THE GRANULARITY APPROACH OF LEARNING OBJECTS TO SUPPORT ADAPTABILITY IN ADAPTIVE LEARNING SYSTEMS

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ABSTRACT

The main goal of this paper is to examine the fine granularity of learning content and its impact of the adaptability process in Adaptive Learning Systems (ALS). For that purpose, we present the concept and the essence of learning objects. Then, we approach some content models by clarifying the adopted levels of granularity and/or aggregation. After that, we discuss the fine-grained as a fundamental characteristic to reach the adaptability and individualization required in ALS. Finally, we propose our own model of learning objects by underlining the levels of granularity considered and by presenting a use case of its ability to meet the properties associated with fine-grained and adaptability.

Keywords: *Adaptability, Learning Content, Adaptive Learning Systems, learning object, granularity, learning content.*

1. INTRODUCTION

The question of the learning content was always raised if we wish to create or reform a curriculum. This issue is mainly present in all the speeches of *politicians*, *specialists of education* and *practitioners* [1, 2].

The learning content issue and its designation is still open to interpretation [3]. Most of the debate proposed in the related literature is shaped around the used terminology and attributes. Firstly, the naming changes, and instead of speaking about the learning content, we use various terms such as: *educational resources*, *digital resources*, *digital contents*, *learning resources*, *learning materials*, *learning objects*, etc. Secondly, developing and understanding of the educational resources is not helping by the many different definitions within the literature that range from the very general to the highly specific [4].

But, whatever the used terms and characterizations, the educational resource (digital or not), constitutes a primary basis for teaching and learning. Moreover, there are particular features of digital resources that can support learning environments to meet the needs of diverse characteristics of learners.

For Adaptive Learning Systems (ALS), the question of digital resources involves several research directions. The first concerns the representation of digital resources to be manipulated by computers. The second one focuses on the research of educational resources tailored to a specific learning context [2]. This aims to find suitable resources according to the preferences and needs of a specific learner, and at a precise moment in their learning. The third orientation of research is related to recent advances in the standardization of Web-based learning resources [6]. Research in that direction includes specifications as IEEE LOM [7], SCORM [8] or CISCO among others. This issue has resulted in a degree of consensus about the concepts of reusable “learning Objects” (LO), in particular about the aggregation levels of learning content [9].

Nonetheless, even if these models revealed some stability on the design of LOs and a few principles to produce them, this progress remains probably insufficient to capture the essence of the learning object approach. We can cite for example, the confusion surrounding “granularity” as important attribute of LOs and which is apparent in the literature as we will present later in this paper. The granularity as mentioned in [10], has a crucial impact on the ability to adapt, aggregate and to arrange content suiting the needs and preferences of the learner.

In this paper, we are particularly interested in granularity of LO and its impact on the courses adaptability. We focus on adaptive learning environments that can automatically generate individual courses according to the learner's profile. The course is generated from educational granules that are combined to form individual paths of learning. This work is in line with the uses of LO and the studies of their finesse for adaptability in the particular field of Adaptive Web-based Systems as referenced in [5].

This paper aims to study the advantage of the fine granularity to enhance adaptation in particular ALS, called Adaptive Hypermedia Systems (AHS). We will firstly begin by "demystifying" the concept of Learning Objects. We explore next, some structural issue of content models. The section three will appreciate the granularity, as a fundamental characteristic to achieve adaptability and individualization in the field of ALS. In the next section, we propose our own content model and study next its ability to meet the supposed objectives of adaptability.

2. ESSENCE OF LEARNING OBJECTS

The term "Learning Object" (LO) is one of the relatively recent labels of "learning resources" that emerges during the last decade, in the field of education. The associated concepts do not escape to ambiguity, bounded at many different definitions proposed in the literature.

There are various definitions of the term LO as David Wiley observes, "*the proliferation of definitions for the term 'learning object' makes communication confusing and difficult*" [11]. Most of the definitions focus on the general principles governing the LO concept such as: reusability, interoperability, the learning intention and the independence of the context. Balatsoukas [9], gives a typical example of definition provided by Polsani [12]. This author defines a LO as an independent and autonomous unit of learning content, which is predisposed to be re-used in different instructional contexts.

Other authors such as Bibeau [6] regards a LO as the smallest unit of information or the smallest tool of data processing (or software) used in an educational context, with an educational intention allowing learning through the technology support.

