Contents lists available at ScienceDirect

Information Sciences

journal homepage: www.elsevier.com/locate/ins

An ontology-based multi-domain model in social network analysis: Experimental validation and case study

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ARTICLE INFO

ABSTRACT

The use of social network theory and methods of analysis have been applied to different domains in recent years, including public health. The complete procedure for carrying out a social network analysis (SNA) is a time-consuming task that entails a series of steps in which the expert in social network analysis could make mistakes. This research presents a multi-domain knowledge model capable of automatically gathering data and carrying out different social network analyses in different domains, without errors and obtaining the same conclusions that an expert in SNA would obtain. The model is represented in an ontology called OntoSNAQA, which is made up of classes, properties and rules representing the domains of People, Questionnaires and Social Network Analysis. Besides the ontology itself, different rules are represented by SWRL and SPARQL queries. A Knowledge Based System was created using OntoSNAQA and applied to a real case study in order to show the advantages of the approach. Finally, the results of an SNA analysis obtained through the model were compared to those obtained from some of the most widely used SNA applications: UCINET, Pajek, Cytoscape and Gephi, to test and confirm the validity of the model.

1. Introduction

Today, the term 'social network' is associated with a number of interactive tools that can be found on the Internet such as Facebook, Twitter or Instagram. However, especially in the area of social sciences, the term "social networks", makes reference to a finite set of actors and the relationships that link them [1]. These social networks are considered as social structures in which communication processes and transactions between people take place. Once the concept of a social network is defined, the Social Networks Analysis quantifies the relationships between the actors with the aim of creating matrix and graphic networks that represent these relationships as a whole, and thus analyzes the different characteristics of the system that is being studied, indistinctly of the type of relationship to which they belong: political, economic, kinship, friendship, cooperation, conflict, etc. [2,3].

Social Network Analysis (SNA) techniques have mushroomed extensively in recent years in different areas of study within multiple domains. In the field of health, it applies both to socio-health management and studies into different diseases

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within the population [3]. Some examples applied to medicine include the study of affiliation networks of HIV health centers of men of color who have sexual relations with people of the same sex, enabling different patterns to be established and thus helping to prevent the disease in this population [4]. Another example in which the prevention of different sexually transmitted infections is also sought is that of Niekamp et al. [5] or a qualitative study of secondary school teachers' perception of Social Network Analysis metrics in the context of alcohol consumption among adolescents [6]. SNA is not only applied to health, this technique is also being applied in different domains, for example, the use of SNA to assess and predict future knowledge flows of an insurance company [7] or a study responsible for measuring the impact of Google Docs on student collaboration [8].

The complete procedure, which involves carrying out a Social Network Analysis, begins with the development of a questionnaire by the expert in Social Network Analysis. The subsequent data collection after its completion by a population group, modeling the data, the application of an SNA application to obtain global and local measurements [9–11] and finally the interpretation of the aforementioned measures by the SNA expert. This complete procedure involves a high temporary cost on the part of the SNA expert, especially when it comes to modeling the data collected to create the different social networks that you wish to analyze, as well as there being a high probability of making mistakes at some step which means potentially repeating the social network analysis on numerous occasions.

The automation of the Social Network Analysis procedure to reduce time and eliminate the appearance of errors is possible using any computational solution. But Semantic Technologies offer added value within the entire procedure that other technologies do not. Thanks to the semantic web, it is possible not only to automate the process for obtaining and collecting data together with the SNA measures [12], but also to obtain conclusions from an applied SNA automatically. Furthermore, as a result of the proposed problem, it has been found necessary to apply technologies that help the expert to automate the entire SNA procedure applied to any domain. For this reason, in the wake of the problems arising from the complete procedure of an SNA, this research proposes a solution using semantic technologies based on the creation of a multi-domain ontology in the field of SNA.

To date, solutions to SNAs using existing semantic technologies have not come up with a complete solution to the problem. The conceptual models found have facilitated compliance with the basic rules of the semantic web, which suggest the reuse of existing ontologies when trying to solve a problem. However, none of the solutions found is a complete solution.

