Handbook of Research on ePortfolios

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Chapter XX
eLearning Tools for ePortfolios

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ABSTRACT

This chapter describes eLearning tools that focus the learner's attention on meaning, rather than rote learning of text and rehearsing problem-solving procedures. These tools are the Interactive Concept Discovery Learning Tool and the Meaning Equivalence Reusable Learning Object (MERLO). Results of several evaluative implementations of these novel instructional methodologies, which encourage learners to interact directly with the conceptual content of to-be-learned material, demonstrate their potential to enhance learning outcomes and to provide authentic, credible, evidence-based demonstration of mastery of learning and formative assessments of learning processes and outcomes for inclusion in 'learning ePortfolios'.

INTRODUCTION

It is generally agreed that an important function of a "learning ePortfolio" is to store records that provide authentic, credible demonstration of an individual's mastery of learning. However, at present there are no accepted standards and therefore the format of such records and their content are open to interpretation by individual learners and institutions alike. For example, a large university in Canada has been recently offering workshops to students and faculty on "How to Use our Learning Management System (LMS) to Create Presentations of

Students' Learning" for inclusion in their ePortfolios. Such presentations usually contain graded assignments, including term papers, problem sets, and so forth. While such presentations may be viewed as authentic demonstrations of learning, the precise interpretation of "mastery of learning" remains open. This is a crucial issue; it is clear that future success of learning ePortfolios is critically dependent upon the credibility of the records as an authentic demonstration of mastery of learning. In this chapter we describe two novel eLearning tools that were designed to generate such records including their rationale, details of the instructional methodologies, and results of several evaluative implementations.

WHAT IS "MASTERY OF LEARNING"?

Credible evidence for mastery, or deep comprehension, of learned material is a necessary component of successful completion of a learning experience. However, what particular evidence is required and what lends credibility to such evidence are the subjects of a lively debate among experts in the learning community (Bransford, Brown, & Cocking, 2004). The development of the novel eLearning tools described in this chapter was motivated by a rationale that views deep comprehension as good knowledge of the conceptual content of learned material. Indicators of deep comprehension are various manifestations of an ability to identify and flexibly adapt conceptual content to different situations, and the spontaneous generation of different representations that highlight and clarify various relevant features of the conceptual situation under consideration. Learners who attain deep comprehension of a particular subject area can produce multiple representations (statements) that share equivalence of meaning, recognize that a statement encodes a particular conceptual content, and also recognize other statements that may or may not "look like" that specific statement, encode equivalent meaning.

In the next part of this chapter, we will offer an operational definition of *concept* in the context of semantic analysis; describe concept parsing algorithm (CPA), a generic semantic procedure that identifies the lexical labels and building blocks of concepts in unstructured text (Shafrir & Etkind, 2005); and describe two applications of CPA in eLearning that result in the generation of digital records particularly suitable for inclusion in learning ePortfolios, one for learners who explore the conceptual content of digital text through the Interactive Concept Discovery Learning Tool, and the other for domain experts and instructors who use CPA for detailed and accurate mapping of the conceptual content of course material and for the construction of Meaning Equivalence Reusable Learning Objects (MERLOs) that focus learners' attention on meaning (patents pending).

What is "Concept"?

Unlike words in natural language, "concept" in a discipline must be precisely and clearly defined; for conceptual content of a scientific discipline to be successfully captured by language, the meaning of the words must first be disambiguated. "Concept" is a regularity, an organizational principle behind a large collection of facts, an invariant, a pattern in the data. How are concepts—patterns in the data—encoded and communicated? All content areas use "code words" to communicate meaning; it is easy to verify that such codes exist in all disciplines: science, medicine, social science, humanities, as well as in the professions.

Lexical Labels of Concepts

The use of "code words" as lexical labels of concepts within a context in a discipline differs from the use of these same words in ordinary language in two important ways:

1. Lexical labels of concepts do not encode the literal meanings associated with their constituent words in the daily use of the language; rather, each such label encodes a connoted meaning, a meaning rooted in the regularity being considered, that differs from the literal meaning of the word(s).
2. Lexical labels of concepts do not have synonyms; rather, each label functions like a proper name of the signified concept.

