# Designing Lesson Content in Adaptive Learning Environments

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***Abstract*—Online learning is widely spreading and adaptive learning environments are increasing its potentials. We present a scenario of adapting learning content towards individual student characteristics taking into consideration his/her learning style type and subject matter motivation level. We use an ontology based student model for storing student information. The scenario of designing lesson content tailored to individual student needs is presented as a cross section of learning style and motivation level, based on the learning object's educational metadata. Our future work will be to provide experiment and to test our proposed guidelines in order to get feedback on how learners see the adaptive learning environments tailored to their individual learning style and motivation characteristics.**

***Index Terms*—adaptive learning environments, learner models, student ontology.**

## I. Introduction

The common problem in e-learning environments is that they cannot offer customization for the student and that they can only offer identical contents to all the consumers. Also, it is often stressed out that current e-learning systems lack in accompanying, guiding and motivating individuals and should follow more user-centered approach. Web-based education is reaching a large number of learners and beside that it poses a valuable advantage over traditional classroom teaching, and the possibility to adapt to individual learners, which is hard to achieve in common teaching process. One of the main problems with e-learning environments is their lack of personalization.

Recently, few attempts have been made to model user cognitive and affective attributes in order to achieve system's adaptivity according to the needs of individual user. And while researchers agree on the importance of adaptation towards user cognitive and affective characteristics, there is *"little agreement on which features can and should be used and how to use them"* [1].

In order to clarify and represent knowledge structure for our learner model, we used ontological approach. The ontology of a given domain identifies specific classes of objects and relations that exist in particular domain, and form a hearth of any knowledge representation system [2]. Our approach tend to pursue adaptation according to obtained user profile, containing user's preferences, knowledge, goals, navigation history and possibly other relevant aspects that are used to provide personalized adaptations.

We discuss here about designing lesson content tailored to individual users, taking into consideration specific *learning style* (Kolb learning style) and subject matter *learning motivation*. Analyzing coordination between student's learning style and his motivation for specific teaching material we give guidelines for preparing learning materials according to different learner's characteristics. Those guidelines are based on pedagogical strategy and motivation factor with a strong psychological background.

The paper is organized as follows. After Introduction, Section II gives some related work on lesson content adaptivity in learning environments. In Section III, we propose ontology based learner model structured according to IMS LIP specification. Section IV presents motivational issues concerning e-learning environments. In Section V is presented our approach in designing lessons towards learning style and motivation. Section VI presents teaching scenario in designing lesson content and shows practical examples of presented scenario. Section VII concludes paper and describes future work.

## II. Related work

Adapting lesson content according to learning style is pointed out many times. Depending on the applied learning style theory different adaptation strategy is performed. In [3], a mechanism is developed to model student's learning styles and present the matching content to individual student, based on the Felder-Silverman Learning Style Theory. Using a pre-course questionnaire to determine a student's learning style or the student may choose the default style and then provided with material according to his individual learning style.

Guidelines and examples on content adaptation and presentation depending on various learning style in combination with instructional design theories are presented in [4]. Lessons are designed based on combinations of educational material modules, supporting several levels of adaptation towards individual learning style. An empirical study is needed to evaluate the educational effectiveness of the adaptations.

In [5] is provided theoretical and empirical research on learning styles in UK, US and Western Europe and has identified 71 models of learning styles, among which 13 are categorized as major models. Certain models are popular in different areas: in the US, for example, the Dunn and Dunn learning styles model is used in a large number of elementary schools; while in the UK, both Kolb's Learning Style Inventory (LSI) and Honey and Mumford's Learning Styles Questionnaire (LSQ) are widely known and used. A model of pedagogical agent that use learner's attention to determine motivation factors of the learner is presented in [6]. It takes into account the learner's focus of attention, current task and expected time for finishing the task to infer his focus of attention in order to determine his confidence, confusion and effort. An experimental study has shown a high accuracy in predicting learner's motivation.

A survey of four learning style models and the experience that engineering educators had in their practical applications is presented in [7]. The practical applications of Kolb model indicated that teaching students about learning styles helps them learn the course material because they became aware of their thinking processes and helps them develop interpersonal skills.

## III. LEARNER MODEL

Our learner model (LM) is based on learner model ontology which is structured according to IMS Learner Information Package (IMS LIP) specification [8]. Packaging learner information according to the IMS LIP specification assumes that packages do not necessarily contain all the available elements supported by the specification, since all elements in LIP are optional and are left to the learner model developer to decide which elements are relevant for his application.

Our ontology has eleven segments named Identification, Goal, QCL, Accessibility, Activity, Competency, Interest, Transcript, Affiliation, Security Key and Relationship as recommended by IMS LIP and extended with new Psychological segment explained in [9] containing most relevant personal learner characteristics that can influence the teaching process, like his cognitive and affective personal characteristics. Since ontology is modeled on conceptual level it is independent on final representation language. In order to create sharable and reusable learner model ontology we converted it into RDF/RDF Schema format.

