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Towards an Ontology of Biomedical Educational Objectives

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Abstract

The domain of medical education combines educational objectives and cognitive functions with the subject-matter of organism structures, functions and malfunctions as well as diagnostic and interventional techniques.

A re-structuring of learning objectives guided by principles of ontology seems promising as this gives the means to compare, classify, and validate learning objectives using formal methods.

Although large parts of the subject-matter of medical education are already covered by existing biomedical vocabularies, there still exist several challenges for designing an ontology of educational objectives. Emphasis is given to the representation of plans and cognitive entities on the one hand, and on prototypical "blueprint" entities on the other.

Introduction

A high-quality education of undergraduate and graduate students as future health professionals is a cornerstone for the sustained delivery of high quality and effective health services. Formalization and standardization of educational content can be an important means to reduce the complexity and inconsistency in this highly dynamic field with its rapidly emerging and evolving contents.

Educational objectives are the core of every proficient teaching and learning assessment process[1]. For over 50 years educational objectives have served as "explicit formulations of the ways in which students are expected to be changed by the educative process"[2]. Given this important function, in medical education, a large number of educational objectives have been collected in catalogues, either on a central basis for a group of medical schools[3] or on a local basis for single institutions.

Despite the laborious effort to compile large bodies of educational objectives, the targeted audience – teachers, learners and curriculum developers – has had limited benefit. It is difficult to access the tremendous amount of educational objectives in a certain subject-matter in any practical way: Subject-matters in a medical curriculum are as diverse as the expected knowledge and skills of the future professionals, covering the whole range of pre-clinical and clinical disciplines. Curriculum content also includes teaching-related factors such as contact hours or specific learning aids.

Up to now, learning objectives have been published in narrative form without any reference to standardized terminologies. As a consequence, their content is subject to different interpretations. Further, their arrangement in hierarchies is intuitive but informal, e.g., the Taxonomy of Educational Objectives[4]. As a result, in current practice, the sequence, consistency and coherence of the complex structure of a compilation of learning objectives within a curriculum can neither be exhaustively checked nor displayed in a principled fashion.

This is the reason why we propose to follow principles of formal ontology for the representation of learning objectives. This *Ontology of Biomedical Educational Objectives* (*OBEO*) is intended to support tools for annotation, consistency checking, and navigation within educational objective catalogues. We propose to align this ontology with an upper-level ontology, like DOLCE[5], and also link it to established biomedical terminologies and ontologies. Here, SNOMED CT[6] would be the first choice due to its high coverage of the clinical domain and being an accepted standard resource. For the basic biomedical sciences, several OBO Foundry ontologies[7] would constitute a useful completion as the most prominent ontological source in this domain.

The Function and Structure of Learning Objectives

The formulation of educational objectives plays a central role in the development of a medical curriculum by addressing the needs of the learners[8]. The importance of educational objectives becomes obvious in the scope of their different roles in the educational process[1].

Educational objectives provide

- focus for instruction,
- guidelines for learning,
- targets for formative and summative assessment,
- instructional intent to others, and
- possibilities for instruction evaluation.

Today, educational objectives are usually placed as intended learning outcomes at the final stage of an instruction process which allows assessing the

students' performance after the learning process. Defined in such a way, educational objectives represent clearly what is expected from the students *after* the training, e.g., through demonstrating knowledge, performance in psycho-motor or communication skills, or even in the complex behavior associated with certain attitudes.

Educational objectives in a medical curriculum are typically formulated as follows:

- *The physician is able to assess a patient presenting this problem* [from a list of given medical problems] *in a well-structured way, and to establish a differential diagnosis.*
- *She/he is able to propose appropriate diagnostic, therapeutic, social, preventive and other measures, and to provide urgent intervention in case of life-threatening problems.*[3]

This learning objective states *who* will do *how much* (or *how well*) of *what*. Thus a learning objective statement comprises an *agent* (usually the learner) who performs a certain *action* which indicates a defined *performance level* to proof his or her acquired *knowledge*, *skills*, or *attitude* towards some given *subject*.

Using the BioTop domain upper-level ontology together with the DOLCE upper-level ontology[5] and the OBO Relation Ontology[9], we can express a learning objective as a *goal* represented by a *biotop:immaterial-nonphysical-entity*[a] and which is part of some *biotop:plan*. Since many different things can constitute an *obeo:learning-objective* in one context but not in another one, we express this by introducing the *obeo:learning-objective-role*. The learner is an instance of *biotop:human* who is *ro:agentIn* in a *biotop:action*, as defined in the *obeo:learning-objective* and in whom it is *internally represented*. For the existence of an *obeo:learning-object*, the *biotop:action* does not need to be instantiated but it can be *only obeo:realized-by* the specified *biotop:action* (cf. Fig. 1).