The remainder of this article is arranged as follows: Section 2 is a literary review of the semantic technologies applied to the analysis of social networks; Section 3 describes the design of the research and the procedure for the creation of a multi-domain conceptual model in the area of SNA; Section 4 details the results obtained after the validation procedure of the generated model; Section 5 sets out the final conclusions from the experiments carried out throughout the research.

2. Literature review

2.1. Difficulties in Social Network Analysis studies

Many of the researchers in different fields are in need of epidemiological studies and more specifically cross-sectional studies. These types of studies are based mainly on obtaining information from different groups of people through the use of surveys and then, curating the data and carrying out a social network analysis [13–15].

To date, researchers have carried out the surveys using different tools such as Google Docs [8], SurveyMonkey [16] or Survio.com. These tools are very useful because they allow you to create surveys in a simple way and obtain the data in different formats. It is possible to obtain this data in CSV format or on an Excel spreadsheet. However, after obtaining the data, the subsequent analysis must be carried out completely by the researchers. Often, the questionnaires really show data that are useful after their prior treatment (data curation).

Some of the validated questionnaires in the field of health are, for example, FAS II[1], AUDIT[2] [17], KIDSCREEN 27[3] [18] or EDADES.[4] These questionnaires are usually used to obtain information on the socioeconomic level of the target group (FAS II), as well as finding out the risk of alcohol consumption in the population (AUDIT and AGES) or to know the levels of personal satisfaction existing in different areas (KIDSCREEN). However, these questionnaires are made up of questions that have a value, and after the sum total of these values are calculated, a numerical result is obtained that represents a real risk or an area in which the respondent is located.

Many researchers currently have to carry out the collection and curation an analysis of data manually, finding different problems such as the excessive time used to handle the data obtained in the surveys, the appearance of a multitude of relative errors due to a mistake in the sum of the data by the researcher, etc. Some of these errors have been mentioned in different studies. One example is the study of Morris et al. Which mentions that the large amount of lost data in the collected data set is a serious problem, [19]. This problem caused difficulties in the subsequent SNA. Other problems found on this kind of study are, for example: (i) difficulty in being able to create new networks taking into account the values in the weighted

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[1] FAS II: Family Affluence Scale II.
[2] AUDIT: Alcohol Use Disorders Identification Test.
[3] https://www.kidscreen.org/espa%C3%B1ol/cuestionario-kidscreen/kidscreen-27/.
[4] EDADES: Encuesta sobre alcohol y otras drogas en España http://www.pnsd.msssi.gob.es/profesionales/sistemasInformacion/sistemaInformacion/encuestas_EDADES.htm.

relationships, (ii) errors in curing data produced by manually transferring the data, and (iv) difficulty in interpreting the results by not obtaining possible conclusions through prior analysis, among others [20].

Following the line of researchers who have conducted studies through surveys, another problem that is often found is the collection of the same variables in different time periods. For example, if you want to analyze changes in behavior in a group of people over time, it is common to request that they repeat the same survey after a few months, so that, when dealing with this data, any other problems may be seen, together with the difficulty in processing the data and comparing the same population at different times [21].

2.2. Semantic technologies (Ontological engineering and KBS) in SNA

It is true that digital social networks are on the rise and more and more techniques related to artificial intelligence (data curation, data mining, natural language processing, etc.) are being applied [22–27]. However, in the field of social networking within the context that we have introduced in this article, there is not much scientific literature that has tried to solve or improve existing software systems by adding knowledge engineering.

Within the engineering of knowledge and the creation of conceptual models within the analysis of social networks, we find studies such as that of Khaled and colleagues [28], which created a recommendation system based on the semantic analysis of social networks in learning environments. Although the ontology they show in their research is interesting, the problem is that it focuses on a very particular problem that cannot be extrapolated, for example, in case studies such as the one explained in this article.

Another study combining semantic technologies, on this occasion, the use of RDF applied to SNA is that set out by researchers Raji and Surendran [29]. This manuscript discusses the importance of the use of knowledge engineering in social network analysis and mentions an applicable RDF model. However, this model can be used exclusively for data obtained through the extraction of data from online social networks. As already mentioned in this article, it cannot be applied to an SNA applied to data obtained through surveys.