Here, we propose guidelines for designing lessons tailoring to individual student characteristics according to underlying learner model ontology taking into consideration learner's learning style based on Kolb and his motivation for subject matter. The information on student's learning style is provided in his LM and can be reused for different purposes.

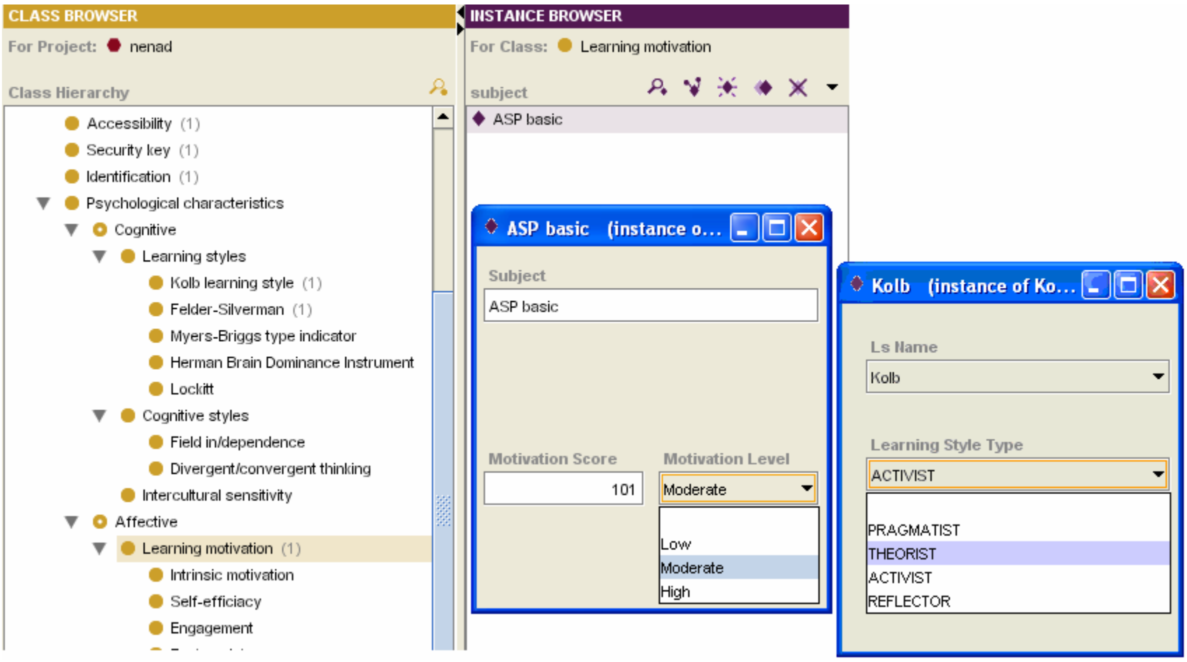


Figure 1. A screenshot of Protege 3.0 learner model ontology

The motivation factor towards some subject matter is determined with the pre-course test that is specially designed for gathering student's motivation and explained in more detail in the next section. Subject matters learning motivation consists of four components: *intrinsic motivation, self efficacy, engagement* and *test anxiety*. The learner's motivation is modeled as one of tree levels: low, moderate and high.

The final motivation level is obtained from test score and explicitly represented in LM ontology, together with Kolb learning style type value, Fig. 1. The motivation test scale exceeds the scope of this paper and will not be presented here. In the process of defining psychological concepts of learner ontology we relied on previous psychological research and we also had a help of educational psychologist as a domain expert.

Our Psychological preferences concept includes Cognitive and Affective classes. Affective concept contains Achievement motivation, Learning motivation, Emotions and Aspiration level concepts by now. Cognitive concept includes Learning style (including five learning style models that have been used effectively in education), Cognitive style and Intercultural sensitivity concept with their sub concepts and properties. We used the Protégé 3.0 plug-in named OntoViz for ontology visualization and Fig. 2 depicts the Learning motivation concept with its properties aimed for capturing learner's motivation level for specific subject matter. The figure also shows an instance named ASP basic denoting that student has moderate motivation for ASP subject according to the pre-course test result.

For the purpose of building suitable learner model with all relevant learner information we created the Learner Profile Editor (LPE), as an integral part of an ontology-based learner modeling system named LeMONT. The Learner Profile Editor is ontology-based editor for acquiring explicit learner data according to the proposed ontology. LPE has a role of instantiating learner ontology. It enables learners or teachers to edit, browse, update and visualize the specific learner profile.