Complex relations exist between the type of action to be performed by the learner and the type of subject. E.g., there are subtypes of *biotop:action* for the cognitive domain, *such as obeo:remembering*, *obeo:understanding*, *obeo:applying*, *obeo:analyzing*, *obeo:evaluating*, or *obeo:creating*. This can be represented as a hierarchy of cognitive actions[2, 4].

To broaden the view on educational objectives as intended learning outcomes, a list of possible learning outcomes is given according to[10]:

- reactions to learning,
- modification of attitudes and perceptions,
- acquisition of knowledge and skills,
- behavioral changes,
- changes in organizational practice, and
- benefits to patients.

In this context, educational objectives can be defined more generally in terms of professional conduct or competencies a health care professional should exhibit, as well as more specific tasks a physician is expected to perform in respect to the medical domain.

Reference to the Subject-Matter in the Definition of Educational Objectives

The large body of educational objectives in medicine is related to well-defined medical topics as those covered by a broad range of biomedical vocabularies.

Therefore, an educational objectives ontology will have to include or to refer to existing terminological and ontological sources in order to cover the subject-matter of the domain knowledge and skills to be demonstrated or performed. Important features for the definition of specific medical educational objectives are anatomical and biomolecular structures, etiology, epidemiology, clinic, and diagnostic features of diseases, clinical pathways, diagnostic and interventional techniques, etc.

Although most of this content is already covered by current biomedical ontologies, terminologies, and classification systems, e.g., SNOMED CT, ICD, OBO, their inclusion into the definition of learning objectives leads to new ontological challenges, as there are major differences between the standard usage of domain ontologies and their usage in the context of describing learning objectives:

- In the standard approach, ontology classes are instantiated by particular objects or processes that have a concrete spatiotemporal existence. For example, the rationale of having a class *snomed:influenza* in a clinical ontology is to describe what is *universally true* for all instances of this class and what, consequently, can be asserted for each individual influenza that instantiates this class.

[a] *biotop* identifies classes and relations from BioTop, *obeo* classes and relations from the Ontology of Educational Objectives (OBEO), *dol* classes and relations from DOLCE, *snomed* concepts from SNOMED CT and *ro* relations from the OBO Relation Ontology.

