Competency-based Approach to support Learning Objectives in Learning, Education and Training

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Abstract: Learning objectives (LOs) are statements of intent that describe what a student will know and be able to do at the end of a course. However, the definition of well-formed LOs is a challenge in instructional design. This paper describes a competency-based approach to support the integrated definition of LOs in learning, education and training systems. This approach is based on a system-wide definition of competency levels according to a predefined taxonomy. The implementation of the approach is demonstrated in the learning content management system EDMedia.

1 Introduction

Learning objectives (LOs) are well-known for a long time. They were conceptualized and used during the Second World War to make teaching and learning more efficient. Later, this approach was also applied to public schools. But, only the work done by Benjamin Bloom [Bl56] can be seen as the first step towards to a broad utilization of LOs. However, the definition of well-formed LOs is a challenge in instructional design. The time devoted to construct LOs in courses is low and the majority of authors have dismissed the importance of LOs. But there are many reasons why authors should care about LOs, for example, they communicate instructor and course expectations to the student. Due to this fact, the utilization of LOs in learning, education and training (LET) systems have to be facilitated in order to cope with the challenges of instructional design. Our proposed approach aims at supporting the integrated definition of LOs in LET systems based on competency levels.

The remainder of this paper is organized as follows: The second chapter gives a brief introduction to LOs and states the differences to learning goals, followed by an explanation of Bloom's taxonomies. After that, the importance of learning objective statements (LOSs) and the relationship between LOs, learning activities and evaluation is described. The third chapter provides a comprehensive overview of our approach and chapter four presents their implementation in the learning content management system (LCMS) EDMedia. Concluding remarks and references complete the paper.

2 Related Work

2.1 Learning Objectives

From an educational perspective, LOs are statements of intent that describe what a student will be able to do as a result of learning. They help to clarify, organize and prioritize learning and students are able to evaluate their own progress and encourage them to take responsibility for their learning.

2.2 Learning Goals

The terms LOs and learning goals are sometimes used interchangeable, but there are different. Learning goals are general statements concerning the overall goals, ends or intentions of learning. LOs are the individual stages that students must achieve on the way in order to reach these goals. In short, learning goals are general, objectives are specific and goals are like strategies, objectives are like tactics.

2.3 Bloom's Taxonomy

In the 50s of the last century, Benjamin Bloom led a team of educational psychologists trying to dissect and classify the varied domains of human learning. The efforts resulted in a series of taxonomies in each domain, known today as Bloom's taxonomies [Bl56]. Bloom's taxonomies divide LOs into three interrelated domains namely *cognitive* (knowledge), *affective* (attitude) and *psychomotor* (skills). The cognitive domain involves knowledge and the development of intellectual skills. In this domain, Bloom et al. distinguish between six different levels namely *knowledge*, *comprehension*, *application*, *analysis*, *synthesis* and *evaluation*. These six levels are hierarchically ordered and can be thought of as degrees of difficulties (see Table 1).

Category	Difficulty
Knowledge	Very easy
Comprehension	↓
Application	↓
Analysis	↓
Synthesis	↓
Evaluation	Very difficult

Table 1: Cognitive Domain of Bloom's Taxonomy

The affective domain describes the way people react emotionally, such as feelings, values, emotions, motivations and attitudes and the psychomotor domain is based on learning physical skills, which includes movement, coordination and manipulation. The development of these skills requires practice and can be measured, for example, in terms of speed and precision.

2.4 Learning Objective Statements

As mentioned earlier, LOs are statements of intent that describe what a student will be able to do as a result of learning. The definition of good LOSs explains the intended learning outcome and answers the question what the students should be able to do at the end of the course that they could not do before. According to Foster [Fo03], LOSs should be SMART (*specific, measurable, achievable, realistic, time-bound*) and also simple, clear and precise. Mager [Ma62] defines three characteristics, which are essential for insuring clear statements of LOs namely *behavior*, *conditions* and *criterion*. Behavior means, a LOS should identify the type or level of learning. The choice of an adequate verb is also very important. Condition means, a LOS should describe the conditions under which the behavior is to be completed and criterion means, a LOS should make clear when it is satisfied fulfilled. This can be done with a statement indicating a degree of accuracy or a quantity or proportion of correct responses. In the following, the LO *"After learning this course, the student will be able to compute the eigenvalue of matrices and vectors in 70% of cases"* is separated into the even mentioned parts.

- Condition: *After learning this course*
- Behavior: *The student will be able to compute the eigenvalue of matrices and vectors*
- Criterion: *The computations of the eigenvalue in a subsequent test will be in 70% of cases correct*

2.5 Magic Triangle

The Magic Triangle (see Figure 1) represents the relationship between *learning objectives*, *learning activities* and *evaluation*.