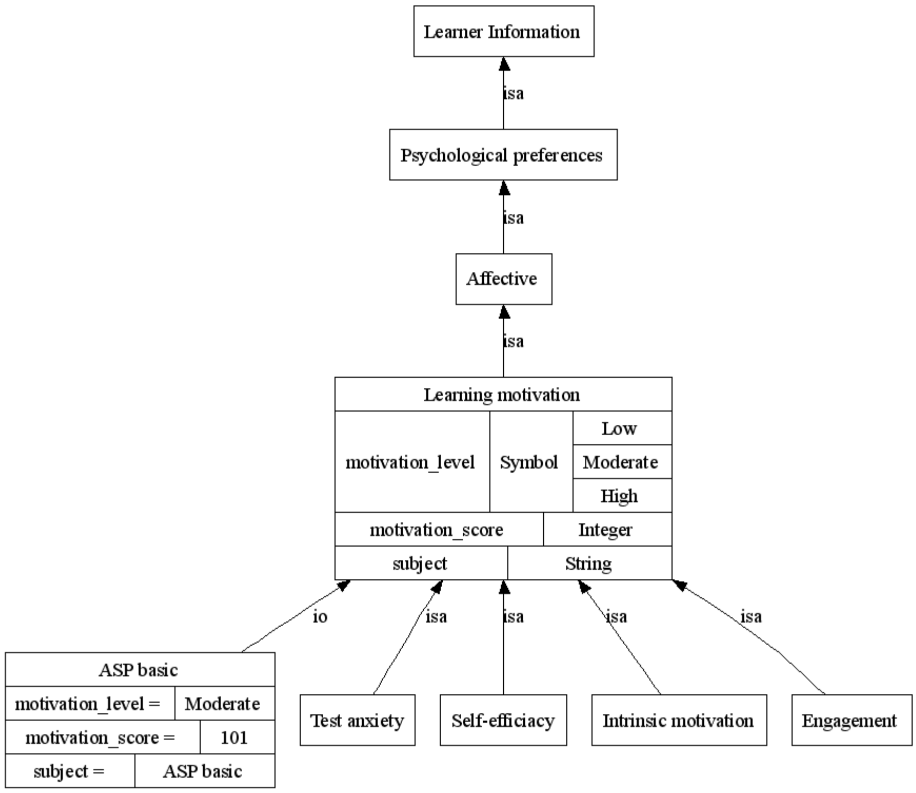


Figure 2. *Learning motivation* concept with instances by OntoViz

Existing users enter the system through a login process and new users can be registered by providing username, password and learner_id property that will be associated with the profile. When logged in, the learner can view or edit its own profile or if the user is a teacher, he can list existing profiles or create a new one through the LPE interface.

Fig. 3 shows the learner's *Psychological preferences* property including his/her affective and cognitive characteristics and its sub properties and their values. Values assigned to form fields are retrieved from existing learner profile stored in learner model database. If a property has multiple maximal cardinality defined in the ontology model, LPE allows the user to add more than one value/instances to the property. When the user updates learner model, the model is saved in database and also in learner model RDF file. The RDF file containing models of all learners is saved after each learner model update.

## IV. MOTIVATION AND SELF-REGULATED LEARNING

Self-regulation of cognition and behavior are important aspects of student academic performance. Also, students' effectiveness in traditional or e-learning environment is a multifactor phenomena. As pointed out in [10] the three major components of self-regulated learning are:

- Students' metacognitive strategies for planning, monitoring and modifying their cognition;
- Students' management and control of their effort on academic tasks;
- Students' actual strategies to learn, remember and understand subject matter (rehearsal, elaboration and organizational strategies).

The aims of teaching process in web-based learning environments correspond to the components of self-regulated learning, but the possibilities of applying them differ from traditional classroom teaching providing more opportunities for web-based education. Among the main aims of teaching process are: planning, monitoring, modifying, managing and controlling students' learning process.

From the other hand, self-regulated learning strategies are not enough to promote student performance in e-learning. The presence of motivation factors is necessary. The students' motivation has significant impact on the teaching process and learning performance. For instance, e-learning feedback can stimulate motivation. The students, who are provided with positive performance feedback concerning their competence on a task, have higher levels of intrinsic motivation for the task, than students who don't receive performance feedback [11].

Adaptive learning environments can make a faster and more sophisticated feedback than the other learning situations. This way, good organized e-learning material can have a great impact on the improvement of the students' motivation and performance.

Motivation components influence self-regulation of cognition and behavior. According to [12], components of learning motivation include:

- Self-perception of ability;
- Intrinsic motivation (intrinsic value of subject matter);
- Engagement or subject effort;
- Test anxiety as the affective motivation component.

Ability perceptions have a pivotal role in many theories of human motivation and action [11], so it is very important to moderate achievement-related behavior.

The performance feedback in web-based learning environments and its results can have positive or negative impact on the future motivation and self-regulation of learning in the following way:

- If the feedback makes the perception of incompetence, that will diminish intrinsic motivation;
- If the feedback makes the perception of competence, that will amplify intrinsic motivation.

There is a positive correlation between the feedback of the achievement (which makes ability perception) and learning engagement.