Kassiri and Beloudha [30] propose a Unified Semantic Model (USM) based on the union of three standards combined with other three new ontologies to satisfy different needs found and related to the analysis of social networks applying semantic technologies. Its model is enriching from the point of view of digital social networks. However, they focus again on a specific case that cannot be extrapolated to our problem.

Guillaume Ereteo was the author who did the most work close to solving our problem [31–33]. The research of Guillaume Ereteo stands out when reviewing the existing scientific literature in the field of SNA and semantic technologies. Guillaume presents a system that carries out an SNA under a conceptual model generated by him and his research group [34]. This PhD thesis stems from the project called ISICIL Information Semantic Integration through Communities of Intelligence online.

The purpose of this research was to help analyze the characteristics of heterogeneous social networks that arise from the use of applications, applying semantic technologies to Social Network Analysis. SNA makes use of graphical algorithms and Semantic Web frameworks to represent and exchange knowledge through RDF, SPARQL and frameworks that use RDFS and OWL. There are therefore three main objectives:

- To transform data collected from social networks in the network to representations based on ontology.
- Carry out a Social Network Analysis that takes advantage of semantic technologies.
- Detect and semantically label communities of online social networks.

They use both OWL and the SPARQL query language in their methodology. They have developed the main ontology in their research which is based on FOAF (Friend Of A Friend) and an extension of it, in addition to the SIOC (Semantically-Interlinked Online Communities) and SCOT (Social Semantic Cloud of Tags) ontologies. FOAF is an ontology that describes people, their activities and their relationships with other people and objects. SIOC provides methods to interconnect different discussion sites, such as blogs, forums and mailing lists. Finally, SCOT represents a semantic model for social labeling.

To complete their ontology and the extraction of SNA, they use SPARQL through a proprietary tool called Corese that implements SPARQL with homomorphisms that facilitates the obtaining of RDF.

Their ontology called SemSNA allows a more complex analysis to be carried out using semantic technologies. Furthermore, their system can be used to improve and obtain more information in the future from an SNA than by applying any simple SNA application, thanks to semantics.

However, this ontology is only the beginning of an SNA. More concepts and properties are necessary to carry out a complete SNA.

3. Material and methods

This research uses ontological engineering for knowledge modeling applied to a particular domain. An ontological knowledge model is an abstract structure of concepts, in which each concept has properties and relationships to represent the knowledge connotations. On the other hand, a knowledge model can thus be seen as a schema for knowledge description. When a model is implemented, the concepts are implemented into a domain ontology that allows the declarative knowledge

and task ontology to be represented so that procedural knowledge can be inferred. The instances are then included into the schema to become a knowledge base. Making use of the different guidelines proposed in different studies [35–42], we propose four characteristics for the modeling of an OWL-based, Knowledge-Based System development as listed below:

1. *Analyzing the problem scenarios:* There are three kinds of knowledge: domain knowledge, task knowledge and inference knowledge. These correspond to an initial domain ontology, task ontology and semantic rules and SPARQL queries in a Knowledge-Based System. Thanks to the analysis of the problem scenario it is possible to identify the tasks and the task knowledge needed for problem solving in relation to the domain knowledge.
2. *Modeling the initial ontology:* This process of modeling the domain ontology may be achieved from different methodologies, for example, making use of Web sources such as open data and other published ontologies. It is possible to say that the domain ontology is hierarchical declarative knowledge. This task allows us to obtain a hierarchical taxonomy, different semantic elements such as properties (such as object properties, data properties, etc), classes, subclasses and instances that are contained in different classes that have been previously defined. Furthermore, it is necessary to use a specific vocabulary related to the domain of the problem.
3. *Modeling the rest of the ontology to solve the problem completely*: To carry out a task, it is necessary to create a task ontology in which the problem solving has been implemented. Making use of different kinds of properties, such as object properties, data properties and different characteristic of these, it is possible to infer other different properties that give rise to a different axiom for implementing the reasoning process.
4. *Developing the semantic rules required and SPARQL queries*: In a KBS, it is necessary to transfer the human expertise into machine understanding, therefore, this task is carried out by axioms. There are two kinds of axioms in KBS: logical axioms and non-logical axioms. The first type, logical axioms, are used to collect available known facts to infer implicit knowledge; nevertheless, non-logical axioms are formulas such as arithmetical operations. One way of programming non-logical axioms is to make use of semantic rules such as the SWRL or queries that modify the ontology into SPARQL Queries [35–41]. SWRL and SPARQL Queries are commonly used for building inference mechanism in OWL-based Knowledge-Based Systems.