Flamand & Gervais [13] identified three categories of LOs. They distinguish the media objects that are less complex and context-free (image, video, animation, etc.), utilitarian objects (software for modelling, etc.) and learning objects composed of basic elementary information (facts, ideas, concepts, principles, processes).

Finally, other designs such as those of Downes [14], consider the size of a LO as important. Barron [15], in trying to examine this approach, suggests that five to nine items of information (text, image, video, photos, etc.) can be combined to form a LO. Other work conducted in this direction, including those of Mortimer [16], address the size of a LO in terms of instructional time, ranging from 15 minutes to 2 hours of learning.

In addition to these theoretical conceptualizations that may seem unfamiliar [17], other definitions emerge from various studies on new standards (SCORM, LOM, IMS, etc.). For LOM [7], "*a learning object is an entity digital or non-digital, that can be used, reused or referenced in an activity during Technology Supported Learning*". Normetic [18] adds to this definition, the technological support that includes multimedia content, instructional content, educational software and software tools used in the context of Technology Supported Learning. Finally, the online Wisconsin center of resources [19], defines a learning object as "*small learning units that can be used for duration of learning varying between 2 and 15 minutes*".

In the following, we propose an exploration of some models of educational contents in relation to new developments bound to the learning objects, and in connection with the works on the standardization and the associated technologies.

3. REVIEW OF CONTENT MODELS

The Content Models allows describing the components used to build a learning experience from Learning Objects. They also define how the lower levels of learning resources are aggregated and organized into instructional higher-level units. In this section, we review briefly the models SCORM, LOM, and the model RIO/RLO, in an implicit comparative perspective of their structure.

3.1. The SCORM Content Model

SCORM (Sharable Content Object Reference Model) [8] is a process of standardization of educational content. The aggregation model defines an associated structure with three levels of aggregation, indicating three main components: the *assets*, the *SCOs* (Sharable Content Object), and *COs* (Content Organization). An asset represents the smallest piece of reusable educational content. The assets may be Web pages, animations, pictures, videos, etc. A SCO is an entity (or grain) of content that has a pedagogical sense, which can be reused in other contexts and is recognizable by a SCORM platform. A SCO can be composed of several assets. A CO can represent the structure of content. It brings together educational resources in a package to be an educational activity. A CO is bound to a tree structure that acts like a table of contents.

We note that SCORM does not prescribe neither the size of a SCO, nor that of a package. We also underline that the assets and SCOs correspond more at least to criteria of reusability, unlike COs that can not be reused since they depend on a set of well-defined rules for sequencing and navigation in a course, a lesson, etc.

3.2. The LOM Aggregation Model

LOM (Learning Object Metadata) [7] defines a content model capable of indexing the LOs. This model consists of four levels of aggregation or of “functional granularity”. The first level is the lowest level of aggregation; it consists of *raw media* or *fragments*. The second level includes a collection of learning objects of level 1, such as a *lesson*. A collection of learning objects of level 2 such as a *course* constitutes the third level. The fourth level of granularity is composed by a *set of courses* which lead to a certificate or a diploma.

We note that these different levels of aggregation defined primarily functional granularity of learning objects, but no distinction is made between learning units, activities and resources.

Similarly no information is given about the size of a learning object.

3.3. The RIO/RLO Content Model

In 2003, Cisco Systems has published a strategy based on the concept "RLO / RIO”. The structure of content is composed of two basic levels: the *RIOs* and the *RLOs*. A RIO (Reusable Information Object) is a reusable granule independent of the publishing format. A RIO is presented under five various types of knowledge, including *concepts*, *facts*, *procedures*, *processes* or *principles* and associated with *assessments* (usually two) to evaluate the learner’s assimilation of different concepts, facts, etc. A RLO (Reusable Learning Object) is the result of a combination of five to nine (7 ± 2) RIOs, attached to an *overview* and *summary*, to meet a clearly defined educational objective.

We note that both RIOs and the RLOs can be represented by different formats such as: text, audio, animation, video, applets, etc. We also emphasize that for this model, other levels of functional granularity are mentioned. Indeed, a course consists of modules, a module is a combination of RLOs, an RLO is a lesson, a RIO is a topic composed of subtopics (definitions, examples, tables, etc.). Finally, the Cisco model considers each level of aggregation as a learning object.

