

# Design of the Semantic Models of an Educational Domain

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## Abstract

*The paper develops a topic of the semantic modeling an educational domain. A part of the normative student model determining domain knowledge is a subject student model. The subject student model picks out the educational domains from all the multitude of the domains, so the subject model is a model of an educational domain, or a model of a subject. The subject student model is a part of it and consists of five components. The thematic subject student model represents demands to the curriculum of the subject; the functional one does demands to the students' knowledge; the operational one does demands to their skills, and the semantic one reflects the content of the domain. On the basis of the semantic subject student model, a subsequent semantic structuring the educational domain is carried out. The mechanism of it is construction of the associative and semantic nets.*

## 1. Introduction

One of the main tasks of education is elaboration of teaching standards. In modern terminology, this work deals with student modeling. In a wide sense, the student model means all information about students that is used for the teaching process organization. It is a great number of the exactly represented facts about students that describe different aspects of their state: knowledge, personal characteristics, professional qualities and so on.

There are three standpoints from which student modeling can be considered. Firstly, it is knowledge about which student is; secondly, it is knowledge about student, we want him/her to be; and, at last, knowledge that we can see the student. Data of the first type we can get from examination of student behavior in the educational process, so we can call them the behavioral student model. It changes together with the student, so it is called the dynamic or current model. Diagnosis is the process of the student model design [1].

Knowledge about what student is to be seen, that is, requirements to the student final state (as to a specialist) is called normative student model. Properly this kind of

knowledge determines the purpose of studying. Among these are, for example, requirements to the personal qualities of the future specialists, their knowledge and skills in different subjects, characteristics of their physical or psychical states, etc. So, the final purpose of the education is to achieve such a state when the behavioral student model coincides with the normative student model.

The third viewpoint is based on the idea, that, in general case, there are diverse ways, or trajectories, along which students can move during their educational process. On the one hand, these ways may be correct due to right actions of students. Such ways can be foreseen by normative student model: for example, using of different strategies and decision methods for solving the same problems. On the other hand, different ways of behavior can be conditioned by erroneous student acts, and teacher can oversee many of their errors. Teacher's work on determination of possible student errors is extremely useful from the standpoint of didactic (we learn from mistakes!). Set of these errors forms a specific student model called the buggy model [2].

The part of normative model that determines subject knowledge or knowledge in a subject, is called the subject student model [3]. So the subject student model determines content of subjects. In knowledge engineering, such knowledge is called the expert knowledge, or the model of the domain. The subject model picks out the educational domains from a great number of different domains, so it is the model of an educational domain, or the model of a subject. The notion "subject student model" allows to do the student modeling finished, because this notion unites all the aspects of the model's design (what student should be, what student is, what student can be). It is especially justified because design of an educational domain substantially differs from the design of other domains. The fact is that purposes of modeling educational domains and not educational ones are different. Any activity is carried out by the way of problems solving, and these problems are specific for different activities. In industrial, research activities the problem solving results, are their straight products, and, thus, the activity aims correspond to a fact of the problem solving, or solutions.

According to the activity approach to education, the educational aims consist of forming the acting mode. In other words, a result of solving of educational problems in itself has no pragmatic interest; the only requirement to it is to be correct. The problem solving process represents the main importance, since the acting mode is forming in the course of it. This thought explains distinctions in the model's design aims. Model's design of not educational domains has to provide publicly meaningful results, model's design of educational domains does process of problem solving. In order to teach person some activity, it is necessary to distinguish all actions of this activity, and in each action does all operations that provide success of this action. One of major problems of student modeling concludes in this. Model's design of not educational domains does not have such a problem.

In work [4] it is shown, that five component of subject knowledge can be picked out and, according to them, there are five components of subject student model: thematic, functional, procedural, operating, and semantic. Thematic model shows about what subject knowledge are; functional model determines what functions the knowledge carries out; procedural model describes the order and character of the domain's objects transformation; operating model sets all skills that must be formed during teaching; semantic model determines semantic part of subject knowledge (declarative knowledge).

In this paper a semantic model's design of educational domain is described.

## 2. Semantic subject student model

Semantic knowledge in different subjects is contained in textbooks, teaching manuals, other educational literature. Each kind of educational literature, in some sense, is the model of this subject. The textbooks are the most extended models.