The implications of this formulation will be examined in this chapter; as we shall see, they are considerable. For example, it is easy to verify that textbooks and articles in learned journals, while discussing conceptual content of the particular discipline, "read like" natural language. In other words, while containing a "secret code" that re-defines parts of the lexicon (by using "ordinary words" as lexical labels that denote precisely defined, abstract concepts), text in these books and journals still obeys syntactical, morphological, and grammatical rules of the natural language in which it is written. This seems to hold across disciplines and across languages.

There is no uniform format of lexical labels of concepts. A lexical label may be a single sign or a sequence of signs in a mono-level sign system—namely, words in natural language. For example, the words "strangeness," "color," and "spin" are lexical labels of concepts in particle physics, where they encode meanings that are very different from their literal meanings in English; "scaffolding" is a lexical label of a concept in learning theory, unrelated to the construction industry; genetics contains the lexical label "bi-directionality"; and "flying buttress" is a lexical label of a concept in architecture that is unrelated to flying. A lexical label may also be one or more words borrowed from another primary sign system (i.e., another natural language; for example "bulimia nervosa"), or signs borrowed from a secondary sign system (e.g., CO_2; ♬), or a combination of several such elements in a multilevel sign system (e.g., F# Major). As one can see, lexical labels function like proper names of concepts.

What is the Meaning Attached to a Lexical Label of a Concept?

A paragraph in a textbook that contains a lexical label may provide an approximate definition of the concept associated with it. However, in order to qualify as a *concept statement that specifies the meaning of the concept,* the paragraph must provide a comprehensive encoding of the regularity under consideration. Concept statements may be found in textbooks or may be formulated by domain experts, and must include not only the lexical label of the concept but also describe its building blocks—that is, all the important features of the concept. Here is an example of a paragraph that may be identified as concept statement (Sternberg & Williams, 2002):

As children mature, their cognitive functioning changes. They acquire new mental skills that enable them to better perceive, process, encode and memorize information. Cognitive development is the study of changes in mental skills that occur through biological maturation and experience. Cognitive development does not stop when children mature, but continues throughout the lifespan. (p. 40)

While this paragraph provides a broader background, the core sentence of interest is the definition of the concept here identified by the lexical label *cognitive development* in the context of child development:

Cognitive development is the study of changes in mental skills that occur through biological maturation and experience.

A close examination reveals that the concept with the lexical label *cognitive development* is defined here by co-occurrence of three other subordinate concepts (mental skills, biological maturation, experience), and particular relations between them (changes, occur through). Schematically, this sentence may be parsed into three sets:

Cognitive development = {[mental skills, biological maturation, experience], [changes, occur through], [linguistic descriptors]}

We may denote these sets as:

[Ci] = [mental skills, biological maturation, experience] is a set of co-occurring concepts [C_1, C_2, C_3].
[Rj] = [changes, occur through] is a set of relations [R_1, R_2].
[Lk] = [linguistic descriptors] is a set of additional linguistic elements [L_1, L_2,…] that obey syntactical, morphological, and grammatical rules of the language.

Concept Parsing Algorithms (CPAs)

Systematic examination of concept statements in different disciplines reveals that they may be parsed in a fashion similar to the above example. This may be formulated as the following generic rule:

$$C' = \{[Ci], [Rj], [Lk]\} \quad (1)$$

Where C' is a superordinate concept, and [Ci], [Rj], and [Lk] are the three sets described above. We use equation (1) as an operational definition of a concept, a generic format that may be used as concept parsing algorithms—a formula that provides guidance for discovering the meaning of a lexical label of a concept by identifying its "building blocks." Superordinate concepts whose building blocks contain only subordinate concepts, but no relations (i.e., [Rj] is an empty set) are called *containment concepts* (Laurence & Margolis, 1999). Superordinate concepts whose building blocks contain both subordinate concepts and relations (i.e., [Rj] is not an empty set) are called *inferential concepts* (Shafrir & Etkind, 2005).

INTERACTIVE CONCEPT DISCOVERY LEARNING TOOL

Interactive Concept Discovery Learning Tool is a novel *semantic search* tool based on concept parsing algorithms outlined above. It is an intuitive, interactive procedure that allows a learner to search large digital databases of unstructured text (e.g., World Wide Web, eJournals and eBooks in libraries, organizational eArchives). It allows the learner to discover the building blocks underlying a lexical label of a concept within a particular context (specific content area within a discipline)—namely, co-occurring subordinate concepts and relations—as well as to construct concept maps that clearly identify not only the conceptual content of course material, but also its internal conceptual structure (e.g., hierarchical and lateral relations among concepts and their building blocks).