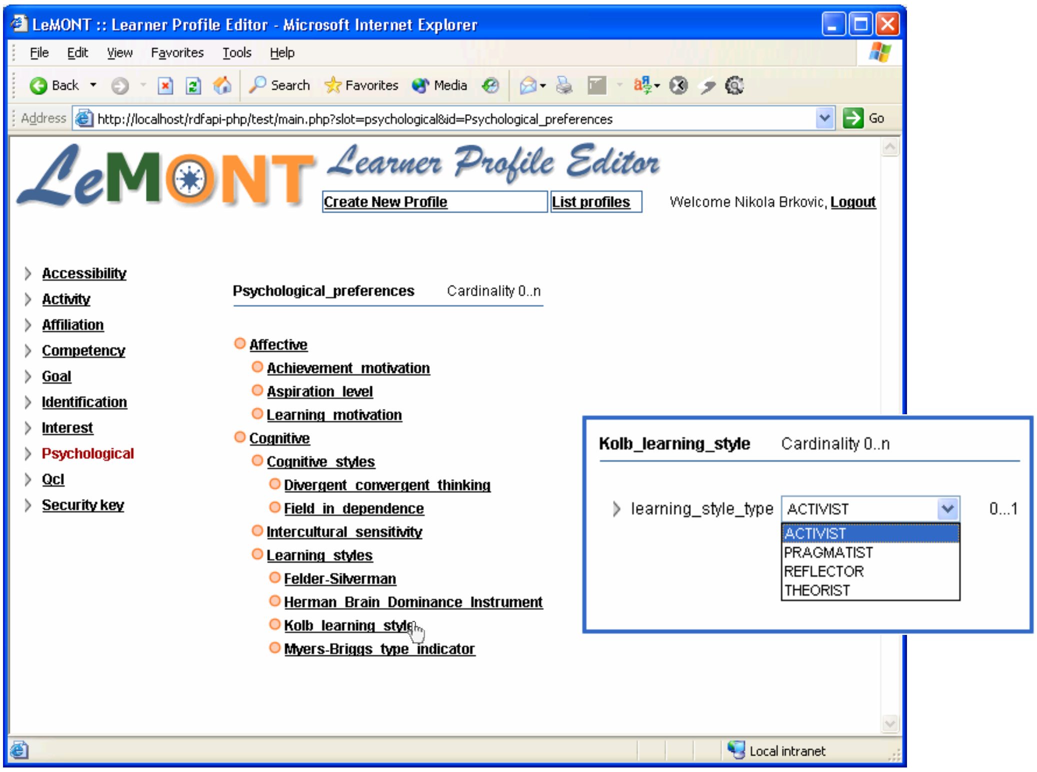


Figure 3. The LPE screen with *Psychological preferences* concept

There are many learning motivation scales and instruments for measuring motivation factors. Our model for adaptive web-based learning environments uses *Subject matter motivation scale* from Bjekic and Brkovic [12]. The Table I presents a portion of our instrument for measuring motivation factors for different motivation components. Such pre-test questionnaire provides valuable information on students' subject matter motivation, and together with his/her learning style gives us a solid base for directing teaching process in adaptive web-based systems.

TABLE I.
EXAMPLES OF MOTIVATION COMPONENTS ITEMS FROM SUBJECT MATTER MOTIVATION SCALE [13]

| Components of motivation | Item | Response scale |
|---|---|---|
| Intrinsic Value of Subject Matter | I prefer subject matter that is challenging so I can learn new things. | *Not much at all - Very much* |
| Self-perception of ability | I'm certain I can understand the ideas taught in this course. | *Not much at all – Very much* |
| Subject engagement or Subject effort | How hard are you working to learn about this subject matter? | *Not hard at all - As hard as I can* |
| Test anxiety (Test relaxation) | I worry a great deal about tests. | *Never – Very often* |

## V. DESIGNING LESSONS TOWARDS LEARNING STYLE AND MOTIVATION

Having in mind that each learner is an individual with his/her own motivation for studying and learning habits, we took learning style into consideration for designing teaching materials. Individual learning style affects the way that learner accepts and assimilates information, and can be used as an indicator of how learners perceive, interact with and respond to the teaching process. The importance of tailoring teaching process towards individual learning style is pointed out many times.

The overview of learning style models that have been used effectively in engineering education and importance of understanding individual learning styles is emphasized in [7], and also practical examples of improvements are shown. Also, in [13] is pointed out that both low and average achievers earn higher scores on standardized achievement tests and aptitude tests when taught through their learning styles preferences.