From the standpoint of didactic, there are two parts in the contents of any textbook [5]. To the first part belongs information that directly forms the contents of a subject, the subject knowledge, or CON-1. The second part, CON-2, contains information, serving CON-1 (for example, information from mathematics or other subjects, computations, interpretations, explanations), information about application and using CON-1 in other subjects, technique, life etc.

In textual knowledge sources (including textbooks), knowledge engineering picks out the primary supervision material, the scientific notions system, the author's thoughts and results of his/her personal experience, and also some «general places», or «water». Thus, it is possible to speak about CON-3 presented in textbooks along with CON-1 and CON-2 that mainly contains the

«water». Our practice of the semantic subject student models design shows, that sometimes, especially in textbooks on humanitarian subjects, CON-3 can achieve an extremely large volume.

Properly, exactly CON-1 forms the semantic model of the domain, or the semantic student model. However this knowledge in textbook is not picked out specially, it is distributed over the textbook, it interlaces with other knowledge, and is not formalized.

### 2.1. Semantic facts

Semantic knowledge is the declarative component of subject knowledge, that is factual knowledge, since procedural one is realized by skills (operating knowledge). This way, in order to build some formalized semantic (rich in content) subject model on the basis of a textbook, it is necessary to pick out the facts from the textbook and group them.

The general questions of the presentation of the facts in teaching are considered in works [6]. The facts can be various by their structure, they can be complex or compound. However the elementary facts constitute a basis; they are united with different relationships and as a result they form the complex facts. For example, a physical fact «The process of change in course of time of mutual bodies regulation is called by mechanical motion», which is the mechanical motion definition, can be broken down into three simpler facts:

1. *time grows;*
2. *a mutual bodies position changes;*
3. *some process is called the mechanical motion.*

We can't decompose these facts into simpler ones and, therefore, they are elementary facts. Although they contain the subject terms, they have no subject sense, or semantics. The subject sense only appears when these elementary facts are united together. The simplest by its composition fact having a subject sense, was named as a semantic fact. A semantic fact is always a finished and simple thought being expressed by one sentence, or statement. Properly, the semantic facts play the role of the domain knowledge units because the finer portions of this knowledge have no subject sense.

The above-mentioned definition of mechanical motion is a semantic fact. Moreover, any notion definition is a semantic fact. But not only definitions are semantic facts, they have different meaning. Notions, phenomena, processes, laws, theorems, inferences, causes, consequences, properties, signs, models etc. can be the subject of semantic facts.

### 2.2. Semantic synopsis

The full set of semantic facts composed in the material

study order is the semantic subject student model. It is called semantic synopsis. Hence, a semantic synopsis is the full set of laconically represented thoughts of the domain. Published separately, it forms a very thin brochure because there are no computations, proofs, and explanations in it. Nevertheless, it contains all the regulations of the course being studied. For user's convenience the synopsis can be broken down into some thematic headings.

All the semantic synopsis statements have their numbers. Each statement has a number, consisting of two parts, parted by the point. The first part is the number of a heading to which a given statement belongs; the second part is the number of the statement in the given heading. Besides, there are some numbers after statements. These numbers point on the statements, which determine the given statement, on which it depends, from which it follows. Intercourses between the statements can be very simple, for example, references on terms that are used in the given statement, and more complicated, deep, for example, cause and effect. These intercourses, conceptually, define a structure of subject knowledge, determine development of the subject, the formal logical reasoning scheme, and students have to fill it with its concrete maintenance. This circumstance helps to increase the teaching efficiency by using semantic synopsis.

To summarize briefly, we would like to mark that the semantic synopsis is extremely useful and for the teacher. Firstly, teacher can actively apply a synopsis in the teaching process; secondly, work on synopsis gives teacher new pictures of the subject.

It is important to say that composing of semantic synopsis is a very complex (although and thankful) work. It requires deep knowledge of the subject, abilities to analyze, synthesize, and summarize the teaching material from the teacher. Such a work makes teacher to consider each sentence, each thought stated in textbooks. At the beginning of this work, one can open with big surprising how in exactly and improperly many notions and statements are formulated in textbooks and other literature and how these inaccuracies get across from one book to another without changes. In general context this does not stand out, but often becomes obvious if attention is paid on a concrete statement.

