ASSIGNMENT FOR UNIT 4
INTELLIGENT SYSTEMS

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Contents

1 Introduction

Computational ontologies encode a description of some specific domain, for some purpose. They have a logical structure, and must match both domain and task. On the other hand, the recently arising ontology design patterns make it easier to progress into a unified framework for multiple domains. These knowledge patterns make modeling decisions clear, and avoid some of the ontological confusion that can otherwise appear.

In this paper, we will find different situations in which these patterns could be useful in the education domain. These situations will be helpful for the final part, where an ontology network will be developed. Additionally, as an important role of ontologies is their reusability, we will focus on reusing as much as possible existing ontologies and ontology design patterns.

Al the work done is compiled and can be seen in the following GitHub repository: https://github.com/javiegal/education-ontology.

2 Part I

In this section we will identify 5 different situations in which an n-ary relation pattern could be modeled. All of these situations fall in the education domain. While the first two will be related to data obtained from the 2018 PISA report [1], [2], the last relation patterns will be taken from a learning guide corresponding to the Master's Programme in Data Science [3].

In each section we will show a visual representation of these patterns, however the OWL code can be found at the appendix of this document.

2.1 "Outperforms"

"Boys outperformed girls – by five score points – in mathematics, on average across OECD countries[...]" [2, Page 18].

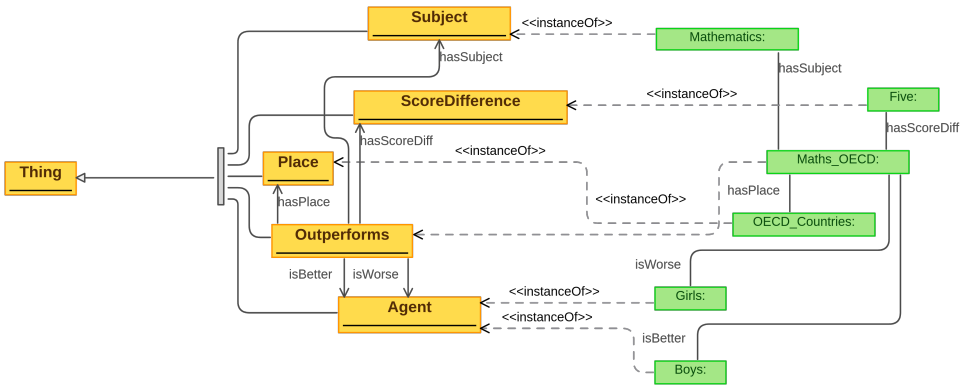

Figure 1: "Outperforms" n-ary relation.

2.2 "Formal schooling"

"The report uses "15-year-olds" as shorthand for the PISA target population. PISA covers students who are aged between 15 years 3 months and 16 years 2 months at the time of assessment and who are enrolled in school and have completed at least 6 years of formal schooling, regardless of the type of institution in which they are enrolled, and whether they are in full-time or part-time education, whether they attend academic or vocational programmes, and whether they attend public or private schools or foreign schools within the country." [1, Page 22].

For the diagram (Figure 2) and OWL/XML code (Appendix) we will use an easier example: "John has completed six years of academic full-time programmes in a public school and is starting his seventh year".

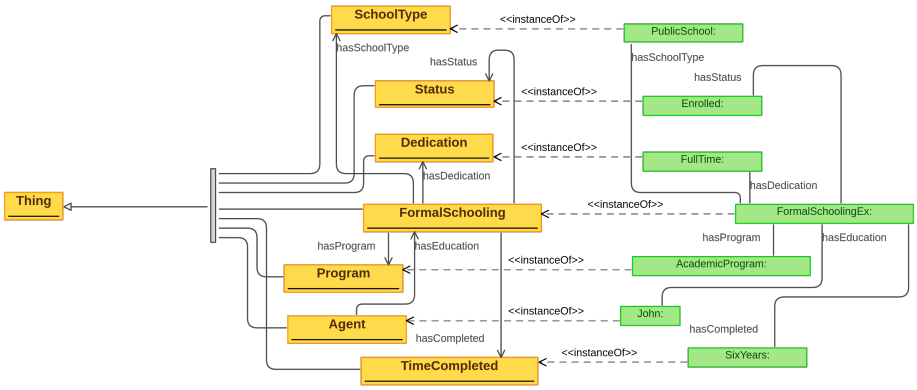

Figure 2: "Formal Schooling" n-ary relation.

2.3 "Course Relation"

Since the next three relations can be combined into one graph, we will only show an approximate visualization for each of them. On the other hand, the union can be seen in Figure 3.