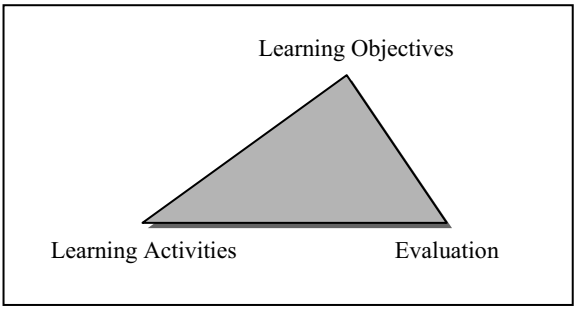

Figure 1: Magic Triangle

Learning activities encompass all activities that are chosen to foster learning towards reaching the LOs. Evaluation or tests allow the author to check the degree to which the students are reaching the objectives. If these three components are congruent then learning is in an optimal way. If these three components are not congruent then students become discouraged and could complain that the test did not have anything to do with what was explained in the course and they will stop paying attention to them.

3 Proposed Approach

The basis of the competency-based approach to support the definition of LOs is the uniform definition and use of competency levels in LET systems.

3.1 Competency-based Classification of Learning Objects

As mentioned in chapter two, Bloom's taxonomies provide a structured way to define LOs. But, it can also be extended to competencies. Competencies can be written by building their structure upon the Bloom's taxonomies, from the lowest to highest level in the cognitive, psychomotor and affective domains. To following the approach, each learning object in a LET system has to be classified according to preselected taxonomies. Depending on the LET system, learning objects can be pictures, videos, audio files, animations and text. The classification encompasses a competency level choice for each domain of the selected taxonomies. For example, an author has classified a learning object as follows:

- Cognitive: Knowledge (Level 1)
- Affective: Receiving phenomena (Level 1)
- Psychomotor: Set (Level 2)

Based on this classification, a competency vector can be built. According to this example, the resulting competency vector is as follows:

$$\overrightarrow{CL}_{LearningObject} = \begin{pmatrix} 1 \\ 1 \\ 2 \end{pmatrix} \quad (1)$$

Notice: The example above is based on Bloom's taxonomies, but any other taxonomy can be applied as well.

3.2 Competency-based Classification of Courses

Upon the system-wide classification of learning objects has been done, the author can design a course for a specific topic by aggregating the relevant learning objects. Based on the selected learning objects, the competency vector of the course can easily be computed by the rounded down arithmetic mean of all competency vectors of the learning objects (see Formula 2).

$$\overrightarrow{CL}_{Course} = \left\lfloor \frac{1}{n} \sum_{i=1}^{n} \overrightarrow{CL}_{LearningObject_i} \right\rfloor \quad (2)$$

The automatic computation of the competency level of the course is optional. It can be regarded as a recommendation and each author can adjust the calculated competency vector to his or her individual needs.

3.3 Definition of Learning Objective Statements

The next step in building a LO-based course is to define LOSs. A LOS must describe the competency to be learned. Moreover, the choice of an adequate verb is crucial to identify the level of learning. Bloom et al. proposes a variety of recommended verbs for each domain and level. The following table lists some adequate verbs for the cognitive domain of Bloom's taxonomies.

Category	Verbs
Knowledge	defines, describes, identifies, knows, labels, lists, matches, names, outlines, recalls, recognizes, reproduces, selects, states
Comprehension	comprehends, converts, defends, distinguishes, estimates, explains, extends, generalizes, infers, predicts, summarizes, translates
Application	applies, changes, computes, constructs, demonstrates, discovers, manipulates, modifies, predicts, produces, relates, shows, solves, uses
Analysis	analyzes, compares, contrasts, deconstructs, differentiates, discriminates, distinguishes, identifies, illustrates, infers, outlines, selects
Synthesis	categorizes, combines, composes, creates, devises, designs, explains, modifies, plans, reconstructs, relates, reorganizes, rewrites, summarizes
Evaluation	appraises, compares, concludes, contrasts, criticizes, critiques, describes, evaluates, explains, interprets, relates, supports

Table 4: Adequate Verbs for the Cognitive Domain

Due to the fact that the course is classified, either automatically or manual according to Bloom's taxonomy domains and levels, the LET systems can recommend suitable verbs for the definition of LOSs.

