

Generating Answerable Questions from Ontologies for Educational Exercises: *Types of Questions and Templates*

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1 Design choices of templates

There are core choices for the template design within the context of ontology-based question generation in anticipation of their quality. For the templates themselves, there are four core options:

- Type A: Fixed template structure where one fills in the slots with the relevant variable (class, object property (OP), quantifier) fetched from the ontology, at that level of specification; e.g., *Is a [owl:thing] [owl:objectproperty] [quantifier] [owl:thing]? as template which could have an instantiation resulting in, e.g., “Is a cultural heritage object a member of some collection?”*.
- Type B: As Type A, but specify the category at least, especially for the OWL class; e.g., that it has to be a `dolce:process`, or a `bfo:continuant` (cf. `owl:thing`), so that for the template instantiation, it will pick that or any of its subclasses so as to broadly constrain the filler type. This is likely to increase the quality of the syntax and semantics of the generated questions. A foundational ontology is well-suited for this.
- Type C: As Type B, but tailor the template with the domain ontology vocabulary to some degree; e.g., select a high-level class from the domain ontology, e.g., `CulturalEntity` from `Cultural-On`, so that the considered slot of the template will only be instantiated with a subclass of `culturalon:CulturalEntity`. One may expect better semantics of the questions, but it comes at the cost of reduced generalisability across domain ontologies.
- Type D: Contextualise the templates based on the ontology vocabulary using NLG techniques, but do not perform tailoring of slots with any ontology vocabulary. This assumes that the question quality is more dependent on the linguistic realisation module of the NLG process than on the representation of the domain knowledge.

2 Types of questions and templates

The types of questions considered in this paper are adjusted from [1] and extended with questions from the Webclopedia QA typology [4] that is based on actual educational questions. They are also included in [3] and are shown to be

Table 1: Numbers of variants of templates by type of template.

Group of TQ	No.	Type of Questions (TQ)	A/B	C	D
Yes/No	<i>i</i>	Two classes and one property	4	6	6
	<i>ii</i>	Two classes, one property, and a quantifier	4	4	10
	<i>iii</i>	One Endurant and one Perdurant	4	4	1
True/False	<i>iv</i>	Two classes and one property	4	6	10
	<i>v</i>	Two classes, one property, and a quantifier	4	6	20
Equivalence	<i>vi</i>	Equivalence	2	5	3
Subclass	<i>vii</i>	Two classes and one property	1	4	5
	<i>viii</i>	Additional quantifier	1	1	10
	<i>ix</i>	One class and one property	4	4	4
Narrative	<i>x</i>	Narrative	2	2	6
		Total	30	42	75

suitable for education [8]. We chose this typology because its question templates are abstract (not domain-specific), which is appropriate for the generalisability purpose, and it is based on 17,384 questions and their answers.

Templates of different question types are specified, and each slot in the template is replaced by the appropriate class or Object Property (OP) or quantifier in an ontology. An example of study using this technique is “Inquire Biology” [2] which is a smart textbook that makes use of an ontology and template-based NLG to generate questions relating to the content. We selected DOLCE [7] for the Type B templates, but one could take another foundational ontology. For the Type C examples below, terms in Cultural-On are used but one can adopt other domains. Each question template is mapped to Description Logic (DL) queries to check that the generated question is answerable by the ontology. For Type D, we devised several templates (e.g., templates in active/passive voice and hasX OP naming format) for each type of questions.

Each type of questions has several variants of templates, such as the ‘category’ of the OP’s name or label (i.e., phrasing something in the present or past tense, active or passive voice) and article (‘a’ or ‘the’), and singular vs plural. Then, e.g., for Type D templates, when the fetched OP’s name is in the passive voice, the algorithm will select the template that has a slot that expects passive voice. Due to space limitations, we present only a few templates in the paper; all templates are available in the supplementary material.

The aggregate number of variants of templates designed for the three approaches are presented in Table 1. The different numbers of variants are due to peculiarities of the approaches, such as more tailoring with domain ontology vocabulary (hence $|\text{Type A/B}| \leq |\text{Type C}|$), and accommodating active/passive voice or not.

3 Question specifications

This section presents our 10 types of educational questions with their axiom prerequisites and templates. The examples of questions presented in this doc-

ument were generated from the ontologies: Cultural-ON [5] —Cultural ONtology: Cultural Institute/Site and Cultural Event Ontology— or AWO (African Wildlife Ontology) [6] by our third approach (Appr 3) with Type D templates and Algorithm 2. The details about the approaches are presented in the file: *Approaches.pdf*.

3.1 Yes/No Questions

These questions expect yes or no as answer. Since the ontology operates under Open World Assumption, the answer to a question is no only if the ontology explicitly states so. We have defined three different types of questions for Yes/No Questions.

