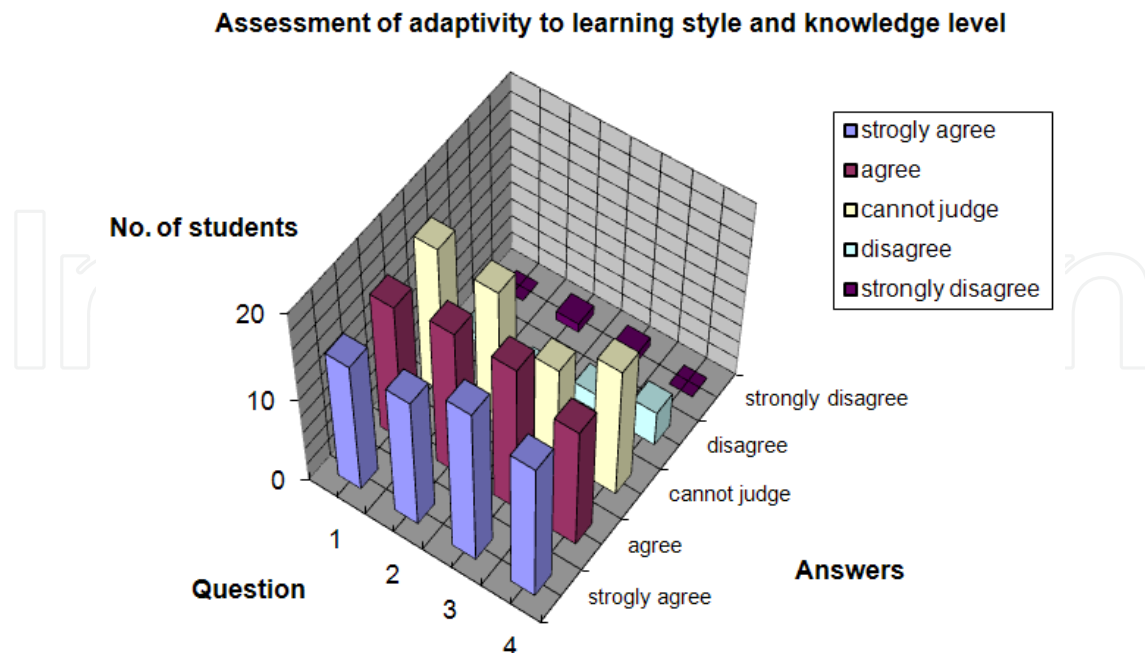
Assessment of adaptivity to learning style and knowledge level

Fig. 9. Results about assessment of adaptiviy to students learning styles and knowledge level

The results presented in fig. 9 show a rather positive feedback on the effectiveness of platform adaptivity to learning styles (questions 1 and 2) as well as to student knowledge level (questions 3 and 4). The majority if students do agree on the effective adaptation of courseware according to the student character issues such as learning style and knowledge. Though they are some students who cannot judge on this, learners regard learning objects delivered to them by the platform as valuable and useful for individual learners.

Next four questions (statements of the survey) regard the issue of preference of adaptive platform to non-adaptive one. They are given below:

1. I prefer an adaptive e-learning platform to non-adaptive one with similar implementation.
2. Adaptive learning does lead to greater knowledge and results compared with non-adaptive learning.
3. I would use this adaptive learning system again.
4. I would recommend this adaptive learning system to other students.

Fig. 10 provides results about general assessment of ADOPTA as an adaptive e-learning system. It is important to underline students recognize the benefits of adaptive systems concerning obtaining greater knowledge and results compared with non-adaptive learning. The majority of them agree on the fact the adaptive learning does lead to greater knowledge and results compared with non-adaptive learning, which has been proven by this field trial (see fig. 8). There are few students who are not sure. In general, the majority of students regard adaptive learning as a more arguing and effective way of technology-enhanced learning than the traditional non-adaptive one.
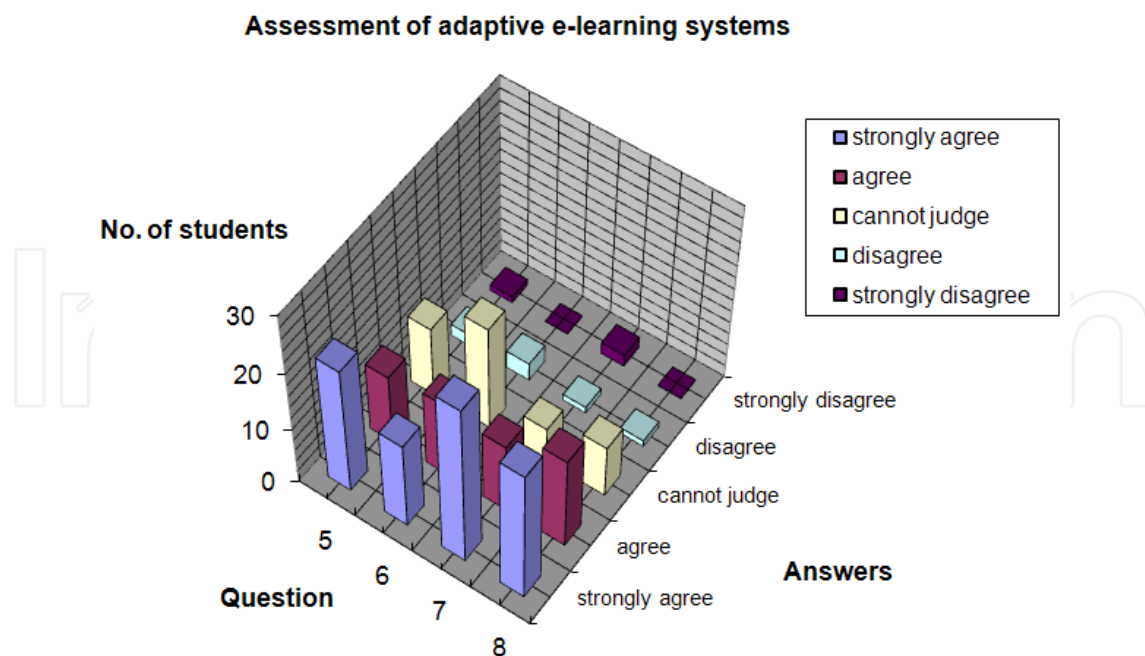
Fig. 10. Results about a general assessment of ADOPTA