Motivation is a pivotal concept in most theories of learning. It is closely related to arousal, attention, anxiety and feedback. Increasing learner's motivation during online course is one of the key factors to achieve a certain goal. Receiving a reward or feedback for an action usually increases the likelihood that the action will be repeated. In [14] is pointed out that behavioral theories tend to focus on *extrinsic motivation* (i.e., rewards) while cognitive theories deal with *intrinsic motivation* (i.e., goals). The structure of subject matter learning motivation make possible to differentiate the next directions of modeling distance learning instructional materials. Applying the subject matters learning motivation scale before starting online course can provide valuable information about student's motivation level determining the teaching process. The learning motivation scale combines information on four motivation components*: intrinsic motivation, self efficacy, engagement* and *test anxiety.*

Combining student's Kolb learning style and motivation level give us guidelines for tailoring lessons towards individual student needs. Kolb learning style model classifies students as having a preference for 1) *concrete experience* or *abstract conceptualization* (how they take information in), and 2) *active experimentation* or *reflective observation* (how they internalize information) dividing learners into four types: *pragmatist, theorist, activist* and *reflector*. Further, student's motivation level modeled as *low, moderate* and *high* determines the quantity and semantic density of learning material. For example, high motivated learners can accept larger quantity of learning materials and tend to learn faster then low motivated learners who tend to learn slowly and need permanent positive feedback and encouragement. If high motivated learners follow the design strategy for low motivators they could loose their interest in subject and could became impatient. From the other hand, providing low motivators with lessons designed to fit the high motivators would result to abound the course due to its complexity. A survey of Kolb learning style type and motivation level applied to designing learning material is given in Table II.

## VI. IMPLEMENTATION SCENARIO

According to Table II, we created a teaching scenario for designing lesson content, based on different Kolb learning style type, Table III. Learning material should contain knowledge modules*: theory, examples, practice* and *test*, represented with appropriate learning objects. Besides, each page should provide optional links to *Index, Problem sets, Case study* and *Group discussion* ordered according to the scenario for special learning style type from Table III. As presented in table, a value (1, 2, 3) is assigned to each knowledge module stating its importance and order on the web page. Contents that have value 0 assigned to them denote that such content type should not be presented to the learner, because his learning style type doesn't prefer it or doesn't need it. For instance, *Theorist* learning style type should be presented with (1) theoretical content, followed by (2) example and then (3) test. Practicing should not be presented as obligatory knowledge module for this learning type since they don't like studying trough application of knowledge. In the optional part, links should be ordered by (+1 - *Problem sets*, +2 - *Case study*, +3 - *Index*) without *Group discussion* link, since he doesn't like team work. For each lesson module, a desirable learning resource type is shown. Specific learning resource type should be selected according to educational metadata *resource type* attached to each learning object, see [15].

The level of motivation takes part in the teaching process primarily in the quantity of information presented to the student. For example, high motivated students tend to learn faster and to accept learning material in bigger quantities, while low motivators must be presented with smaller knowledge chunks with appropriate feedback, trying to increase their motivation. Approaching the teaching process from the aspect of student's learning style type and his motivation level means presenting student with learning material according to Table II, and providing him with set of learning objects (LO) that are appropriate to his motivation level.