The research process can be divided into four phases including: (1) searching for the ontologies phase, in which researchers search for different ontologies related to the domain of the problem to be solved; (2) the modeling phase, the domain ontology, task ontology and inference rules were jointly constructed in this phase; (3) the development phases, in which the team develop the Knowledge-Based System that makes use of the previously constructed ontology; and (4) experiment and evaluation phase, in which the system is tested using a real case and the results is compared with other validated applications to validate it. In Table 1 it is possible to see a summary of the different phases and tasks carried out.

3.1. Analyzing the problem scenarios

The problem of carrying out a complete Social Network Analysis can be generally understood as the interaction between sources of knowledge related to people, other sources related to questionnaires (or surveys) and sources related to the terms of the Social Network Analysis. As shown in Fig. 1, multiple sources of knowledge are involved and there are also interactions between the sources of knowledge. An ontology model related to people is easier to conceptualize because there is an ontology called FOAF that has conceptualized concepts as a person and all his or her properties and the different kinds of relationships between people and other subjects [43]. In relation to the domain of questionnaires, as a concept it includes questions, different types of questions, answers, different types of answers, the answer to a question from a person and other concepts and their different relationships. The Social Network Analysis knowledge, for example, includes SNA concepts such as SNA indices such as degree, indegree, outdegree, betweenness and other relevant data of a network. Our solution needs to relate these different kinds of knowledge sources to offer us conclusions on a Social Network Analysis in a specific network of people who have previously completed a questionnaire.

To implement the analysis of the problem scenarios, two researchers specialized in Social Network Analysis have participated as consultants in verifying knowledge sources and problem scenarios from the beginning. After that, three knowledge engineers then formalized the problem solving in different non-logical axioms:

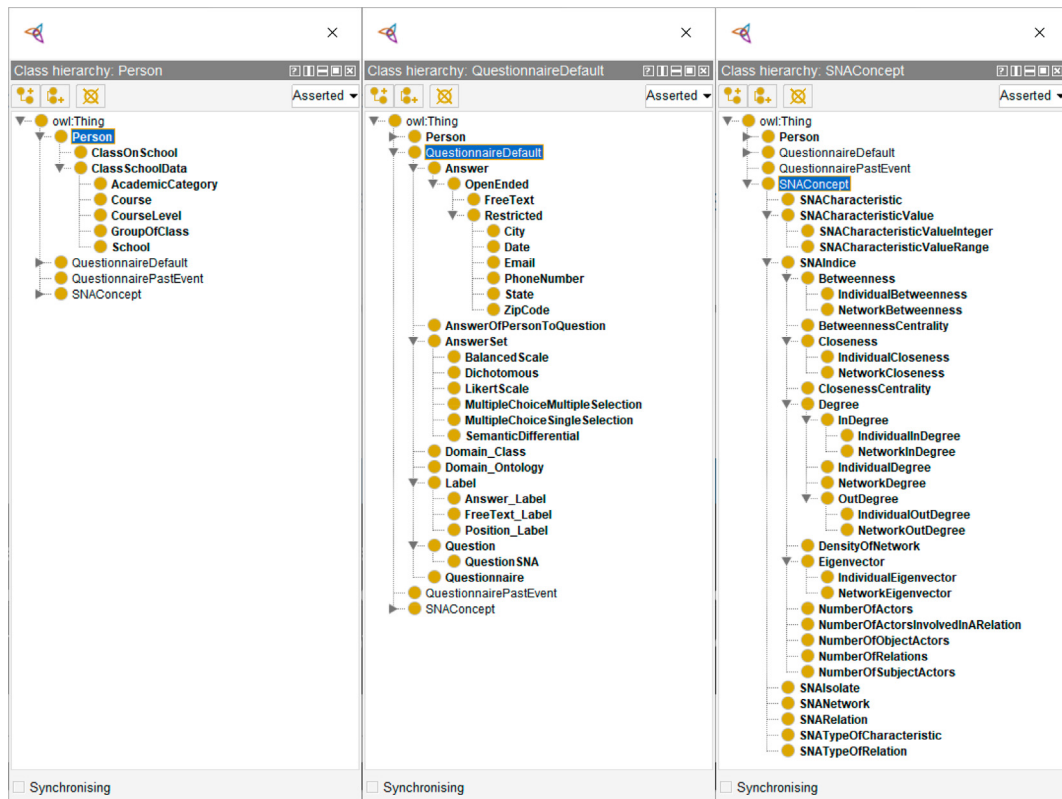(1) Relating concepts between people and questionnaires