The learner begins a search in the Interactive Concept Discovery Learning Tool by identifying the lexical label of a particular concept within a context in a discipline, then evaluating the consistency of appearance of co-occurring concepts and their relations across different documents found to contain this lexical label. In each successive iteration, the learner can read/save found documents online, mark/save lexical labels and candidate features of building blocks, evaluate the degree of relevance of a particular found document to the specific conceptual content under consideration, and construct alternative graphical representations of links between concepts and their building blocks.

A stored comprehensive record of a learner's sequence of all iterations allows for a detailed reconstruction of the learning episodes generated by the Interactive Concept Discovery Tool over time; it reveals the learner's consistency of "drilling-down" for discovering deeper building blocks of the particular concept, and the temporal evolution of outcomes of the learning sequence. This digital record is an authentic, evidence-based demonstration of mastery of knowledge that can be used as a springboard for a follow-up class—and chat room discussions—and provide a credible record to the individual's learning ePortfolio.

Discovering the Meaning of "Color"

We will demonstrate some aspects of the Interactive Concept Discovery Learning Tool by exploring the lexical label "color." The *Oxford English Reference Dictionary* lists 15 different senses (11 nouns and 5 verbs) for "color" (presented as "U.S. spelling of 'colour'"). The first example is of a learner in a biology course who is interested in discovering the building blocks of the superordinate concept "color," using the World Wide Web as a database of unstructured text. Following the specification of the lexical label "color" in the discipline of "biology" in the context of "vision" in the Interactive Concept Discovery Learning Tool, the learner finds 111,000 relevant documents. Further guided iterative sequences reveal that the set [Ci] contains co-occurring subordinal concepts 'retina', 'photoreceptor', 'cones', and 'rods', still further 'drilling down' reveal additional, deeper co-occurring subordinal concepts: 'wavelength', 'red', 'green', and 'blue'. At this stage, the Interactive Concept Discovery Learning Tool identified 287 documents that contain all the above mentioned features of the superordinal concept "vision," and ranked them by degree of relevance.

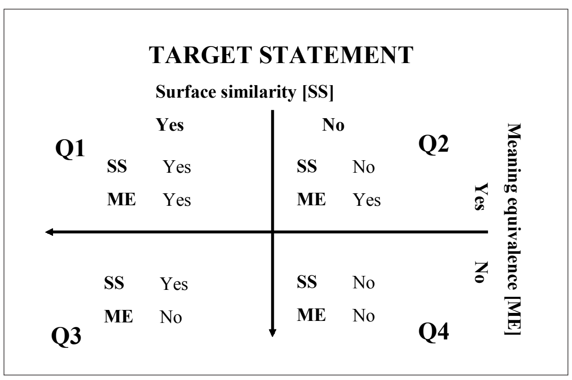
The second example is of a learner in a physics course who is interested in discovering the building blocks of the superordinate concept "color," using the World Wide Web as a database of unstructured text. Following the specification of the lexical label "color" in the discipline of "physics" in the context "chromodynamics" in the Interactive Concept Discovery Learning Tool, the learner finds 4,780 relevant documents. Further guided iterative sequences reveal that the set [Ci] contains co-occurring subordinal concepts 'quark', 'gluon', and 'charge'; still further 'drilling down' reveal additional, deeper co-occurring subordinal concepts: 'red'; green'; and 'blue'. At this stage the Interactive Concept Discovery Learning Tool identified 281 documents that contain all the above mentioned features of the superordinal concept "vision," and ranked them by degree of relevance.

It is interesting to note that "color" is a lexical label of two entirely different superordinate concepts in the disciplines of biology and physics that encode two different meanings in the contexts of "vision" and "chromodynamics," respectively. In both cases, the Interactive Concept Discovery Learning Tool guided the learners to identify, evaluate, and recognize more and more co-occurring candidate subordinate concepts, as features in the building block set [Ci] in equation (1) above.