Yes/No Questions with two classes and one property. (i)

Using Thing or any of its subclasses, the template “Does a X OP a Y?” can be generated if $X \sqsubseteq \exists OP.Y$ or $X \sqsubseteq \forall OP.Y$ (Answer: Yes), or if $X \sqsubseteq \neg \forall OP.Y$ (Answer: No). Template examples of this type are:

Type A template: *Does a [Thing] [OP] a [Thing]?*

Type B template: *Does a [Endurant] [OP] a [Thing]?*

Type C template: *Does a [CulturalEntity] [OP] a [Thing]?*

Type D templates: *Does a [T_Noun] [OP_Verb] a [T_Noun]?*

Does a [T_Noun] [OP_Verb_Prep] a [T_Noun]?

For Type B, Endurant or any of its subclasses can be slotted in [Endurant], and for Type C, CulturalEntity or any of its subclasses can be slotted in [CulturalEntity] if their axiom patterns are satisfied. For Type D, T_Noun states that the class name Thing is a noun, OP_Verb means that the OP name is a verb, and OP_Verb_Prep indicates it also has a preposition. For instance, Appr 3 with Type D templates and Algorithm 2 can generate the question: “Does an offer include a ticket?” from the axiom $Offer \sqsubseteq \exists includes.Ticket$.

Yes/No with two classes, one property and a quantifier. (ii)

The template: “Does a X OP some Y?” can be generated and results in ‘Yes’ if $X \sqsubseteq \exists OP.Y$, and ‘No’ if $X \sqsubseteq \neg \exists OP.Y$. Then, the template “Does a X OP only a Y?” results in ‘Yes’ if $X \sqsubseteq \forall OP.Y$ and ‘No’ if $X \sqsubseteq \neg \forall OP.Y$. Examples of templates for this type of questions are as follows:

Type A template: *Does a [Thing] [OP] [quantifier] [Thing]?*

Type B template: *Does a [Endurant] [OP] [quantifier] [Thing]?*

Type C template: *Does a [CulturalEntity] [OP] [quantifier] [Thing]?*

Type D templates: *Does a [T_Noun] [OP_Verb] some [T_Noun]?*

Does a [T_Noun] [OP_Verb_Prep] only a [T_Noun]?

where the token [quantifier] can be either ‘some’ (\exists) or ‘only’ (\forall). For instance, from the axiom $Site \sqsubseteq \forall hosts.Event$, Appr 3 can generate the question: “Does a site host only an event?”.

Yes/No Questions with one Endurant and one Perdurant. (iii)

Generating instances of this question type requires ‘participates-in’ relation within the ontology by adopting the foundational ontology DOLCE [7]. So, the template “Does a X Y?” can be generated if $X \sqsubseteq \exists \text{participates-in}.Y$ (Answer: Yes), or if $X \sqsubseteq \neg \exists \text{participates-in}.Y$ (Answer: No). “Does a [Endurant] [Perdurant]?” is an example of a template (Types B and D) for this question type, where Endurant and Perdurant are DOLCE categories. For instance, from the axiom $\text{BumbleBee} \sqsubseteq \exists \text{participates-in}.Fly$, Appr 3 can generate the question: “Does a bumble bee fly?”.

3.2 True/False Questions

The expected answers to these questions are either ‘True’ or ‘False’. The answer to a question is false if the ontology explicitly states so. We have defined two different types of questions for True/False Questions.

False Questions with two classes and one property. (iv)

The template “A X OP a Y. True or False?” can be generated if $X \sqsubseteq \exists OP.Y$ or $X \sqsubseteq \forall OP.Y$ (Answer: True), or if $X \sqsubseteq \neg \exists OP.Y$ (Answer: False). Template examples of this type are:

Type A: A [Thing] [OP] a [Thing]. True or false?

Type B: A [Endurant] [OP] a [Thing]. True or false?

Type C: Does a [CulturalEntity] [OP] a [Thing]. True or false?

Type D: A [T_Noun] [OP_Is_Nouns_Prep] a [T_Noun]. True or false?

A [T_Noun] [OP_Verb_Prep] a [T_Noun]. True or false?

where OP_Is_Nouns_Prep means that the OP name is composed of ‘is’, nouns and a preposition. For instance, from the axiom $\text{Phloem} \sqsubseteq \exists \text{proper-part-of}.Stem$, Appr 3 with Type D templates and Algorithm 2 can generate the question: “Phloem is a proper part of a stem. True or false?”.

True/False Questions with additional quantifier. (v)

The template “True or false: A X OP some Y” can be generated, if $X \sqsubseteq \exists OP.Y$ (Answer: True), or if $X \sqsubseteq \neg \exists OP.Y$ (Answer: False). Then, the template “True or false: A X OP only a Y” can be generated, if $X \sqsubseteq \forall OP.Y$ (Answer: True), or if $X \sqsubseteq \neg \forall OP.Y$ (Answer: False). Template examples of this type are:

Type A: A [Thing] [OP] [quantifier] [Thing]. True or false?

Type B: A [Endurant] [OP] [quantifier] [Thing]. True or false?

Type C: Does a [CulturalEntity] [OP] [quantifier] [Thing]. True or false?

Type D: A [T_Noun] [OP_Has_Nouns] that is only a [T_Noun]. True or false?