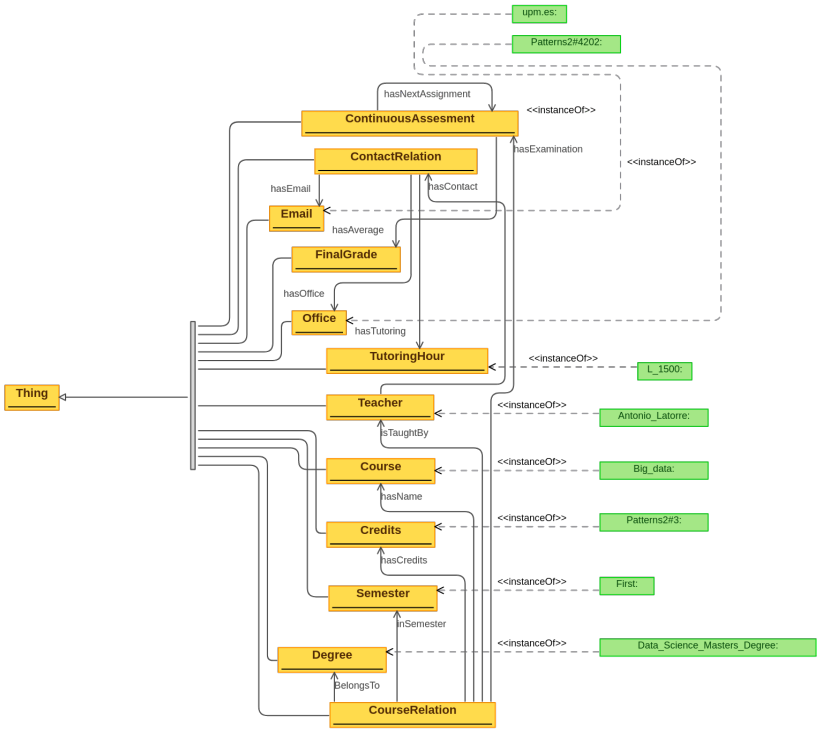

Figure 3: Last three n-ary relations.

The knowledge to develop these relations was obtained from the learning guide of one of our courses [3]. Referring to it, the first information given about a course are characteristics like name of the subject, degree programme, semester of tuition, etc. Figure 4 represents the first relation related to all this information.

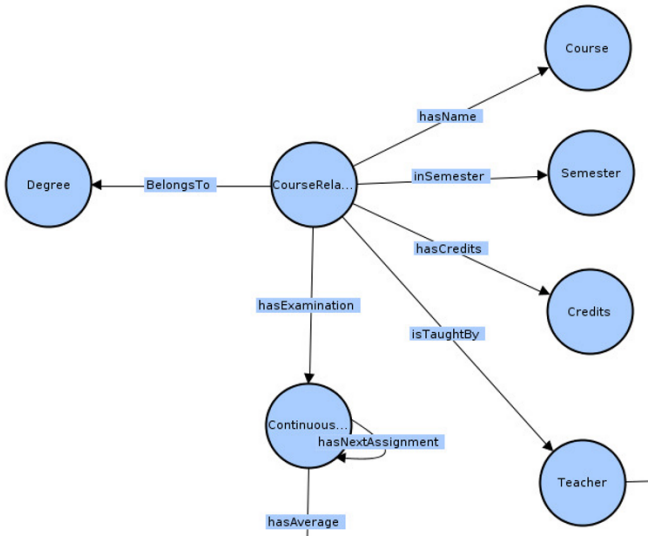

Figure 4: Course Relation visualization

2.4 "Contact Relation"

Following with the information given in the guide, in the educational domain, it is important to have contact with the faculty members teaching the subject. A relation pattern can be extracted from all the contact information. It is shown in Figure 5.