3.4 Evaluation of Learning Objectives

Defining a simple, clear and precise LO is crucial, but the evaluation of the LO is important more than ever. For a human it is more or less difficult to decide whether the LO is satisfied or not, but for a LET system it is impossible to make a reliable decision about the fulfillment of the LO, which solely exists in textual representation. The proposed methods to overcome the even described problem are pre- and post-tests in conjunction with LOs (please notice the relation to the Magic Triangle in chapter 2.5, which proposes an evaluation to check whether the student has reached the LOs). The author of a course not only defines LOs, but also assigns pre- and post tests to learning objects of the course. Additionally, the author has to define a threshold for each test as a criterion of acceptance. The purpose of the pre-test is to find out, which learning objects of the course are already known by the student. The character is more like an initial conversation between the student and the system instead of a real assessment test. It is recommended to use simple question types like true-false or multiple-choice for pre-tests. If the student reached the predefined threshold, the pre-test is solved satisfactorily and the related learning object can be skipped. After the pre-test and the review of the course content, the student should be able to accomplish the post-test of the course. In the ideal case, the student reached all thresholds of the post-tests and achieves the LO of the course. In the other case, the system recommends learning objects whose questions are not solved satisfactorily. The post-test can be accomplished later again. Figure 2 illustrates the whole process. The grey bars indicate the pre- and post-test results and the black bars the respective thresholds.

4 Implementation

The proposed competency-based approach to support the definition of LOs has been implemented by the Business Area Data Representation and Interfaces, Fraunhofer IDMT, in a project called EDMedia [KP06]. EDMedia represents a LCMS that provides learning, communication, self-assessment, authoring and content management options with easy-to-access information in an accurate, well-designed user interface. It requires authorization and provides secure use according to user rights and causes a general separation of content, presentation and system logic. Moreover, it ensures the interoperability of the content by the use of XML-based exchange formats namely ADL SCORM [Sc09], IEEE LOM [Lo02] and IMS QTI [Qt06] and allows creation and composition as well as import and export of content on learning object basis.

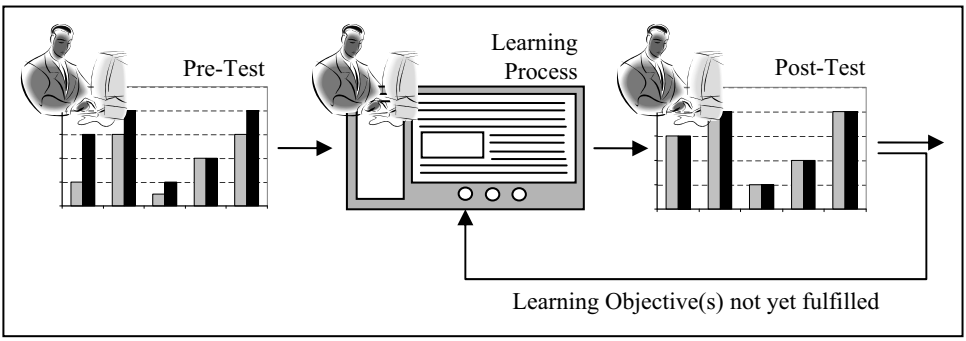

Figure 2: Iterative Learning Process

4.1 Classification of Learning Objects

In EDMedia, learning objects are accompanied with improved metadata according to IEEE LOM. This facilitates the flexible construction of personalized learning, which is a fundamental requirement in individual and organizational arrangements. Moreover, this description of resources allows for reusability of high-quality content and interoperability. Learning objects in EDMedia are based on various media formats and sophisticated hypermedia-based navigation strategies according to up-to-date user-centered learning design aspects [Ma01, MM99]. In addition to that, each learning object is classified according to predefined taxonomies. Due to the fact that Bloom's taxonomies are properly the most widely used taxonomies in the field of LET, EDMedia has implemented Bloom's taxonomies by default. Figure 3 shows, how such a classification of a learning object in EDMedia looks like.

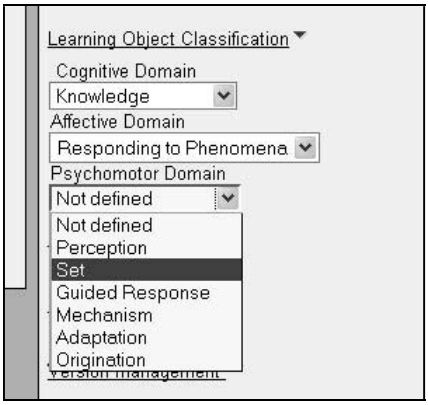

Figure 3: Classification of a Learning Object in EDMedia

4.2 Definition of Learning Objectives

The definition of LOs in EDMedia is supported by an auto-complete mechanism, which recommends the most appropriate verbs according to the calculated or manual set competency level of the course. As an example, if the competency vector of the course is (1, 0, 0) and the author types an *r* in the text field, EDMedia proposed the verbs *recall*, *recognize* and *reproduce*, because the initial letter of the verbs is an *r*. Figure 4 below displays this scenario. The auto-complete mechanism facilitates defining simple, clear and precise LOSs.