TABLE II.
A SURVEY OF KOLB LEARNING STYLE TYPE AND MOTIVATION LEVEL APPLIED TO DESIGNING LEARNING MATERIAL

| | | Learning style | | | |
|---|---|---|---|---|---|
| | | **DIVERGER / REFLECTOR** | **CONVERGER/PRAGMATIST** | **ASSIMILATOR/THEORIST** | **ACCOMMODATOR /ACTIVIST** |
| **Common for all motivation levels** | **Basic question and learning motivator** | *Why?* | *How?* | *What?* | *What if?* |
| | **Types of learning** | Discovery learning, conclusion generating | Practical learning | Verbal reasoning receptive learning, reading | Problem solving |
| | **Types of thinking** | Induction | Analogies | Deduction | Analogies and deduction |
| | **Useful activities to students** | Lessons with plenty of thinking time, Brainstorming | Skills practicing activities, implementation of ideas, peers feedback | parallel analog source of information explanations, experts interpretations | Skills practicing, problem solving, peers feedback, discussion |
| | **Tasks, questing and testing** | Tasks of causal relation, generating new ideas | Practice examples, implementation, analyses of implementation | Interpretation of theories and generalization | New problem solving |
| | **Instructor role** | Motivator, answering, suggesting | Coach, Practice, give the feedback | Expert | Observer, stay out of the way |
| | **E-support** | Peers suggestions base<br>Computer simulations | Applets, computer animation and simulation, virtual experiment | e-text, data and theories, explanations and case studies | Peers suggestions and analogies base |
| **Common for all learning styles** — **Low motivation** | ✓ Decompose learning material on the simple and short steps<br>✓ Testing after each steps<br>✓ Feedback after each steps, register the success and encourage improvement<br>✓ After error, make simple suggestions, peer suggestions | o basic information, premises operationalized and gradually make more complicated<br>o two steps of the student answering: 1. brainstorming, 2. choosing the answer between given answers<br>o after error, first give the suggestions, repeat the question, explanations or redirection to the simple information<br>o forming suggestions base: investigate the student sample and their frequently answer | • demonstration of implementation, examples familiar to the concrete experience, computer animation of the practical situations and problems, video<br>• tasks: autonomous investigation of the implementation example of the separate concept<br>• testing by the recognition tasks, recognition of the correct activity plan based on the lessons<br>• after error, show the analogues examples of the practical implementation and peers comment | ▪ show the model of concrete lessons learning<br>▪ step examples are derived from the theoretical concepts and information<br>▪ testing the understanding of the final information<br>▪ offer parallel resources with simplified information<br>▪ after error, take the simply suggestions and repetition of the theoretical information | – active learning and step by step operationalized problems display<br>– problem example at the every learning steps<br>– integrated peers suggestions<br>– after error, give the peers suggestions and repeat the analogues resolving problems |
| **Moderate motivation** | ✓ Learning content decomposed on the moderately complex part<br>✓ Testing after integrated and logical consistent part<br>✓ Learning directed by feedback | o premises of learning step by step are based on the separate information and simplified generalizations<br>o involve the interactive simulation and make conclusion on that<br>o two steps of the student's answering: make imagination of the phenomena, choosing the answer, solving moderate complex tasks<br>o after error, reformulated the task, make suggestions, parallel way of resolving, return to back | • practical receptive learning and practical discovery learning<br>• student selects from given theory examples<br>• testing achievement and learning level by finding application examples of the theoretical concepts<br>• after the error, there is discussion by the suggestive questions and practical implementation examples | ▪ the steps: moderate complex theory's part and moderately complex generalizations<br>▪ testing of the verbal statements understanding<br>▪ simple questions between the steps, student select from several verbal answers offered<br>▪ after error, the student are orientated to investigate reason of error and make self-awareness of the thinking procedures | – interactive learning<br>– every logical integrated step followed by the complexes problem examples<br>– use the virtual experiment<br>– use integrated peers answer at the same problems<br>– after error, student solve analog not complex problem, return to the problem unsolved |
| **High motivation** | ✓ Decompose learning content on the medium complex steps<br>✓ Make direction to deductive thinking<br>✓ Testing after complex parts<br>✓ Learning directed by feedback | o receptive learning is necessary at some parts, receptive learning of the complex knowledge and generalizations<br>o steps consist of the basic generalizations, generalizations and regularity<br>o after error, repeat the generalizations and tasks, than give another help | • practical discovery learning<br>• student discovers examples based on the generalizations and autonomous discovering<br>• after error, there are suggestions to repeat experiment and conclusion procedures | ▪ steps are complex and representative theoretical parts and generalizations<br>▪ testing understanding of the logical complex part<br>▪ error is a possibility for learning; error analysis using comparison of theoretical information and given answers | – logical integrated steps are followed by the complex problem examples<br>– testing by solving new problem, student makes the new problem<br>– use virtual experiment<br>– after error, student autonomously decompose problem and investigate the analogous problem<br>– suggest correct answer by using the analogous problem |

TABLE III.
TEACHING SCENARIO FOR KOLB LEARNING STYLE TYPES

| Teaching activities | THEORIST AC/RO (Assimilator) | | PRAGMATIST AC/AE (Converger) | | ACTIVIST CE/AE (Accommodator) | | REFLECTOR Diverger CE/RO | |
|---|---|---|---|---|---|---|---|---|
| **Theory** | 1 | lecture | 0 | | 0 | | 1 | lecture |
| **Examples** | 2 | slides, theoretical examples | 1 | applets, virtual experiment, animation, simulation | 2 | simulation, virtual experiment | 2 | simulation, demonstration(A/V) |
| **Practicing** | 0 | | 2 | self-assessment, exercise | 1 | solving new problems | 0 | |
| **Tests** | 3 | on line tests on concepts and theories | 3 | practical tasks, workbook | 3 | problem sets, skills practicing | 3 | tasks of causal relations (why, if ...then...), multiply choice questions |

| **Optional links** | | | | |
|---|---|---|---|---|
| **Index** | +3 | +3 | +3 | 1 |
| **Problem sets** | +1 | +2 practical tips from expert | +2 | 3 |
| **Case study** | +2 | +1 | +1 | 2 |
| **Group discussion** | - | + peer feedback | + peer feedback | + discusion, brainstorming |

We choosed to incorporate learning object educational metadata named *Semantic density* (SD) denoting the complexity and semantic quantity of learning object [15]. Stating that each LO can have semantic density between 1 and 5 means providing low motivators with LO that have *semantic density* value <= 2, moderate motivated students with SD <= 4 in total and high motivators with learning objects with semantic density value 5. For example, high motivated student will be presented with tree learning objects with total $SD=SD_1+SD_2+SD_3=1+2+2=5$, followed with test. On the contrary, low motivators will be presented step by step with three LO and each time followed with test and appropriate feedback. A possible scenario for reflector learning style is presented on Fig. 4.