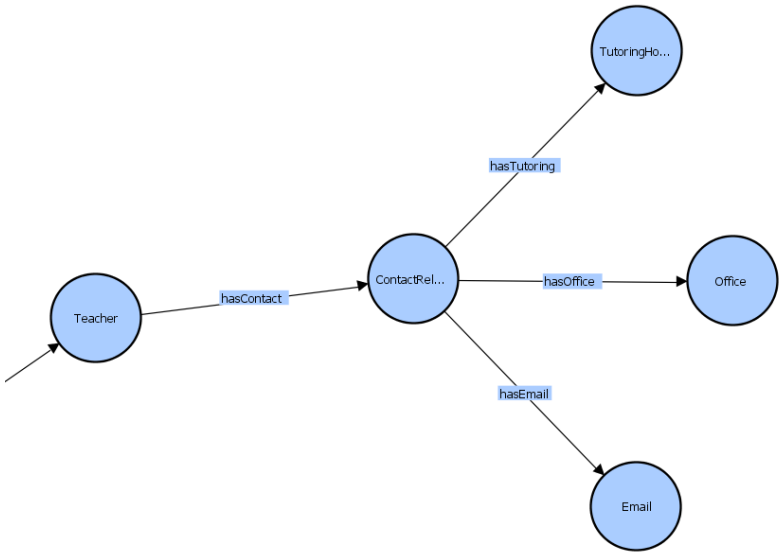

Figure 5: Contact Relation visualization

2.5 "Continuous Assesment"

Finally, moving on to "Activities and Assessment criteria", we will focus on the continuous assessment, which can be modeled as a sequence of ordered instances which will produce the final grade. Figure 6 shows it.

2.6 N-ary relation pattern taxonomy

Figure 7 shows where our patterns should be placed in the n-ary relation pattern taxonomy.

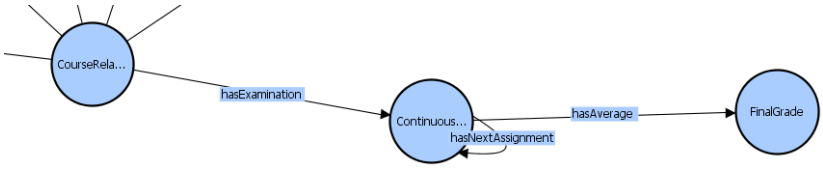

Figure 6: Continuous Assessment visualization

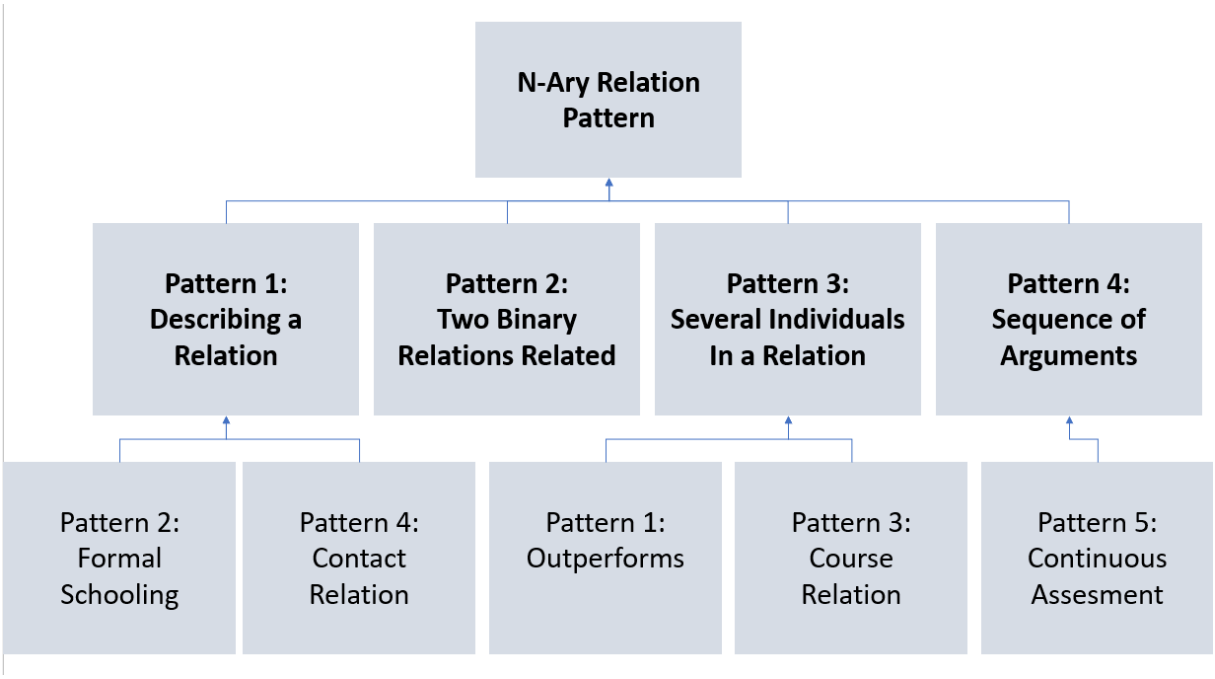

Figure 7: N-ary relation pattern taxonomy.