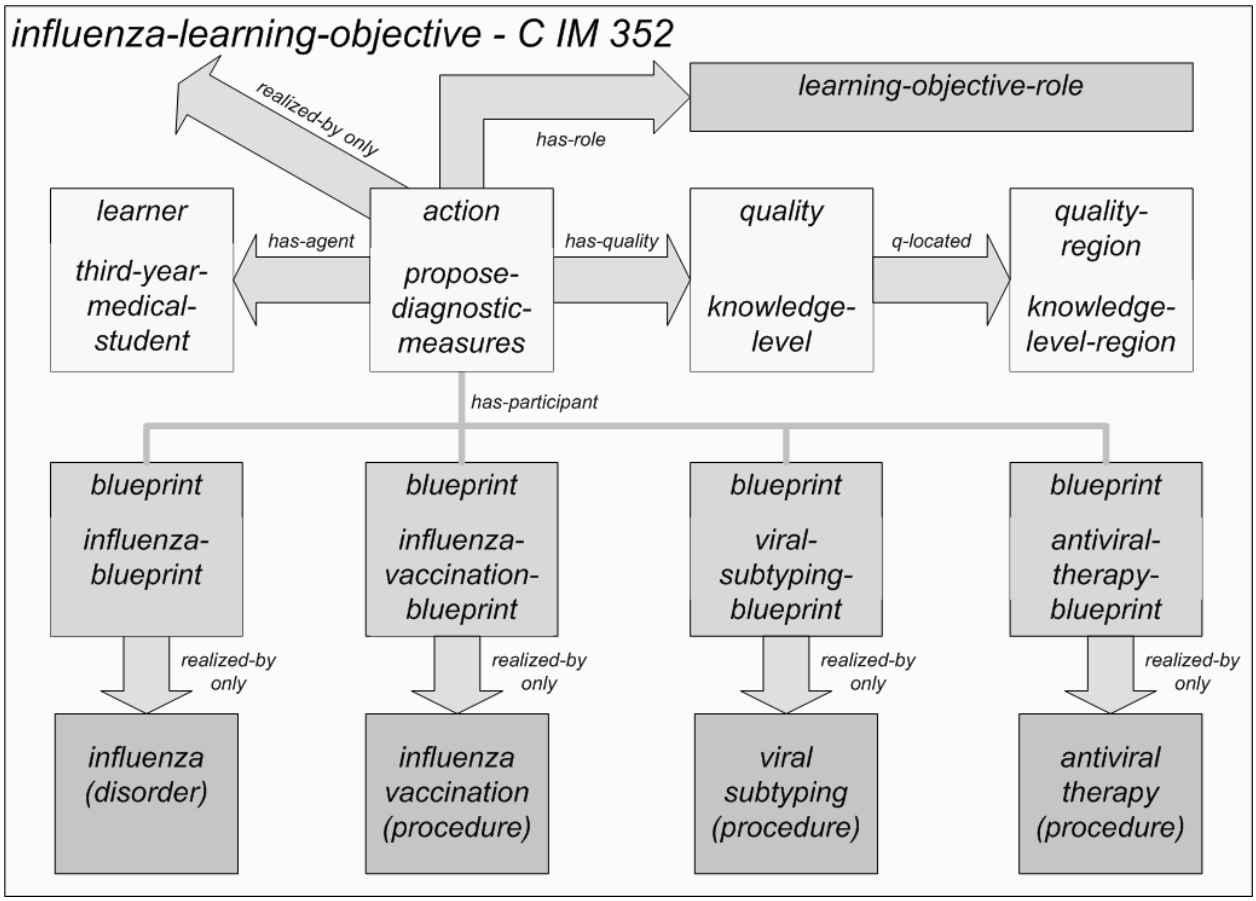

Figure 1: Displayed is a part of a complex *obeo:influenza-learning-object* which can be instantiated *only* by a *biotop:action* with several *biotop:qualities* and the *biotop:role obeo:learning-objective-role*. Biomedical concepts are linked via *oboe:blueprint* classes which are abstractions of concrete medical entities referred by standard terminologies/ ontologies. Blueprints can be tailored to the specific needs in the learning-objective, e.g., by the extension of a subset of the subclasses.

- But if *influenza* is referred to in an educational scenario, the focus is, on the contrary, to convey what is *typically true* for an influenza. So, instead of referring to concrete instances of *influenza* of concrete patients, the reference to *snomed:influenza* in an educational scenario targets a kind of "blueprint" of this disease, but not a class of really existing influenza instances.
- Such representational objects (blueprints of anatomical structures but also of disease courses, clinical protocols, etc.) can be tailored on a broad scale to the learning objectives and specific needs of the learners, thus existing on several levels of abstraction. For instance, a "heart-blueprint" for a gross anatomy course in a medical school will include the ramifications of the heart's electrical conduct system. But this is probably not the case in an introductory course on human biology at high school level. This, again, might be very different from the heart as a topic of pathological anatomy where it is likely to include the different congenital defects, as taught, e.g., in a course for pediatric nurses.

The general problem is to ascertain the ontological nature of blueprint objects and to formally relate them to classes in biomedical ontologies. In BioTop, blueprint objects are best classified under the type *biotop:immaterial-nonphysical-entity* which in turn is a subclass of DOLCE's *dol:non-physical-object* (formerly known as *dol:description*). Although not explicitly provided for neither by BioTop nor by DOLCE, we propose to relate blueprints to the related classes by the relation *obeo:realized-by* For example, we state that a *obeo:influenza-blueprint* is a *obeo:blueprint* that can only be realized by some instance of *snomed:influenza*. In OWL Manchester Syntax notation[11]:

obeo:influenza-blueprint equivalent-to
  obeo:blueprint and
    oboe:realized-by only *snomed:influenza*

Although not very relevant in an educational context, it should be noted that a blueprint object can exist

without ever being realized. This may be the case of a new therapeutic protocol, or the structure formula of a drug that has not yet been synthesized.

Classes like *obeo:influenza-blueprint* can be further specialized in terms of different ways of description, e.g., graphic, textual, etc., or different granularities as deemed adequate for each group of learners.

In any case we have to reject naïve models such as

oboe:learning-objective-I implies
includes some *snomed:influenza* (…)

This states that for each *oboe:learning-objective-I* at least one instance of *snomed:influenza* exists. But the educational objective certainly has not any specific relation to any particular disease instance of a particular person.

Conclusion

Summing up, the reference to biomedical ontologies in the context of creating an ontology for learning objectives requires new modeling patterns, because it is always the (prototypical) description of some type of domain entities which has to be represented in a biomedical ontology. In contrast to clinical ontologies, where process, procedure, or disease types are instantiated by particular patients with their particular diseases, operations, signs, symptoms and diagnostic parameters, these (particular) things are not of interest in an ontology of educational objectives. This motivates the introduction of a new type of entity, a kind of prototypical description we have termed "blueprint". Blueprint entities have not been subject to current biomedical ontologies, although some of them – above all the Foundational Model of Anatomy – show a clear (however not explicit) tendency toward this kind of representation.

As a second but equally important conclusion of this paper we emphasize the need to ontologically redesign the existing informal catalogs and taxonomies which are currently being used in medical education.

The OWL implementation of the ontology can be retrieved at http://purl.org/imbi/obeo.owl.

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