4. GRANULARITY AND ADAPTABILITY

In the field of ALS, adaptability relates to the capacity of these systems to automatically adapt the learning process to the specific requirements and preferences of a particular learner. There are several models of adaptability [5, 23]. In this section we are interested in a specific dimension of adaptability which is usually omitted in literature. This dimension deals with the influence of fine-grained content on the adaptability and individualization required by the dynamic adaptive hypermedia for learning.

4.1. Fine-Grained Content

The granularity is a process that involves breaking down the digital content into smaller chunks or elementary blocks that have a pedagogical sense, also called grain. These grains can be re-combined and assembled to create coherent educational courseware. The way of decomposing this content differs from one model to another. Thus, as we showed in the context of content models (see Section 3); the most used technique is the aggregation. The concept of "granularity" is almost modest, except for some works such as [9, 11, 12, 14, 15, 16].

These authors were interested in the conditions and the valid criterions for determining the type and the level of granularity to be considered. For Wiley [11], the granularity of a LO depends closely on the context in which the granule will be inserted. Other authors such as Polsani [12] argue that the granularity depends on the size of a LO. But the size designated by the author can not be expressed in terms of bytes or duration of a LO. Size here refers to the number of ideas that a LO can transmit.

Generally, a LO must transmit one or few ideas. In the case where a LO consists of several ideas, one of these ideas may be primary and the others derive or depend directly on this one. The "fine grained" is then to combine both the concept of *meaning*, *idea* and *size* as unifying principle, which frees the LO of any consideration related exclusively to the size such as time or the subjectivity of the designer.

4.2. Adaptability and Granularity

The granularity of LOs is a key factor to allow aggregating and organizing content, to adapt the instruction to the preferences of a given learner. An insufficient granularity (using for example *large blocks of contents*), probably prevents the possibility of integrating educational content in new contexts and new ALS. On the other hand, the fact of splitting up contents in several LOs of small size with a main idea, allows several options for adaptation.

The first possibility is to aggregate and arrange multiple objects to create other more consistent and reusable objects. The second possibility is to build and customize a LO by proposing several presentations with different computer interfaces. Another possibility implies a classification of LOs into classes of objects (for example theorems, definitions, etc.), which makes it possible to filter them more easily, improve research and thus to individualize the content.

In addition, the granularity combined with the indexing plays an important role to facilitate the adaptability. Indeed, instead of adding meta-data to big blocks of contents, learning objects of "fine granularity" (as defined in 4.1) are indexed, which increases thus the research space. This distinction also helps to increase the possibilities of finding the most adapted elements to a specific situation. It also allows annihilating the silence of the research, which can be due to an insufficient granularity.

The adaptability here then consists in choosing between the various grains those who are appropriate to a given situation.

To show the correlation between the granularity and adaptivity, we propose in the next sections a learning objects model allowing a flexible representation, respecting the standards and capable of building contents in a dynamic way, from basic fragments, from the representation of the domain and the model of the learner.

5. BUILDING A FINE-GRAINED CONTENT MODEL

The suggested model in this section is not specific to a field of particular training, although it was conceived for the learning of the computer programming languages, for the novice learners. It will thus present a structuring in terms of grains of contents (Fragments, Multimedia Bricks, etc), as well as the concepts of the aimed domain.

5.1. The Learning Objects Model

To enable a granular structuring of the content, by applying the principles introduced earlier, we've broken down our content model in two complementary levels: the *logical level* and the *semantic level*.

- **The Logical level** (Figure 1) corresponds to the structural organization of the contents. In this level, the central concept is that of *document*. A document can be a document of course or an additional document (coming for example from an educational store). A document of course can be generated starting from a set of *fragments* composed of different learning objects (introduction, evaluation, exercise, synthesis, remark, motivation, definition, and example). Each one of these fragments is described by *multimedia bricks*: text, image, sound, video, simulation, animation, etc. We will note that each fragment makes it possible to achieve an educational goal related to a concept of the training area considered.
- **The Semantic level** is composed of the various meta-data which make it possible to describe the various fragments. Here, we used some elements of the Educational section of the LOM standard.

A fragment is described by descriptors such as: type (exercise, example, definition, etc), the type of interactivity (active, expositive, mixed and undefined), the level of difficulty (easy, medium and difficult), the estimated time, the list of multimedia bricks, context of use (one or a combination of concepts). Finally, other attributes belonging to the general description of a fragment have been introduced such as ID, title, author, language, keywords, and pre-requisites. In addition, each multimedia brick is described by other descriptors such as: size, format, identifier of the fragment, and the physical localization.