3 Part II

The second part of this project covers the development of an ontology network about educational material, courses, teachers, subjects, students and some other elements related with education. In the following sections we describe the steps performed to get this ontology. We tried to follow the NeOn methodology for ontology engineering [4].

3.1 Ontological requirements

The first step in order to develop an ontology network has to do with specifying its requirements. They are divided in two different types: non-functional and functional.

3.1.1 Non-Functional requirements

Non-functional requirements are those that does not have to do with the ontology itself, but the way it is developed and the technical aspects you have to take into account. For us, the most important non-functional requirements are the following:

1. The vocabulary must be implemented in OWL code using Protégé.
2. The building of the ontology network should be done reusing as much as possible existing ontologies.

3. The building of the ontology network should be done reusing as much as possible existing ontology design patterns.

3.1.2 Functional requirements

Specifying functional requirements is the first step when you want to represent knowledge with an ontology network. These requirements cover the main questions the designer wants to answer with the ontology to be developed. We show in Table 1 the requirements we wrote at the beginning of this process and their status after the ontology development.

ID	Competency Question (CQ)	Answer	Status
FR1	What person studies at an educational institution?	Student	Accepted
FR2	What person imparts a course at an educational institution?	Teacher	Accepted
FR3	What does a student use to learn in an educational institution?	Educational material: books, articles, videos, slides, notes, learning managing systems, etc.	Accepted
FR4	How does a teacher evaluate a student?	Assignments and exams	Incomplete
FR5	What is a student enrolled in?	Courses and degree programs	Accepted
FR6	Where can a student access to educational material?	Library and learning management system	Accepted
FR7	How can you contact with a teacher?	Email or office	Accepted
FR8	Where can a student see his/her grades?	Learning management system	Rejected
FR9	Which are the most important educational institutions?	School, high school and university	Accepted
FR10	What is the content of an exam?	Units of a course	Accepted
FR11	Who prepares and evaluates an exam?	Teacher	Accepted
FR12	What is a reference of an educational piece of work (education material)?	Another piece of work (educational material)	Accepted

Table 1: Functional requirements.

In order to develop our ontology, we also wrote a glossary with the terms we wanted to represent. This glossary is shown in Table 2. Most of the definitions have been taken from the Cambridge Dictionary [5].

3.2 Reused resources

For the ontology development, some other ontologies have been reused. The criteria for the selection of them will be explained in Section 3.3, but before that this sections summarizes all

Term	Definition
School	A place where children go to learn things.
University	A place where students study at a high level to get a degree.
Student	Someone who is studying at a school or university.
Teacher	Someone whose job is to teach in a school, college, etc.
Subject	An area of knowledge studied at school or university.
Course	A set of lessons about a particular subject.
Unit	A single, complete thing that is part of a larger thing (a course).
Degree	A qualification that proves you have completed a course of study at a college or university.
Assignment	A piece of work or a job that someone gives you to do.
Exam	An official test of how much you know about something, or how well you can do something.
Office	A room or building where people work.
Grade	S mark for a piece of work that shows how good it is.
Notes	Words that you write down to help you remember something.
Slides	A small piece of film that you shine light through in order to see a photograph.
Book	A written text that can be published in printed or electronic form.
Video	A recording of a movie, TV programme, etc. that you can watch on a television or computer.
Institution e-mail account	e-mail account associated with a particular educational institution.
LMS	learning managing system, an online platform used to provide material to the students.

Table 2: Pre-Glossary of Terms.

the reused resources.

- https://schema.org/: Schema is a collaborative, community activity with a mission to create, maintain, and promote schemas for structured data on the Internet, on web pages, in email messages, and beyond. We reused this ontology because it contains many resources regarding educational organizations, programs and courses information.
- https://dbpedia.org/ontology/: DBpedia (from "DB" for "database") is a project aiming to extract structured content from the information created in the Wikipedia project. This structured information is made available on the World Wide Web. DBpedia allows users to semantically query relationships and properties of Wikipedia resources, including links to other related data sets. We used a pair of classes of this ontology in order to represent academic people and academic subjects.
- https://www.w3.org/2003/01/geo/: This is a basic RDF vocabulary that provides the Semantic Web community with a namespace for representing lat(itude), long(itude) and other information about spatially-located things, using WGS84 as a reference datum. We used this vocabulary to represent the place an educational organization is located.
- http://purl.org/ontology/bibo/: The Bibliographic Ontology Specification provides main concepts and properties for describing citations and bibliographic references (i.e. quotes, books, articles, etc) on the Semantic Web. This ontology seemed also helpful for representing educational material: books, notes, slides, articles, etc.