### 3. Domain semantic structuring

An important step of the determination of a structure inherent in knowledge is construction of models in which objects forming this structure are picked out in an explicit form. The concept of the semantic net lies in the ground of such models. It consists of tops that are concepts (objects, events, processes, phenomena and so on) and arcs, joining the tops, that are relationships between the

concepts. Process of building an associative net foregoes to one of the semantic net. Arcs of the associative net do not yet represent interpreted relationships and just indicate the present of the connections. An associative net transfer into a semantic net by means of successive understanding (interpretation) impersonal connections between the concepts.

### 3.1. Associative net of concepts

In work [6] the questions of subject domain modeling by means of associative net are considered. The associative net is a hierarchical structure, and intercourses in it are represented by the production rules. Let's consider the most important results of this work.

To form a new notion, students have to possess some initial knowledge. The educational process is usually organized in such a way, when the beginner studies a new object, already on possessing knowledge, that is sufficient for the first subject notion formation. This knowledge has domestic nature, or the student draws it from popular literature or from other domains. Notions, forming these knowledge, are called the notions of the zero level.

Basing on these notions, student begins to study the subject, so, he/she forms some simple subject notions. These notions are formed on the basis of the zero level notions; they are called the notions of the first level. After mastering the first level notions, student can master more complicated subject notions with the help of the zero and first level notions. So, notions of the second level appear. Going on with such reasoning, notions of the third, fourth and so on level can be defined. So, the process of the notions forming is hierarchical, and a hierarchical notions structure of any object can be built.

For example, definition "Rectilinear motion is the motion having a straight trajectory" has a structure (Figure 1):

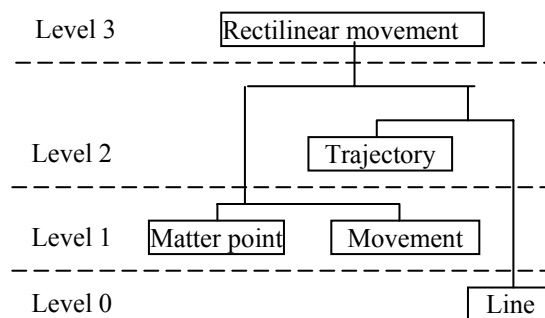


Figure 1. The "Rectilinear movement" structure.

Let's consider the described structure in more details. In work [6] only definitive intercourses between notions of a subject domain were considered. To establish and present connections in an associative net, consisting of

notions, it is convenient to use the knowledge presentation production method. Knowledge, represented by the production method, is clear; easy for reading and understanding. The rules, expressing the independent knowledge "pieces", are independent; it is easy to trace a rules chain that is used for inference. The above given example has such an appearance by using the production method:

IF material point - state - motion  
 AND trajectory - kind - straight  
 THEN motion - name - rectilinear.

In this representation, facts of the conditional part contain notions "material point", "motion", "trajectory" and "straight". These facts, by means of copula "AND", form notion "rectilinear motion". This way, this production rule allows moving from the second notion level (trajectory") to the third one ("rectilinear motion").

Notion "rectilinear motion" is a complex fact and it consists of three elementary ones given as triplets:

- fact 1: material point - state - motion;
- fact 2: trajectory - kind - straight;
- fact 3: motion - name - rectilinear.

### 3.2. Semantic net of semantic facts

Going on with design of the domain model, let's consider not only the notions definitions, but all the semantic facts that represent the main contents of a domain, that is, laws, theorems, principles, postulates, consequences, signs, etc.

Semantic facts also can be represented as an hierarchical structure as it was done for physical notions above. Besides, it is necessary not only to set a presence of logical connections between the facts, but also to define the nature of these connections. This structure is a semantic net, and it is built on the basis of the semantic synopsis.

In Figure 2, a part of semantic net «Kinematics. Basic notions» is represented as an example. The numbers conform to the numbers of the semantic facts in the semantic synopsis. The following designations are accepted for the semantic fact kinds and the connections character as Figure 3 gives that. Here there are only designations for the indicated part of the semantic net. In other parts of the subject, some new fact types and ties between them can arise, so, the designations list is not finished and can be continued.

The use of the semantic domain models opens wide possibilities both for teacher and for student. Their analysis allows planning maintenance of the teaching material and sequence of its exposition according to the teaching aims. Using semantic model, it is possible to reduce the teaching material volume without making harm to its logic and availability.