A [T_Noun] [OP_Verb_Prep] some [T_Noun]. True or false?

where OP_Has_Nouns means that the OP name is composed of ‘has’ and nouns. For instance, from the axiom $\text{Collection} \sqsubseteq \forall \text{hasMember}.CulturalHeritageObject$, Appr 3 can generate the question: “A collection has a member that is only a cultural heritage object. True or false?”.

3.3 Equivalence Questions (vi)

This case is possible provided there is an equivalence relation between two classes. Template examples of this type are:

Type A: *Are there any differences between a [Thing] and a [Thing]?*

Type B: *Are there any differences between a [Endurant] and a [Endurant]?*

Type C: *Are there any differences between a [Plant] and a [Plant]?*

Type D: *Are there any differences between a [T_Noun] and a [T_Noun]?*

The template “*Are there any differences between a X and a Y?*” can be generated and results in ‘Yes’ if $X \equiv \neg Y$, and ‘No’ if $X \equiv Y$ under the Open World Assumption. For instance, from the axiom $\text{King-of-beasts} \equiv \text{Lion}$, Appr 3 can generate the question: “*Are there any differences between a lion and a king of beasts?*”.

3.4 Subclass Identification Questions

These questions can be casted as “Which” questions. We considered the three following cases.

Subclass identification with two classes and one property. (vii)

The template “*Which X OP Y?*” can be generated if there is a class Z that satisfies the axiom pattern $Z \sqsubseteq X \sqcap \exists \text{OP.Y}$ or $Z \sqsubseteq X \sqcap \forall \text{OP.Y}$. Some templates for this type of questions are as follows:

Type A: *Which [Thing] [OP] a [Thing]?*

Type B: *Which [Endurant] [OP] a [Thing]?*

Type C: *Which [CulturalEntity] [OP] a [Thing]?*

Type D: *Which [T_Noun] [OP_Verb_Prep] a [T_Noun]?*

Which [T_Noun] [OP_Is_Nouns_Prep] a [T_Noun]?

where OP_Is_Nouns_Prep means that the OP name is composed of ‘is’, nouns and a preposition. For instance, from the axioms $\text{CulturalInstituteOrSite} \sqsubseteq \text{CulturalEntity}$ and $\text{CulturalInstituteOrSite} \sqsubseteq \forall \text{isSubjectOF.CreativeWork}$, Appr 3 can generate the question “*Which cultural entity is a subject of a creative work?*”.

Subclass identification questions with additional quantifier. (viii)

The template “*Which X OP some Y?*” can be generated if there is a class Z that satisfies the axiom pattern $Z \sqsubseteq X \sqcap \exists \text{OP.Y}$. Then, “*Which X OP only a Y?*” can be generated if there is a class Z that satisfies the axiom pattern $Z \sqsubseteq X \sqcap \forall \text{OP.Y}$. Example templates of this type of questions are as follows:

Type A: *Which [Thing] [OP] [quantifier] [Thing]?*

Type B: *Which [Endurant] [OP] [quantifier] [Thing]?*

Type C: *Which [CulturalEntity] [OP] [quantifier] [Thing]?*

Type D: *Which [T_Noun] [OP_Verb_Prep] some [T_Noun]?*

Which [T_Noun] [OP_Has_Nouns] only a [T_Noun]?

where OP_Verb_Prep means that the name of the OP starts with a verb followed by a preposition; and OP_Has_Nouns means that the OP name is composed

of ‘has’ and nouns. For instance, from the axioms $\text{Collection} \sqsubseteq \text{CulturalEntity}$ and $\text{Collection} \sqsubseteq \forall \text{hasMember.CulturalHeritageObject}$, Appr 3 can generate the question “Which cultural entity has a member that is only a cultural heritage object?”.

Subclass identification questions with one class and one property. (ix)

The template “What does a X OP?” can be generated if there is a class Y such that $X \sqsubseteq \exists \text{OP.Y}$ or $X \sqsubseteq \forall \text{OP.Y}$. Template examples of this type are:

Type A: What does a [Thing] [OP]?

Type B: What does a [Endurant] [OP]?

Type C: What does a [CulturalEntity] [OP]?

Type D: What does a [T_Noun] [OP_Verb] ?

What does a [T_Noun] [OP_Verb_Prep] ?

For instance, from the axiom $\text{Catalogue} \sqsubseteq \forall \text{describes.Collection}$, Appr 3 can generate the question “What does a catalogue describe?”.

3.5 Narrative Questions (x)

A class X in an ontology can be “defined” if it satisfies one of the following criteria: 1) it is annotated with a definition; 2) it has at least one equivalent class; 3) it has at least one superclass, at least one subclass or a combination of both; for instance, “Define X.”. Some templates for this type of questions are as follows:

Type A: What is a [Thing]?

Type B: Define a [Endurant].

Type C: Define a [CulturalEntity].

Type D: What is [MassDefThing]?

where MassDefThing means that the class name is an uncountable noun. For instance, Appr 3 can generate the question “What is equipment?”.

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