3.3 Design decisions

The first step of the development of the ontology had to do with the identification of non-functional and functional requirements. It allowed us to know what we wanted to represent. After that, we looked for some existing ontologies to reuse. The first one we found was Schema. This ontology contained some of the elements we needed. In order to reuse as much as possible, we kept all the classes related to education this ontology offered. After that, we tried to found some new concepts in DBpedia. It was hard, because most of them were already represented in Schema, but we found a couple. On the other hand, for the material concepts, we found BIBO. It represents most of the educational material concepts we needed for our ontology. In order to link it with Schema classes, we decided to make BIBO's *Document* class a subclass of Schema's *Learning Resource* class. Finally, we used wgs84_pos ontology to represent the location of an educational organization.

After the search phase was done, we had some concepts yet not represented, specially teachers and students. We created two new classes for them and tried to incorporate some of the patterns we found in Section 2. "Contact Relation" explained in Section 2.4 was added and "Course Relation" of Section 2.3 was slightly modified in order to fit well with *Schema*'s classes. As we had Schema's *Quiz* class, we discarded "Continuous Assessment" relation of Section 2.5 and created a new "Quiz Relation". The other two patterns did not adapt well to our ontology. Lastly, we added some more classes (such as *Unit* and *LMS*) and properties to have a complete ontology representation.

3.4 Ontology model

The final model of our ontology that reflects the result of the process detailed in previous sections is shown in Figure 8. An OWL/XML code to represent it has also been developed and can be seen in https://github.com/javiegal/education-ontology/blob/main/ontology/education-ontology.owl.

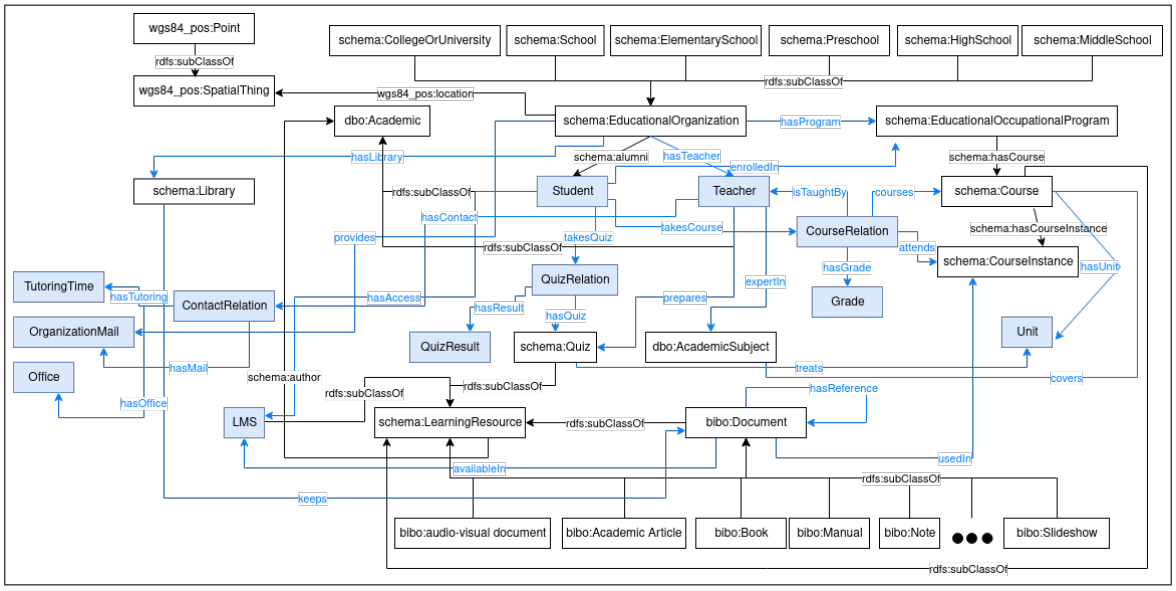

Figure 8: Ontology model.

4 Conclusions

Along this project, we were able to find some n-ary relations in the education domain that we think are useful and can be reused by others. In addition, we also managed to find and reuse

existing ontologies for our own purposes. We believe we got a useful ontology that takes into account some concepts represented in some of the most reliable ontologies. Furthermore, as ontology networks and knowledge representation are rising fields, we think this project was a good way to immerse ourselves in this emerging world.

References

[1] OECD, *PISA 2018 Results (Volume I)*. 2019, p. 354. DOI: https://doi.org/https://doi.org/10.1787/5f07c754-en. [Online]. Available: https://www.oecd-ilibrary.org/content/publication/5f07c754-en.