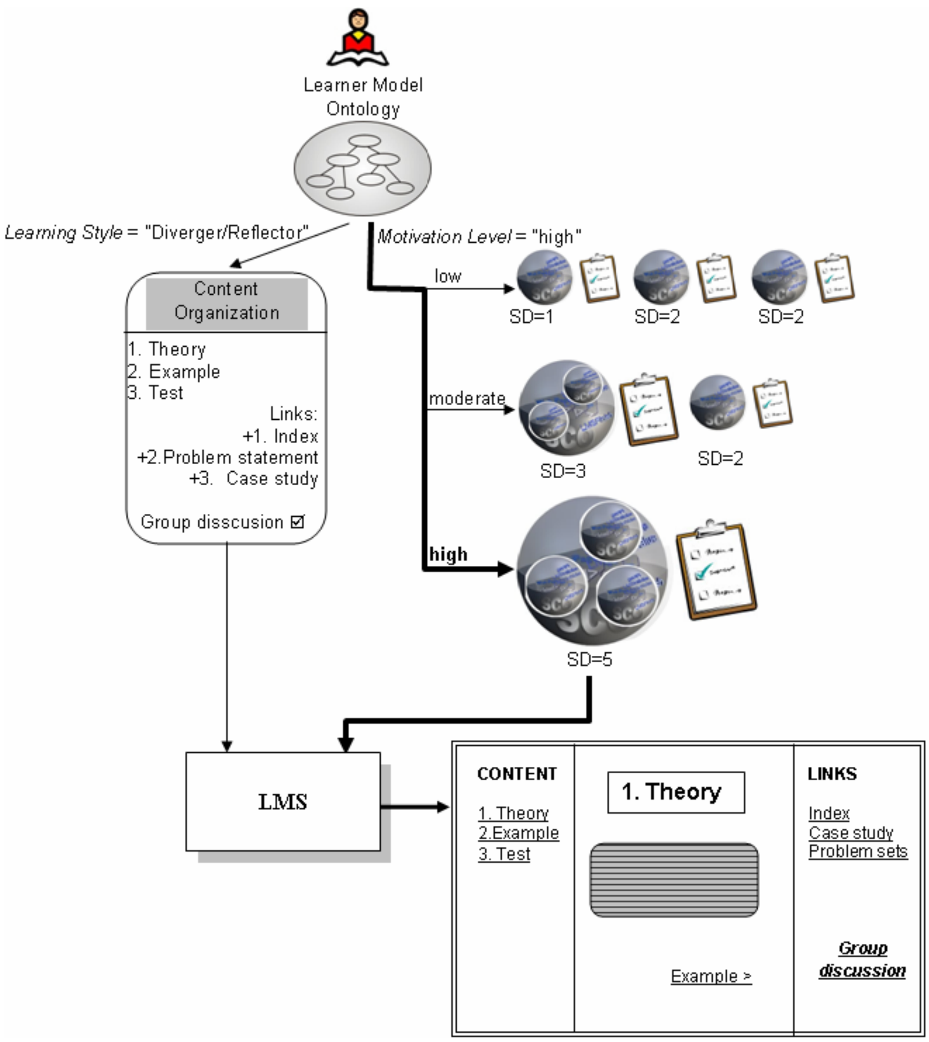


Figure 4. Adaptation scenario for Reflector learning style

### A. *Practical example*

The following example demonstrates presented scenario of adapting learning content tailored to individual student. Learning content is a course in ASP programming and each lesson should contain knowledge modules: *theory*, *examples*, *practice*, *test*, *index*, *problem set*, *case study* and *group discussion* represented with several appropriate learning objects. Learning object educational metadata *Semantic density* is assigned to each LO.

Fig. 5 shows learning content deployed in an adaptive learning environment where logged learner has reflector learning style value, stored in his learner model and low motivation level. The lesson presented is ASP Site Definition, first module - *Theory* according to learner learning style preferences. The left navigational area and optional links area on the left side are ordered as explained in Table III. The middle area – content area contains one learning object - About sites. That LO has semantic density SD=1 and it is all the content learner gets in the first step because his level of motivation is low. Thus, this learner will be presented step by step with several LO and the next link takes the learner to the next learning step.


Figure 5. Learning content presented to reflector learning style with low motivation SD=1

The following Fig. 6 shows the same learning content for the same learning style in the case of high motivation. In this case, the middle content area is a composition of several learning objects with SD>4 because it is the amount of learning content that a learner with high motivation will get.