6. Conclusion

Adaptive hypermedia platforms continue being a challenge in modern development of technology enhanced learning. This chapter addressed practical approaches for design and construction of courseware delivery with adaptation on one hand to learning style and, on the other hand, to knowledge level (i.e., to student performance). The approaches were implemented using the ADOPTA platform, together with a field trial aiming at general evaluation of the platform and assessment of effectiveness of the adaptation to learning style and knowledge. While adaptivity to learner style is achieved on the base of explicit learner pre-tests and adaptive navigation within the storyboard graph, adaptivity to learner's performance is implemented via adaptive content selection by using assessment results at each control page of the course in order to select LOs with appropriate level of complexity for a given learner. Both the types of adaptation are managed by the adaptation control engine of the ADOPTA platform.

The presented results obtained from the field trial are based on questionnaire about realized adaptivity to students learning styles and knowledge level. They reveal a rather positive students appreciation of achieved level and quality of adaptivity and show adaptive courses are an appeal and challenge for students to learn better and more. Here, implementation of the storyboard graph for adaptive course delivery is of crucial importance. The instructor has to select types of LOs appropriate for given polymorphic learning style by taking in consideration distribution of LOs types to learning style as shown in fig. 5 or a similar one. As well, to tune the engine to select at each non-control page of the course LOs with complexity level adequate to assessment results shown by the learner.

Finally, authors have to underline that presented results are context-dependant – they are obtained by conducting an adaptive course with bachelor students in Software Engineering. During the experiments, it has been found these students have in general a learning

character where reflectors and theorists are the predominant learning styles. They are quite possible other results for adaptive course delivery to students with different predominant learning styles.

Though experimental results gained by the initial case study are quite positive, there should be mentioned some shortcomings of the chosen approach. First at all, learning style of an individual is not fixed forever but may evolve with time, even during delivery of a course. Therefore, learning style should be assessed not only by a pre-test in the very beginning of the course but also at some latter points. However, filling up several times the same questioner containing decades of questions for determining individual style would be tedious and boring for learners. A much better approach for the practice will be determining learning style implicitly during the e-learning process, e.g. by an intelligent agent tracking learner behaviour and choice of types of learning objects. Therefore, this should be a starting point for our future works. On other hand, optimizations could be introduced to work process of instructors, as well. For the moment, they should develop paths for adaptive e-learning within the course graph and, next, to set weights of these paths for different learning styles of the chosen style family and to place on pages of the paths and to tune various LOs of different level of complexity. Another, much easier and faster approach would be to set appropriateness of LO for learning styles together with LO complexity level while authoring learning ontology and course content by means of the authoring tool. Next, the instructor should only select within the ontology the order of partitions of the ontology to be delivered to learners. Then, the adaptation control engine will start traversing these ontology partitions in the selected order and will choose LOs appropriate for particular learner style and performance. For sure, such an approach misses ordering and annotation of individual LOs according an advance pedagogical strategy for a specific learner character, however, it would be much easier for practical usage and therefore should be considered for future design and experimental works.

7. Acknowledgment

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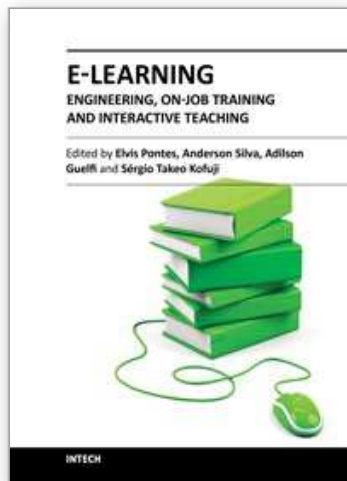
E-Learning - Engineering, On-Job Training and Interactive Teaching

Edited by Dr. Sergio Kofuji

Adaptive E-learning was proposed to be suitable for students with unique profiles, particular interests, and from different domains of knowledge, so profiles may consider specific goals of the students, as well as different preferences, knowledge level, learning style, rendering psychological profile, and more. Another approach to be taken into account today is the self-directed learning. Unlike the adaptive E-learning, the Self-directed learning is related to independence or autonomy in learning; it is a logical link for readiness for E-learning, where students pace their classes according to their own needs.This book provides information on the On-Job Training and Interactive Teaching for E-learning and is divided into four sections. The first section covers motivations to be considered for E-learning while the second section presents challenges concerning E-learning in areas like Engineering, Medical education and Biological Studies. New approaches to E-learning are introduced in the third section, and the last section describes the implementation of E-learning Environments.

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