[2] OECD, *PISA 2018 Results (Volume II)*. 2019, p. 376. DOI: https://doi.org/https://doi.org/10.1787/b5fd1b8f-en. [Online]. Available: https://www.oecd-ilibrary.org/content/publication/b5fd1b8f-en.

[3] *Big Data Learning Guide*, https://www.upm.es/comun_gauss/publico/guias/2021-22/1S/GA_10BA_103000893_1S_2021-22.pdf.

[4] M. C. Suárez-Figueroa, A. Gómez-Pérez, and M. Fernández-López, "Chapter 2 the neon methodology for ontology engineering," 2017.

[5] *Cambridge dictionary*, Jan. 2022. [Online]. Available: https://dictionary.cambridge.org (visited on 01/10/2022).

[6] M. A. Musen, "The protégé project: A look back and a look forward," *AI Matters*, vol. 1, no. 4, pp. 4–12, 2015. DOI: 10.1145/2757001.2757003. [Online]. Available: https://doi.org/10.1145/2757001.2757003.

[7] R. Colomb, *Ontology and the Semantic Web*, ser. Frontiers in artificial intelligence and applications. IOS Press, 2007, ISBN: 9781586037291.

Appendices

A OWL code from part I

A.1 "Outperforms"

```
<?xml version="1.0"?>
<Ontology xmlns="http://www.w3.org/2002/07/owl#"
     xml:base="http://www.intelligent-systems.org/acg/ontologies/Outperforms#"
     xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
     xmlns:xml="http://www.w3.org/XML/1998/namespace"
     xmlns:xsd="http://www.w3.org/2001/XMLSchema#"
     xmlns:rdfs="http://www.w3.org/2000/01/rdf-schema#"
     ontologyIRI="http://www.intelligent-systems.org/acg/ontologies/Outperforms#">
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        /2021/11/Outperforms"/>
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    <Prefix name="rdf" IRI="http://www.w3.org/1999/02/22-rdf-syntax-ns#"/>
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</Ontology>



<!-- Generated by the OWL API (version 4.5.9.2019-02-01T07:24:44Z) https://github.
    com/owlcs/owlapi -->
```

Listing 1: “Outperforms” n-ary relation in OWL/XML

A.2 “Formal schooling”

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<?xml version="1.0"?>
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     xmlns:xml="http://www.w3.org/XML/1998/namespace"
     xmlns:xsd="http://www.w3.org/2001/XMLSchema#"
     xmlns:rdfs="http://www.w3.org/2000/01/rdf-schema#"
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165     <ObjectPropertyRange>
166         <ObjectProperty IRI="hasEducation"/>
167         <Class IRI="FormalSchooling"/>
168     </ObjectPropertyRange>
169     <ObjectPropertyRange>
170         <ObjectProperty IRI="hasProgram"/>
171         <Class IRI="Program"/>
172     </ObjectPropertyRange>
173     <ObjectPropertyRange>
174         <ObjectProperty IRI="hasSchoolType"/>
175         <Class IRI="SchoolType"/>
176     </ObjectPropertyRange>
177     <ObjectPropertyRange>
178         <ObjectProperty IRI="hasStatus"/>
179         <Class IRI="Status"/>
180     </ObjectPropertyRange>
181 </Ontology>
182
183
184
185 <!-- Generated by the OWL API (version 4.5.9.2019-02-01T07:24:44Z) https://github.
        com/owlcs/owlapi -->
```

Listing 2: “Formal Schooling” n-ary relation in OWL/XML

A.3 “Course Relation”, “Contact Relation” and “Continuous Assessment”

```
1  <?xml version="1.0"?>
2  <Ontology xmlns="http://www.w3.org/2002/07/owl#"
3        xml:base="http://www.intelligent-systems.org/acg/ontologies/Patterns2#"
4        xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
5        xmlns:xml="http://www.w3.org/XML/1998/namespace"
6        xmlns:xsd="http://www.w3.org/2001/XMLSchema#"
7        xmlns:rdfs="http://www.w3.org/2000/01/rdf-schema#"
8        ontologyIRI="http://www.intelligent-systems.org/acg/ontologies/Patterns2#">
9      <Prefix name="" IRI="http://www.intelligent-systems.org/acg/ontologies/
           Patterns2#"/>
10     <Prefix name="owl" IRI="http://www.w3.org/2002/07/owl#"/>
11     <Prefix name="rdf" IRI="http://www.w3.org/1999/02/22-rdf-syntax-ns#"/>
12     <Prefix name="xml" IRI="http://www.w3.org/XML/1998/namespace"/>
```