MEANING EQUIVALENCE REUSABLE LEARNING OBJECT (MERLO)

We now move on to describe a second application of Concept Parsing Algorithms for concept mapping of content areas in the disciplines. At the core of MERLO are comprehensive concept statements that encode the conceptual content of a particular course. In preparation for MERLO construction, domain experts and instructors carry out detailed concept mapping by using the Iterative Concept Discovery Learning Tool. Each important *concept* may be represented by one (or more) *concept statements;* in turn, each concept statement is used to construct several *target statements* (representations), each encoding important features of the concept, as well as features that, in the instructors' experience, present particular difficulties for learners. Each target statement anchors an *item family* (see Figure 1); in addition to the target, an item family also includes additional statements that are thematically relevant to the particular target statement, but that: (1) may (or may not) bear surface similarity to the target; and (2) may (or may not) share equivalence-of-meaning with the target (Shafrir, 1999).

Figure 1. Template for constructing an item-family in MERLO



MERLO is then a multi-dimensional grid of item families centered on individual target statements that encode different features of an important concept; collectively, these item families encode the complete conceptual content of a course (a particular content area within a discipline). Statements in the four quadrants—Q1, Q2, Q3, and Q4—are thematically related to the target statement and are classified by two sorting criteria: surface similarity to the target, and equivalence-of-meaning with the target. Statements in quadrant Q1 (see Figure 1) are similar in appearance to the target and also share equivalence-of-meaning with the target. Statements in quadrant Q2 are not similar in appearance to the target but, nevertheless, share equivalence-of-meaning with it. Statements in quadrant Q3 are similar in appearance to the target, but do not share equivalence-of-meaning with it. Finally, statements in quadrant Q4, although thematically related to the target statement, are not similar in appearance to the target and do not share equivalence-of-meaning with it. In statements that belong to quadrants Q2 and Q3, there is valence mismatch between the two sorting criteria, while in statements in Q1 and Q4 there is no valence mismatch.

MERLO guides the sequential teaching/learning episodes by focusing learners' attention on meaning. Item-families are used to construct individual test items. The novel format for MERLO item construction was designed to assess deep comprehension of conceptual content by eliciting responses that signal learner's ability to recognize and/or construct multiple representations that share equivalence-of-meaning. A typical MERLO item contains a target statement and four additional statements from quadrants Q2, Q3, and Q4. In our experience, inclusion of statements from quadrant Q1 makes items too easy, because the valence match between surface similarity and meaning equivalence is a strong indication of shared meaning with the (unmarked) target statement; hence Q1 statements are excluded from MERLO items. Task instructions in a MERLO test are:

At least two out of these five statements—but possibly more that two—share equivalence-of-meaning. Please mark all statements—but only those—that share equivalence-of-meaning.

In other words, the learner is asked to carry out the task in situations where the particular target statement is not marked, that is, the features of the concept to be compared are not made explicit. In order to perform this task, learners first need to decode the meaning of each stimulus in the set. This process is typically carried out by the learner, by analyzing the underlying conceptual features that define the meaning of each stimulus. Successful analysis of all the stimuli in a given five-stimulus set (item) requires deep understanding of the conceptual content of the specific domain being assessed. MERLO item format requires both rule inference and rule application in a similar way to the solution of analogical reasoning items. MERLO item type is designed not only to be used in the context of formative assessment of deep comprehension, but also to explicitly support instruction and remediation by quantifying partial knowledge of conceptual content, and thus providing detailed diagnostic information in the learner's response set.

MERLO Scoring Algorithms

There are several ways to score MERLO test items. *Quadrant-specific scores* are proportional scores that are first calculated for each item for the target statement and for statements from each quadrant, and then collapsed over all the items in the particular MERLO test. Quadrant-specific scores provide detailed and accurate feedback because they identify and pinpoint 'soft conceptual spots' of individual learners. Quadrant-specific scores also provide helpful cues for classroom and chat room discussions and individual remediation. Specific diagnostic information about comprehension deficits show up as depressed scores on quadrants Q2 and Q3; in these quadrants there is a mismatch between the valence of surface similarity and meaning equivalence dimensions. However, the interpretations of these two scores are very different:

- A depressed proportional score on Q2 indicates that the learner does not include in the 'boundary of meaning' of the group of related concepts certain statements that share equivalence-of-meaning (but not surface similarity) with the target and therefore should be included; such depressed score signals an over-restrictive (too exclusive) understanding of the meaning underlying the group of related concepts.
- A depressed score on Q3 indicates that the learner does not exclude from the 'boundary of meaning' of the group of related concepts certain statements that do not share equivalence-of-meaning (but that do share surface similarity) with the target and that therefore should be excluded; this signals an under-restrictive (too inclusive) understanding of the meaning underlying these concepts.