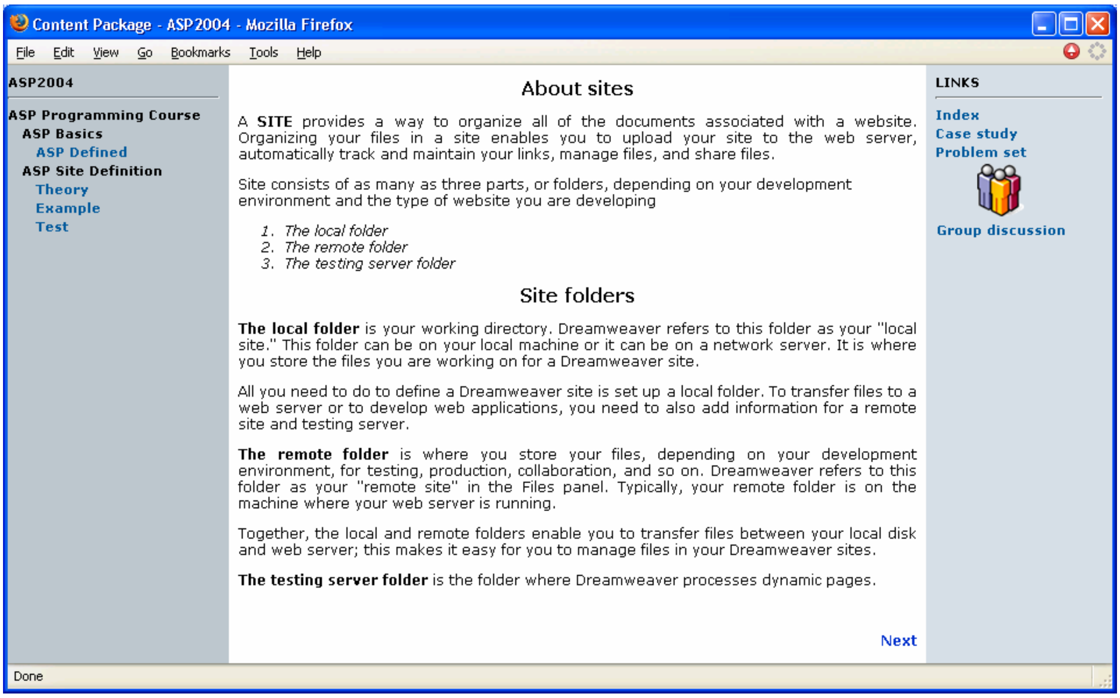


Figure 6. Learning content presented to reflector learning style with high motivation SD=5

Next, we will present the same lesson that is displayed to learner of different learning style, for example to a converger, with high motivation level. Converger likes examples and skills practicing activities and his main navigation area is ordered as shown in Fig. 7: starting with example in the form of some animation or simulation, followed by practicing activities and final the test. The optional links area, ordered like case study, problem set, index and group discussion link is visible. Additional theory link is available in the case of learner's need to go through theoretical background even if it is not preferred by his learning style. The main content area contains a flash animation that demonstrates what an ASP site is and how ASP site folders can be created. This animation has identical semantic density as the text presented in Fig. 6.

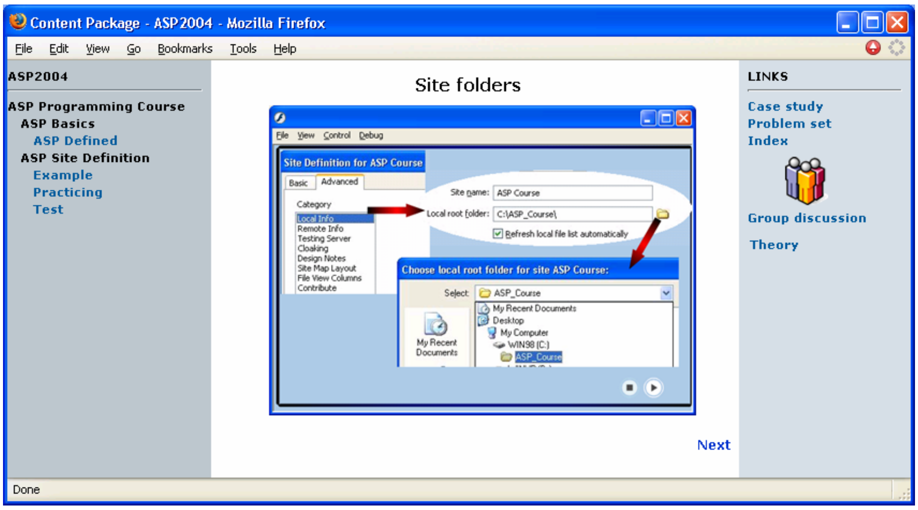


Figure 7. Converger learning style with high motivation SD=5

Presented practical examples show in what way an adaptive learning environment generates content organization and displays learning content that is created according to presented adaptation algorithm. As Fig. 5-7. show, each learning style/motivation preferences are presented with appropriate content organization derived from learner model and LO metadata.

## VII. Conclusion

We presented an approach of tailoring lesson content towards individual student's learning style and subject matter learning motivation. An ontology-based learner model provides us with necessary information on student's learning style and motivation level. In order to adapt a system to individual users we applied scenario towards specific learning style and student's motivation level, based on learner object's educational metadata resource type and semantic density. The next step would be providing an empirical study to examine the efficacy of matching content to learners concerning these individual characteristics.

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