```
    <Prefix name="xsd" IRI="http://www.w3.org/2001/XMLSchema#"/>
    <Prefix name="rdfs" IRI="http://www.w3.org/2000/01/rdf-schema#"/>
    <Declaration>
        <Class IRI="ContactRelation"/>
    </Declaration>
    <Declaration>
        <Class IRI="ContinuousAssesment"/>
    </Declaration>
    <Declaration>
        <Class IRI="Course"/>
    </Declaration>
    <Declaration>
        <Class IRI="CourseRelation"/>
    </Declaration>
    <Declaration>
        <Class IRI="Credits"/>
    </Declaration>
    <Declaration>
        <Class IRI="Degree"/>
    </Declaration>
    <Declaration>
        <Class IRI="Email"/>
    </Declaration>
    <Declaration>
        <Class IRI="FinalGrade"/>
    </Declaration>
    <Declaration>
        <Class IRI="Office"/>
    </Declaration>
    <Declaration>
        <Class IRI="Semester"/>
    </Declaration>
    <Declaration>
        <Class IRI="Teacher"/>
    </Declaration>
    <Declaration>
        <Class IRI="TutoringHour"/>
    </Declaration>
    <Declaration>
        <ObjectProperty IRI="BelongsTo"/>
    </Declaration>
    <Declaration>
        <ObjectProperty IRI="hasAverage"/>
    </Declaration>
    <Declaration>
        <ObjectProperty IRI="hasContact"/>
    </Declaration>
    <Declaration>
        <ObjectProperty IRI="hasCredits"/>
    </Declaration>
    <Declaration>
        <ObjectProperty IRI="hasEmail"/>
    </Declaration>
    <Declaration>
        <ObjectProperty IRI="hasExamination"/>
    </Declaration>
    <Declaration>
        <ObjectProperty IRI="hasName"/>
    </Declaration>
    <Declaration>
        <ObjectProperty IRI="hasNextAssignment"/>
    </Declaration>
    <Declaration>
```

```
76          <ObjectProperty IRI="hasOffice"/>
77      </Declaration>
78      <Declaration>
79          <ObjectProperty IRI="hasTutoring"/>
80      </Declaration>
81      <Declaration>
82          <ObjectProperty IRI="inSemester"/>
83      </Declaration>
84      <Declaration>
85          <ObjectProperty IRI="isTaughtBy"/>
86      </Declaration>
87      <Declaration>
88          <NamedIndividual IRI="Antonio_Latorre"/>
89      </Declaration>
90      <Declaration>
91          <NamedIndividual IRI="Big_data"/>
92      </Declaration>
93      <Declaration>
94          <NamedIndividual IRI="Data_Science_Masters_Degree"/>
95      </Declaration>
96      <Declaration>
97          <NamedIndividual IRI="First"/>
98      </Declaration>
99      <Declaration>
100         <NamedIndividual IRI="L_1500"/>
101     </Declaration>
102     <Declaration>
103         <NamedIndividual IRI="3"/>
104     </Declaration>
105     <Declaration>
106         <NamedIndividual IRI="4202"/>
107     </Declaration>
108     <Declaration>
109         <NamedIndividual IRI="a.latorre@upm.es"/>
110     </Declaration>
111     <ClassAssertion>
112         <Class IRI="Teacher"/>
113         <NamedIndividual IRI="Antonio_Latorre"/>
114     </ClassAssertion>
115     <ClassAssertion>
116         <Class IRI="Course"/>
117         <NamedIndividual IRI="Big_data"/>
118     </ClassAssertion>
119     <ClassAssertion>
120         <Class IRI="Degree"/>
121         <NamedIndividual IRI="Data_Science_Masters_Degree"/>
122     </ClassAssertion>
123     <ClassAssertion>
124         <Class IRI="Semester"/>
125         <NamedIndividual IRI="First"/>
126     </ClassAssertion>
127     <ClassAssertion>
128         <Class IRI="TutoringHour"/>
129         <NamedIndividual IRI="L_1500"/>
130     </ClassAssertion>
131     <ClassAssertion>
132         <Class IRI="Credits"/>
133         <NamedIndividual IRI="3"/>
134     </ClassAssertion>
135     <ClassAssertion>
136         <Class IRI="Office"/>
137         <NamedIndividual IRI="4202"/>
138     </ClassAssertion>
```