MERLO test items may also be scored for correctness of the learner's decisions to mark (or not to mark) statements within an item. *Positive partial score* is the proportion of correctly marked statements that share within-item equivalence-of-meaning (these are target and Q2 statements), and therefore should be selected; in a similar way, a *negative partial score* is calculated for the proportion of statements that do not share equivalence-of-meaning (these are Q3 and Q4 statements), and therefore should not have been—and in fact were not—selected by the learner. *Positive* and *negative scores* are calculated for each item separately, then collapsed over all the items in the MERLO assessment of a group of related concepts. Positive and negative scores may be interpreted as two complementary indices of deep comprehension, in that they reveal specific misunderstandings and misconceptions held by the learner about the meaning-equivalence of the ensemble of concepts anchored in the test's target statements.

EVALUATIVE IMPLEMENTATIONS

Evaluative implementations confirmed our expectations of the instructional value of detailed feedback from MERLO assessments and provided individual learners with accurate evaluations not only of what they know but—critically—of what they do not know, namely, their 'soft conceptual spots': quantitative assessments of their partial knowledge of conceptual content. Evaluative implementations of the Iterative Concept Discovery Learning Tool and MERLO-supported pedagogy were carried out during 2001-2005 in several collaborative projects in K-12, post-secondary, and workplace learning environments in Canada and abroad. In each project, detailed concept mapping was followed by construction of MERLO and implementation in the classroom, including assessments, feedback, class discussions, and instructors' reports. Examples are:

1. At Ryerson University in Toronto, seven MERLOs in two courses, History of Western Architecture I and II, have been constructed and implemented; this project has continued since September 2002.
2. In a collaborative project with the Russian Academy of Sciences, MERLOs have been constructed and implemented across the high school curriculum in math, physics, and biology in Lycee Technical-Physical High School of Ioffe Institute in St. Petersburg. This project resulted in more than 60 MERLOs (available in both Russian and English) that cover the complete high school curriculum in math, physics, and biology, as well as introductory university courses in these disciplines. This project has continued since June 2002.
3. At the Ontario Institute for Studies in Education of University of Toronto (OISE/UT), five MERLOs in a pre-service teachers training course, Foundation of Learning and Development, were constructed and piloted during the 2002/2004 academic years.
4. At George Brown College in Toronto, four MERLOs in English Spatial Prepositions were constructed in 2002 and used for assessment of deep comprehension of language in three student populations: native English speakers, ESL students, and students with specific reading disabilities.
5. The Material and Manufacturing Ontario (MMO) Center of Excellence sponsored the construction and evaluative implementation of three MERLOs for an in-depth workshop, "Risk Management in the Supply Chain," during February 2002. Following are two illustrations of typical results obtained in these evaluative implementations.

English Spatial Prepositions

Shalit (2005) conducted detailed concept mapping of English spatial prepositions in four categories—anthropomorphic (e.g., front, back);

inclusion (e.g., in, out); proximity (e.g., near, close to); and verticality (e.g., up, down)—and constructed four MERLOs (each containing eight item-families in a particular category). These MERLOs were then used to compose two Meaning Equivalence (ME) tests, each with 16 items; these tests were administered to three groups of college students: E1 (English speakers), E2 (English as second language—ESL), and RD (reading disabled). Means-proportional scores (standard deviations) and results of analysis of variance (ANOVA), shown in Table 1, reveal that: (1) native English speakers outperformed both the ESL and the RD groups; and (2) in all three groups, Q2 and Q3 proportional scores were depressed compared to T and Q4 proportional scores.

In-Depth Workshop: Risk Management in the Supply Chain

Sixteen supply chain managers from several medium and large Canadian companies participated in this workshop (Shafrir & Krasnor, 2002). In preparation for the workshop, a domain expert conducted detailed concept mapping and constructed three MERLOs with a total of 81 item families. Following each of three weekly sessions, each with a different conceptual content, learners took a 10-item ME test. Following completion of each test, participants were given the scoring code, scored each other's tests, and participated in class discussion. Results show that mean Q2 proportional scores increased from Test #1 (M=0.71; SD=0.13) to Test #2 (M=0.85; SD=.11) to Test #3 (M=0.94; SD=.07); differences are significant at the p<=0.5 level. In other words, learners consistently improved their conceptual thinking and refined the demarcation of the 'boundary of meaning' of the conceptual content of learned material.