5.2. The Model Of The Domain

The domain model we propose is represented by a concept graph and relationships between these concepts (Figure 2a). We recall that the concepts are the knowledge to be acquired by the learner. Each concept is connected with fragments themselves pointing multimedia bricks. This model could be instantiated according to the concerned domain model. The relations between concepts can be of different types. The relationship of *pre-requisites* for example indicates that learning a concept A is subject to the control of the concept B which precedes it. The *composition* means that the description of the parent node is performed using the description of its components. The union of all the components forms a generic concept. *Generalization* expresses that a node represents a generic concept and its successors describe the subclasses of this concept, i.e. more specific concepts.

In the simplest learning domains, only the relation of pre-requisites is taken into account. Thus the graph (Figure 2.b), defines a taxonomy of simple concepts without composition, nor generalization. The traversal of this graph is done from top to bottom and from left to right (i.e. the Depth-first Search). Thus, the C1 concept constitutes a pre-requisite of the concepts C2, C3 and C4. But as there is an implicit pre-order relationship, the traversal of the graph will take into account the precedence relations, which goes from left to right. Thus, the presentation of the contents will be done as follows: C1, C2, C5, C6; then C3; then C4, C7 and C8.

Figure 3 shows an example of the domain of computer programming, including the three first-level of knowledge or concepts, with relationships of a pre-requisite, composition and generalization. Reading and interpretation of the model is done in depth.

Thus, the concept "C_Instruction" is a generalization of three types of instructions: an instruction of the type input / output, an assignment statement and a control instruction. A control instruction is either a conditional statement or a repetition again it is a generalization. The assignment consists of the concepts of variables, operator and expression, it is a composition relationship.

Table 1 - presents in an equivalent way the same relation of pre-requisites, in the form of binary matrix. The advantage of this representation is that it is easily comprehensible, easy to handle and to compute by machines. In the matrix, the lines represent the pre-requisite of columns. Thus, the first line expresses the fact that C1 is a pre-requisite of C2, C3 and C4. Line two expresses the fact that the C2 concept is pre-requisites of C5 and C6.

Table 1. The pre-requisites relation represented as a binary matrix.

	C1	C2	C3	C4	C5	C6	C7	C8
C1	0	1	1	1	0	0	0	0
C2	0	0	0	0	1	1	0	0
C3	0	0	0	0	0	0	0	0
C4	0	0	0	0	0	0	1	1
C5	0	0	0	0	0	0	0	0
C6	0	0	0	0	0	0	0	0
C7	0	0	0	0	0	0	0	0
C8	0	0	0	0	0	0	0	0

6. A USE CASE OF THE CONTENT MODEL

The global architecture of AHS proposed in the literature must have three essential parts [20]: *the user model*, *the domain model* and the *adaptation model*. The collaboration of these parts or agents can lead to produce, dynamically coherent, personalized courseware to the learner. To achieve the height level of adaptivity, some generic processes are required. We present briefly in this section two main processes, in connection with the learner model.

6.1.1. Determination of a learning objective

The first element to be determined is the objective of a session, composed of one or more concepts (Figure 4).

In the simplest case, when a learner interacts for the first time with the system, the list of the *acquired concepts* is empty. The concepts that have no pre-requisites in the graph of the concepts and have not been acquired will initialize the list of the *active concepts*, which enable to choose the objective of the session.

Some elements of the learner model can influence this decision. These considerations come from the background knowledge and skills of the learner represented in the learner model like the level concerning the *programming languages* (beginner, intermediate, Expert), or the *background knowledge* composed of a set of programming concepts (variables, decision-making code, loop structures, procedures and functions, data bases, etc.). Some pedagogical rules for such a decision are applied.

6.1.2. Assembling a course

The choice of one or more concept(s) associated with other information coming in particular from representations of the learner, determines a sequence that will then be derived in fragments (Figure 4). If, for example, the model of the learner indicates that he (she) prefers to learn by examples, the sequence will consist of more examples. For exercises, the difficulty level will depend on information extracted from the model of the learner corresponding to his level (Beginner, Intermediate, and Advanced).

This sequence corresponds to a prototypical sequence of fragments to achieve the selected learning concept. For each fragment of this sequence, the system associates a multimedia brick, still according to the model of the learner. If the learner model indicates for example that learner prefer pictures and videos, the system will promote anything that is multimedia. If he (she) prefers reading on the screen, the text associated with fragments will be used to create a course document.