Analysis of the semantic net allows picking out all the lower levels facts, without which it is impossible to study a given part of the course. This way the exposure of the intersubject connections take place.

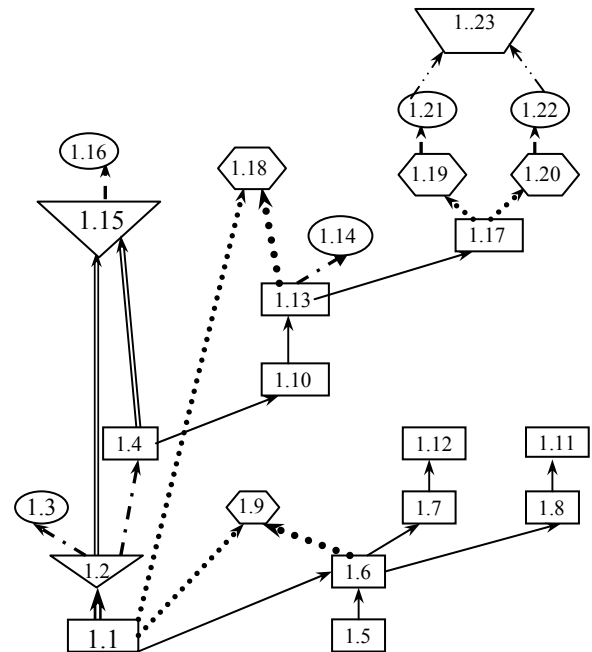


Figure 2. The semantic net for a part «Kinematics. Basic notions»

Logical links indicate what receptions of logic thinking students should have. For example, students have to conduct phenomena classification by some sign (the motion classification according to the form of its trajectory and the nature of the speed change), to make the logical inferences and so on.

Students, that have already got some knowledge and skills in given course part, with the help of semantic

	Determination
	Consequence
	Clarification
	Classification
	Generalization
	Determination
	Investigation
	Classification
	Classifying sign
	Clarification
	Generalization

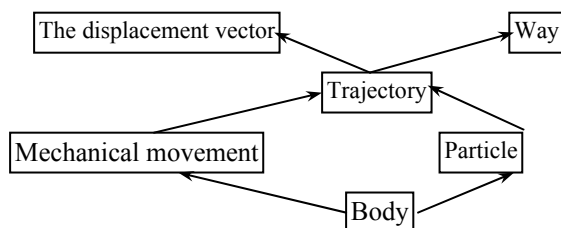
Figure 3. The designations for the semantic fact kinds and the connections character.

net can put in order, fasten their knowledge and form an integral physical presentation. Novices can use the net for orientation, as tourists use the maps of an unknown territory. The facts will serve as key points, and intercourses between them will define direction of motion to aim.

Besides, semantic net can serve as an actions position-finding basis for physics questions and when solving physical problems.

Let's give an example. The question is: "Whether can a way of body be equal to displacement? If yes under what conditions is it possible?"

Let's build a semantic net for the question, originating from his formulation. It is represented in Figure 4.



**Figure 4. The semantic question net.**

It is evident from the net that all terms mentioned in task are related with notion "trajectory". This is very important, because trajectory is not mentioned in the question.

Using definitions or notions from the semantic synopsis, students may reformulate the question in the following manner: whether can trajectory length be equal to the module of the vector, connecting its beginning and end.

Now, students need only general logic skills to answer this question. The trajectory length of a body can be equal to its displacement if a trajectory is a straight line and the body moves straightly without turns. So the use of the semantic net helps students to orientate while answering the question. It is a scheme of the actions position-finding basis [7].

#### 4. Conclusion

In opinion of students as well the teachers applying the semantic modeling in teaching, the semantic synopsis and semantic structuring turned out to be an effective means

of students' work on fixing the teaching material, on preparation to seminars and laboratory studies. The synopsis helps to get a clear idea about the material structure, to pick out and to memorize the substantial moments. Besides, the knowledge "survivability" increases substantially. Students mark that synopsis is very helpful during preparation to exams when there is a danger not to pick out and master the main ideas because of plenty of information. Using the semantic synopsis during semester (work with it does not require much time), students remember all the course statements. When exams come, they have a frame of the course and can quickly fill it with the necessary knowledge.

Such a modeling allows planning, organizing, and guiding the instructional process more productively, working out new kinds of the learning activity.

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