Thinking about a complete Social Network Analysis carried out by a Knowledge-Based System, firstly, a group of people needs to draw up a questionnaire with different kinds of questions. This questionnaire should be drawn up more than once because Knowledge-Based Systems need to compare results to reach conclusions on it. In these questionnaires there are different kinds of questions, answers and one kind of question is related to people who will complete this questionnaire. For example, we can find a question like: *How much time do you spend with any of the people of the list below?* and this question is answered by one group of people about this other group of people. So, this question provides information about the different relationships between a group of people. With this information it is possible to carry out a Social Network Analysis, obtaining different metrics values such as betweenness, centrality or degree of different people in a network and of a network itself.

To achieve formalized different concepts and to link all of the knowledge, firstly it is important to relate the concepts of the people and the questionnaires.

Table 1

Research roles and responsibilities in each research phase.

Phase	Role			
	Project leader	Domain experts		Knowledge engineer
		Expert in SNA	Nurse	
Initiation processes	Setup project meeting, research goals, and milestones.	Validate of SNA problem-solving method.	Analyze problem scenarios.	Creating axioms.
Modeling phase	Host modeling meetings to create domain ontology and task ontology.	Verify declarative knowledge and verification of problem solving.Help to identify tasks and subtasks. Help to identify the steps of semantic rules.	Suggest relevant declarative knowledge sources.	Define domain ontology construct and relevant instances.Define task ontology construct and properties.Define semantic rules and sparql queries through subtasks.
Development phase	Verify the KBS	Test inference mechanisms.	Test inference mechanisms.	Edit ontology and semantic rules using Protégé and edit SPARQL queries using Apache Fuseki.Integrate OWL-based KBS into web-based application.
Experimental phase	Verify experimental results		Evaluating system performance using testing data.	Applying rules and queries to a real case and making a comparisonbetween KBS and UCINET, Cytoscape, Pajek and Gephi results.

Fig. 1. Classes of OntoSNAQA.

(2) Relating concepts between people and social networks

We should also point out the fact that the people's concepts need to be linked with the social network's concepts as well as those of the questionnaires. When a researcher specialized in Social Network Analysis creates a questionnaire, this

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questionnaire has questions to create one or more social network. So, it is known that people who complete this questionnaire will be a member of one or more networks. Knowing this, it is necessary to conceptualize the different links between the people and the networks.

People have different attributes within a network as well as different kinds of relationships and levels such as friendship, fellowship or family relationships for example.

(3) Relating concepts between questionnaires and social networks

Finally, the Knowledge-Based System needs to relate concepts on questionnaires and social networks. For example, a question like "*Indicate your gender*" provides information about a person who is member of a social network, specifically, this question provides the attribute of a person in a network.