7. CONCLUSION

Following the various points presented in this paper, we hope to have posed a first outline of the importance of the granularity of learning objects for the adaptability and the re-use of the learning contents.

This paper sought to specify the fine granularity, by examining some work coming under the field oh AHS, as well as the standards suggested in the literature.

We also presented an outline of a model of content which we designed respecting the various characteristics of the stated granularity. The first advantage of this model is its *hierarchical structure* in the form of “grains” of contents which respect the specifications of the existing standards (LOM, SCORM, etc.). Another advantage lies in the fact that the same fragment or a multimedia brick could easily be re-used in several documents or then directly in another context of learning. We can also note that the model suggested is open. It can indeed employ the proprietary format of the contents, or import it from the web. Moreover, the granularity combined with indexing plays an important role in facilitating adaptability. Indeed, instead of adding metadata to large blocks of educational content, small size granules are indexed, which enlarges the search space. This will also destroy the silence of research, which may be due to an insufficient granularity.

We stressed on the importance of the pedagogical meta-data and the capabilities which they provide for learning resources description, as well as for facilitating learning materials research and therefore individualizing the educational content. Each unit of information (or grain) is described by meta-data file that defines its ID, title, author, language, keywords, and pre-requisites. Other attributes like the type of the unit (exercise, example, definition, etc), the level of difficulty (easy, medium and difficult), the estimated time, the list of multimedia bricks, etc; facilitate the comparison with learners’ preferences. Thus, the most appropriate learning content may be delivered to the learner in flexible and adaptive manner.

We can highlight some correlation of our model compared with recent work focusing on adaptability in dynamic adaptive Hypermedia. We emphasize in particular the work on the project Medyna [21] and work related to the assembly of existing resources by using graphs and decision operators [22]. Our model is also inspired by the work of Brusilovsky [23] for concepts graphs and the relationship between concepts, fragments and multi-media bricks, with a distinction related to the meta-data used and the techniques of assembly and adaptability.

Finally, it is certain that several aspects of these problems still remain to be developed to allow the design of complete curricula. Future work is related to extend this model and the associated prototype to evaluate the system pragmatically.

FIGURES:

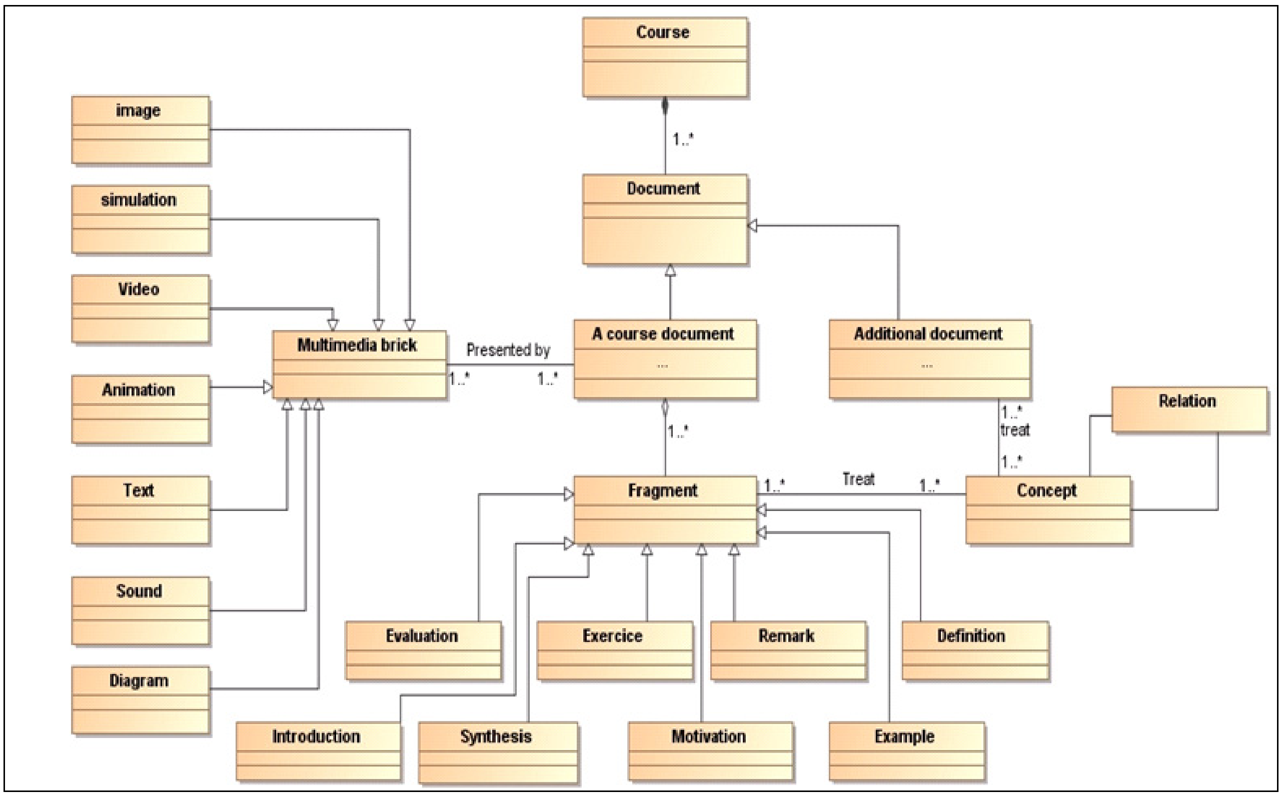

Figure 1 – Structural Architecture of digital Learning Objects Granules.

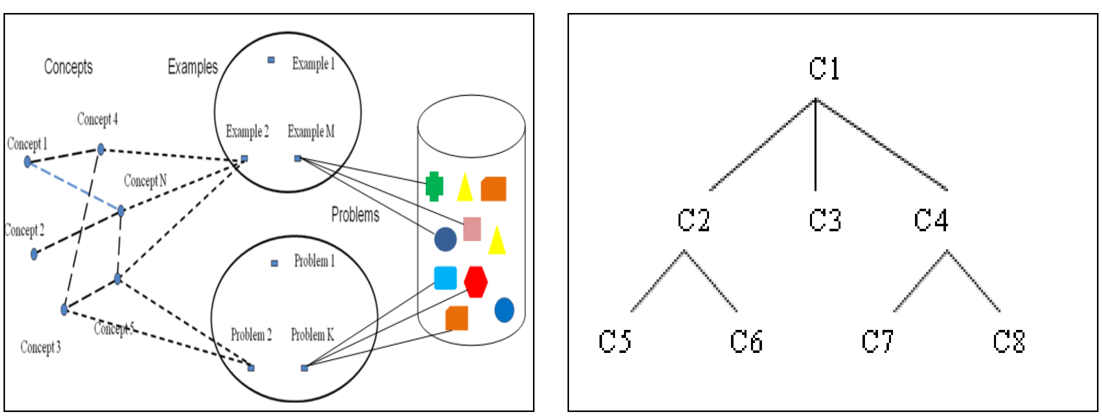

Figure 2 – (a) Representation of the learning domain (inspired by work of Brusilovsy (2000), (b) The Learning concepts graph.