Table 1. Mean (SD) proportional scores and results of ANOVA analysis of ME test of English spatial prepositions for the E1, E2, and RD groups

	E1 (n=98)	*E2 (N=54)*	*RD (N=55)*	*F*
T	.85 (.15)	.79 (.14)	.83 (.13)	3.35*
Q2	.76 (.17)	.64 (.17)	.67 (.18)	9.65 ***
Q3	.79 (.15)	.74 (.63)	.66 (.21)	2.61
Q4	.93 (0.9)	.88 (.12)	.85 (.13)	10.71***

Note: ANOVA (p<=0.5; *** p<=0.001)*

CONCLUSION

A total of 1,981 individual digital records of the new eLearning tools for ePortfolios were generated in these evaluative implementations (see Table 2). Results have shown consistently and across different content areas and across disciplines that:

a. The Interactive Concept Discovery Learning Tool enables learners, instructors, and

Table 2. Number of individual digital records generated by the new e-learning tools in various evaluative implementations

LEARNING ENVIRONMENT	*DISCIPLINE*	*NUMBER OF RECORDS*
K-12	Mathematics	504
	Physics	204
	Biology	96
College	English as a Second Language (ESL)	369
University	Architecture	722
	Psychology	38
Workplace	Business	48

researchers to identify building blocks of important concepts, and to create detailed and accurate concept maps in many content areas in several disciplines.

b. These concept maps may be used for the construction of MERLOs that support research and enhance learning outcomes, not only by helping instructors to focus on conceptual content, but also by providing learners with feedback from self-tests that is immediate, accurate, detailed, and that elaborates "soft conceptual spots" in need of reinforcement and remediation.
c. Concept discovery is learner centered and empowers active learning, and it exposes learners to different points of views and varied representations of conceptual content, accommodates different learning styles, and augments English proficiency of new immigrants (ESL) and students with reading difficulties.
d. MERLO pedagogy is effective across different populations of researchers, instructors, and learners, and across disciplines.
e. Initial construction of MERLO by domain experts is consequently improved and refined following feedback from various implementations.
f. MERLOs offer considerable economy by subsequent reuse for the construction of test items that may vary in format, as well as in degree of difficulty.
g. MERLO is technologically scalable and can be implemented in low-tech classrooms as well as online.

These results support the conclusion that these eLearning tools provide clear and authentic evidence for mastery of learning based on measures that are independent of jurisdiction, grading system, or accreditation differences.

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KEY TERMS

Concept: A regularity; an organizational principle behind a large collection of facts; an invariant; a pattern in the data.

Concept Map: A textual/graphic representation that clearly identifies conceptual content and the internal conceptual structure (e.g., hierarchical and lateral relations among concepts and their building blocks).

Concept Parsing Algorithm (CPA): A formula that provides guidance for discovering the meaning of a lexical label of a concept by identifying its 'building blocks'.

Concept Statement: A comprehensive description of the meaning of a concept; a comprehensive encoding of the regularity under consideration.

Interactive Concept Discovery Learning Tool: A novel semantic search tool based on concept parsing algorithms; an intuitive, interactive procedure that allows a learner to search large digital databases of unstructured text and to discover the building blocks underlying a lexical label of a concept within a particular context (specific content area within a discipline).

Item Family: Anchored in a target statement, an item family also includes additional statements that are thematically relevant to the particular target statement, but that: (1) may (or may not) bear surface similarity to the target, and (2) may (or may not) share equivalence-of-meaning with the target.

Lexical Labels of Concepts: 'Code words' that serve as proper names of concepts within a context in a discipline.

Mastery of Learning: Deep comprehension of the conceptual content of learned material.

Meaning Equivalence Reusable Learning Object (MERLO): A multi-dimensional grid of item families centered on individual target statements that encode different features of an important concept; collectively, these item families encode the complete conceptual content of a course (a particular content area within a discipline).

Target Statement: A description of a particular conceptual situation that includes some important features of a concept.