3.2. Modeling the initial ontology

It should be noted that a domain ontology consists of a general conceptual structure and instances using an "is-a" to establish the subsumption relationships. By asserting instances it is possible to draw up the final concepts. For this reason, a domain ontology is a taxonomy that has not been created to solve problems, but is mainly about a common understanding of the domain for ontological sharing and reuse. Based on the analysis detailed in Section 3.1., before conceptualizing everything that is needed, it might be necessary to search for existing ontologies as explained in Section 2. In our problem, it was mainly necessary to conceptualize the three domains listed below:

- Domain of the people
- Domain of the questionnaires
- Domain of the Social Network Analysis

In order to transfer this knowledge into an OWL-based ontology called OntoSNAQA[5] (Ontology, Social Network Analysis, Questions & Answers), the Protégé is used to create the classes, properties and instances. Fig. 2 shows that the top-level concepts of the three different domains were mainly conceptualized. The child concepts and grandchild concepts are filled with constituent instances (see Fig. 1). Each instance can have its own internal property description (e.g., Fig. 2.). The concepts included are as follows:

(1) *Person:* This concept is completely reused from the FOAF ontology but it would be necessary to add new data properties and two news sub-concepts. Under each concept, the common terms are listed to provide reference and indexing for communication with other concepts and instances.
   - ClassSchoolData: This concept establishes information on a class at a primary school because, in our study, we need this information about the people to create the different relationships automatically. Other sub-concepts such as *AcademicCategory, Course, CourseLevel, GroupOfClass* and *School* have been established in this concept.
   - ClassOnSchool: This concept allows a complete class at a primary school to be represented. Instances of this class, can relate to different concepts about ClassSchoolData. We can see an example of an instance of this class in Fig. 2.
(2) *QuestionnaireDefault:* This ontology is based in an ontology created by Alipour-Aghdam [44] but with a lot of new sub-concepts added. Furthermore, to achieve the objectives of this research, it was necessary to add three new concepts:
   - QuestionSNA: It is a sub-concept of the *Question* class that helps us to represent questions related directly to the networks. For example, a question of this type could be: *How much time do you spend with any of the people on the list below?* This question will be repeated with all the members in a network. If the questionnaire is to be completed by 30 students in a class, this question will be asked 30 times to each student.
   - QuestionnairePastEvent: This concept is necessary to represent a *Questionnaire* completed at a certain time. The questionnaires could be completed by users as many times as the researcher needs throughout his or her research. For example, a user can complete a questionnaire entitled *Breathalyzer risk questionnaire* in 2016 and he or she can do it again in 2017. Thanks to this, it is possible to relate to the different members of a network with the two events from the same questionnaire at different times.
   - AnswerOfPersonToQuestion: This concept represents an answer of a user to a certain question in a certain questionnaire completed at a certain time. This concept allows the concepts of: *Person*, *QuestionnairePastEvent, Question* and *Answer* to be related.

We can see an example of different instances which interact with each other in the ontology developed in Fig. 3.
   (3) *SNAConcept:* As previously mentioned, within the scope of semantic technologies, the INRIA research group to which Dr. Guillaume Ereteo belongs, implemented a conceptual model that allowed the creation of instances within the domain of Social Network Analysis. This model had a series of classes through which typical concepts could be represented in an analysis of a social network such as: *SNAIndice, Degree, Betweenness, Closeness, etc.* How-
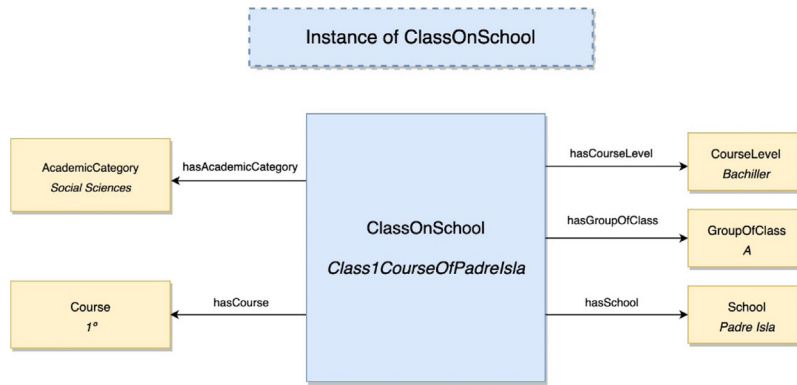