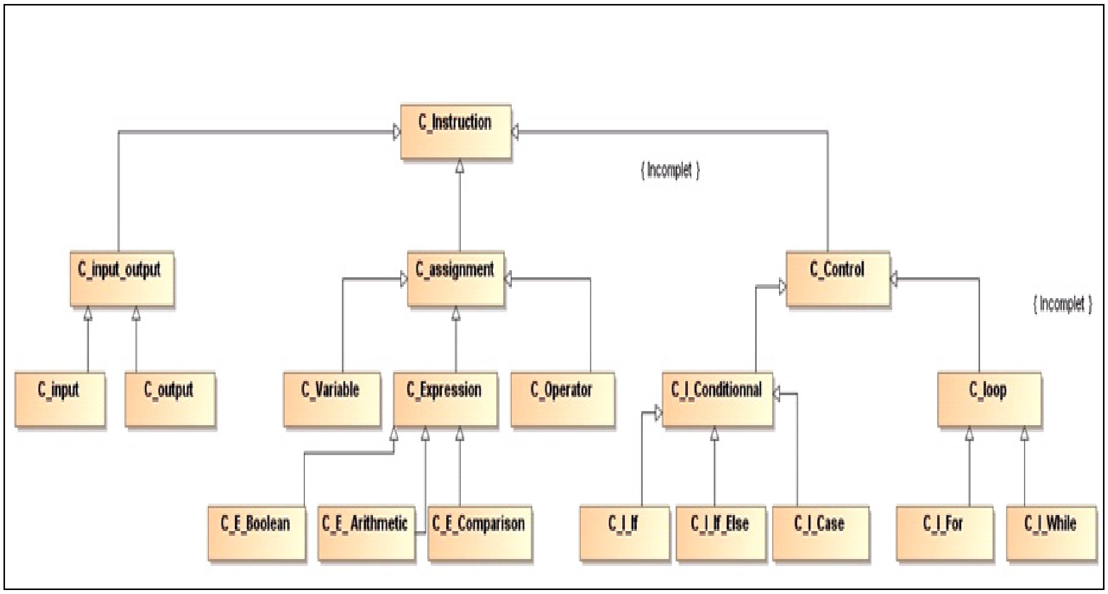

Figure 3 – A graph of learning concepts for computer programming.

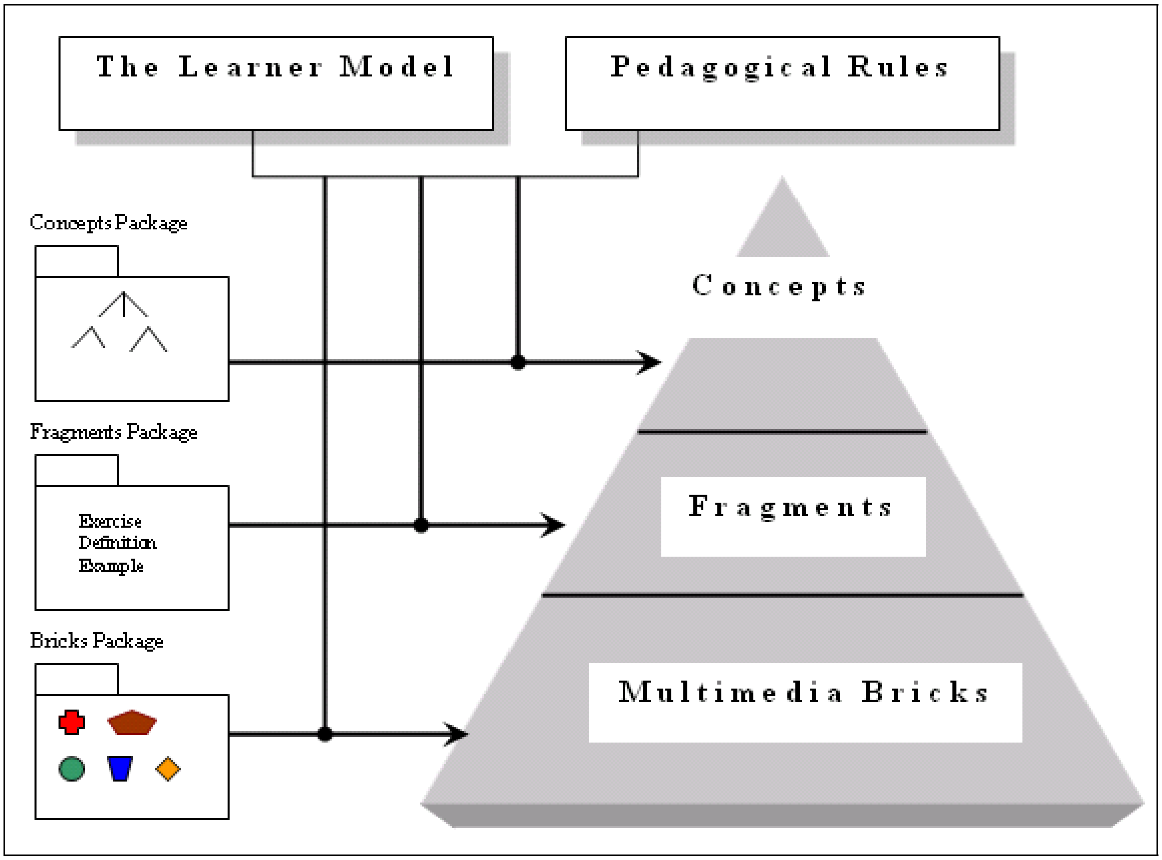

Figure 4 – A part of the process of assembling courses.

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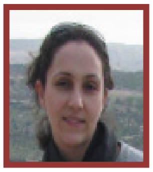

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