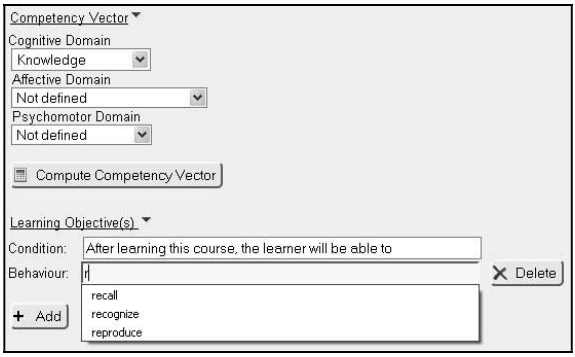

Figure 4: Definition of Learning Objectives in EDMedia

Recommended verbs are stored in a database and can be added, modified and deleted in the authoring environment of EDMedia. The definition of learning objects is also integrated into the authoring environment of EDMedia. It enables the flexible and user-friendly authoring of content.

4.3 Evaluation of Learning Objectives

As mentioned in chapter 3.3, it is crucial for a LET system to assign pre- and post-test to each learning objects of a course in order to verify whether the LOs are satisfied or not. EDMedia satisfies this requirement by defining questions and tests based on the IMS QTI [Im06] specification and by assigning them to courses and learning objects, respectively. After assigning a pre- and post-test to the respective learning object, a score threshold must be defined, which decides whether the student can skip a learning object or not. EDMedia loads the scores of the selected questions and presents it to the author to choose from (see Figure 5).

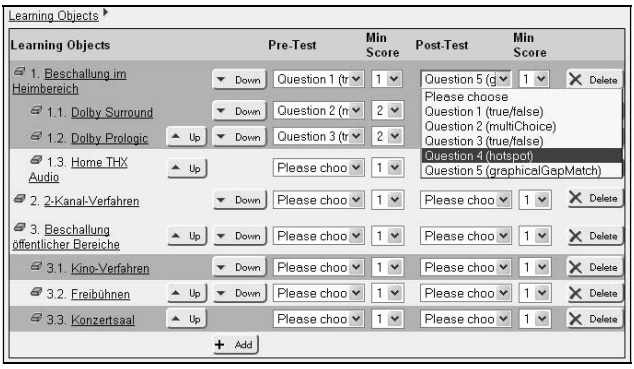

Figure 5: Pre- and Post-Test Assigning in EDMedia

4.3 Learning Process in EDMedia

After defining LOs for a course and assigning tests to them, the student can sign up for that course. Before the student sees any course content, the initial pre-test has to be performed. When the pre-test has been completed, EDMedia displays the course content. According to the pre-test results, some parts of the course are skipped and other are suggested for reviewing. Upon reviewing all suggested parts, the student can take the final test of the course. If the student has reached all thresholds of the post-test set by the author, he/she has reached the LOs to authors' satisfaction.

5 Conclusions

This paper has presented a competency-based approach to support the integrated definition of LOs in LET systems. It has been shown, how learning objects are classified. Based on this classification, the competency vector could be built upon the course (aggregation of learning objects) competency vector could automatically be derived. The competency vectors refer to preselected taxonomies and the dimensions of the vector refer to the domains within the taxonomies.

In this paper, the Bloom's taxonomies have exemplary been selected, because they are the most widely used taxonomies in the field of LET. The competency vector of the course serves as the basis on which the LET system can recommend adequate verbs for defining LOSs. In order to verify that the LOs are reached, each aggregated learning object in a course has to be assigned a pre- and post-test and a threshold as the acceptance criterion for the respective test. Finally, the implementation of the proposed approach in the LCMS EDMedia has been shown. Our approach supports to cope with the challenges of instructional design and furthermore helps to align the Magic Triangle congruent. For the student, this result in a better learning experience and therefore in enhanced learning results.

Future work will address personalization issues in evaluating LOs. It was assumed that presenting all questions to all students is perhaps not the best solution. For that reason, a new adaptive assessment system is being implemented, which takes into account the individual context, prior knowledge and preferences of the students resulting in personalized assessment [SRW10, SDW11]. This not only results in more objective evaluation findings, but also in feedback for an effective and successful transfer of individual or organizational knowledge.

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