```
    <ClassAssertion>
        <Class IRI="Email"/>
        <NamedIndividual IRI="a.latorre@upm.es"/>
    </ClassAssertion>
    <ObjectPropertyDomain>
        <ObjectProperty IRI="BelongsTo"/>
        <Class IRI="CourseRelation"/>
    </ObjectPropertyDomain>
    <ObjectPropertyDomain>
        <ObjectProperty IRI="hasAverage"/>
        <Class IRI="ContinuousAssesment"/>
    </ObjectPropertyDomain>
    <ObjectPropertyDomain>
        <ObjectProperty IRI="hasContact"/>
        <Class IRI="Teacher"/>
    </ObjectPropertyDomain>
    <ObjectPropertyDomain>
        <ObjectProperty IRI="hasCredits"/>
        <Class IRI="CourseRelation"/>
    </ObjectPropertyDomain>
    <ObjectPropertyDomain>
        <ObjectProperty IRI="hasEmail"/>
        <Class IRI="ContactRelation"/>
    </ObjectPropertyDomain>
    <ObjectPropertyDomain>
        <ObjectProperty IRI="hasExamination"/>
        <Class IRI="CourseRelation"/>
    </ObjectPropertyDomain>
    <ObjectPropertyDomain>
        <ObjectProperty IRI="hasName"/>
        <Class IRI="CourseRelation"/>
    </ObjectPropertyDomain>
    <ObjectPropertyDomain>
        <ObjectProperty IRI="hasNextAssignment"/>
        <Class IRI="ContinuousAssesment"/>
    </ObjectPropertyDomain>
    <ObjectPropertyDomain>
        <ObjectProperty IRI="hasOffice"/>
        <Class IRI="ContactRelation"/>
    </ObjectPropertyDomain>
    <ObjectPropertyDomain>
        <ObjectProperty IRI="hasTutoring"/>
        <Class IRI="ContactRelation"/>
    </ObjectPropertyDomain>
    <ObjectPropertyDomain>
        <ObjectProperty IRI="inSemester"/>
        <Class IRI="CourseRelation"/>
    </ObjectPropertyDomain>
    <ObjectPropertyDomain>
        <ObjectProperty IRI="isTaughtBy"/>
        <Class IRI="CourseRelation"/>
    </ObjectPropertyDomain>
    <ObjectPropertyRange>
        <ObjectProperty IRI="BelongsTo"/>
        <Class IRI="Degree"/>
    </ObjectPropertyRange>
    <ObjectPropertyRange>
        <ObjectProperty IRI="hasAverage"/>
        <Class IRI="FinalGrade"/>
    </ObjectPropertyRange>
    <ObjectPropertyRange>
        <ObjectProperty IRI="hasContact"/>
        <Class IRI="ContactRelation"/>
```

```
202     </ObjectPropertyRange>
203     <ObjectPropertyRange>
204         <ObjectProperty IRI="hasCredits"/>
205         <Class IRI="Credits"/>
206     </ObjectPropertyRange>
207     <ObjectPropertyRange>
208         <ObjectProperty IRI="hasEmail"/>
209         <Class IRI="Email"/>
210     </ObjectPropertyRange>
211     <ObjectPropertyRange>
212         <ObjectProperty IRI="hasExamination"/>
213         <Class IRI="ContinuousAssesment"/>
214     </ObjectPropertyRange>
215     <ObjectPropertyRange>
216         <ObjectProperty IRI="hasName"/>
217         <Class IRI="Course"/>
218     </ObjectPropertyRange>
219     <ObjectPropertyRange>
220         <ObjectProperty IRI="hasNextAssignment"/>
221         <Class IRI="ContinuousAssesment"/>
222     </ObjectPropertyRange>
223     <ObjectPropertyRange>
224         <ObjectProperty IRI="hasOffice"/>
225         <Class IRI="Office"/>
226     </ObjectPropertyRange>
227     <ObjectPropertyRange>
228         <ObjectProperty IRI="hasTutoring"/>
229         <Class IRI="TutoringHour"/>
230     </ObjectPropertyRange>
231     <ObjectPropertyRange>
232         <ObjectProperty IRI="inSemester"/>
233         <Class IRI="Semester"/>
234     </ObjectPropertyRange>
235     <ObjectPropertyRange>
236         <ObjectProperty IRI="isTaughtBy"/>
237         <Class IRI="Teacher"/>
238     </ObjectPropertyRange>
239 </Ontology>
240
241
242
243 <!-- Generated by the OWL API (version 4.5.9.2019-02-01T07:24:44Z) https://github.
        com/owlcs/owlapi -->
```

Listing 3: Last three n-ary relation patterns in OWL/XML