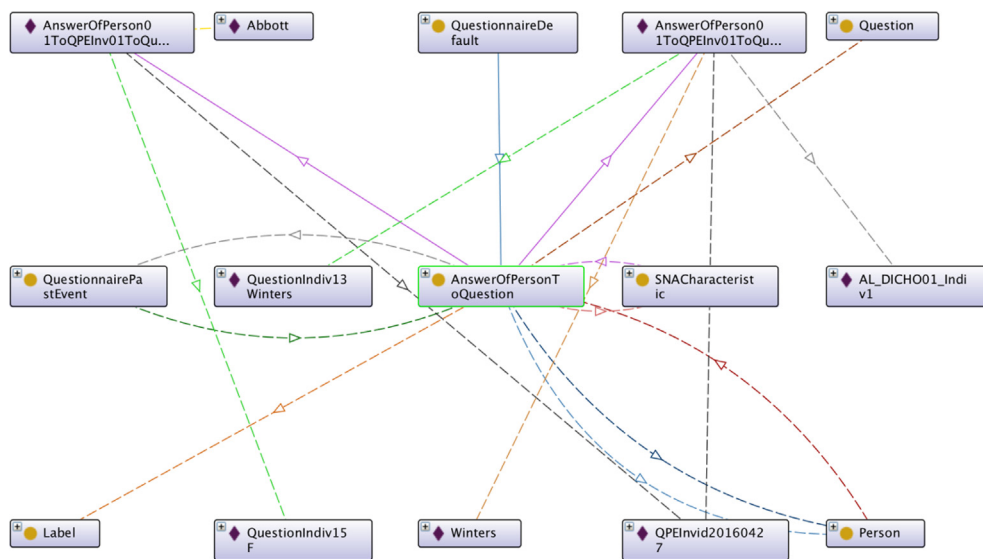**Fig. 2.** Example of ClassOnSchool instance.

Fig. 3. Conceptual representation on a person who has answered a questionnaire at a certain time using OntoSNAQA.

ever, the needs of the model presented, required a larger number of concepts to be added to make it more complete and meet the requirements of the initially proposed objectives. This is why it has been necessary to add 24 new classes to the initial model.

3.3. Construction of task ontology

A task ontology is used for enumerating and representing the specific problems to be solved. Besides constructing the conceptual structure, it is necessary to represent the different properties between the concepts in order to describe the problem-solving knowledge framework. OWL-based properties have different properties. The property values are first defined to separate asserted properties from inferred properties, both the known values and the unknown knowledge. The next step is to establish the corresponding domain and range of the properties. There are two types of properties, data properties and object properties. Data properties represent properties that use a basic data type in its range and object properties use instances of other classes in the range.

The task ontology has three main concepts related to the three domains that would be necessary to represent the achievement of the different objectives in this research. The domains of the different properties are mainly "Personal profile", "Questionnaire" and "Social Network Analysis" described below:

(1) Personal profile: There are 25 properties which have been designed for relating the domain of Person with concepts in the Questionnaires and Social Network Analysis. One asserted property is to give a name to the different concepts and twenty-four inferred properties to represent the different relationships between the Person and the Questionnaires and the Person and the Social Network Analysis. Thanks to these properties it is possible to establish that a person has answered a question in a questionnaire on a certain date, for example:

Abott	hasAnsweredToQuestionnairePastEvent	Quest01of20170530
	hasAnsweredToQuestion	QuestionGender

It is also possible to represent the different results of a person within a network, for example:

Abott	isMemberOf	FriendshipRelation
	hasAnswerOfPersonToQuestion	Answer01OfQPE01toQ01
	hasIndividualDegree	DegreeOfAbottInFriendshipRelation
	isStudentOf	Class1CourseOfPadreIsla
	hasRelation	AbottFriendOfClarck
	hasCharacteristicOfPerson	MaleGender

(2) Questionnaire: Forty-one properties are designed, including ten asserted properties designed to annotate the date on which a person completed a questionnaire, the value of a label which represents an answer, a text of a question and other concepts. Inferred properties allow Questionnaire concepts to be related with Person concepts and Social Network Analysis Concepts. For example, we can see below the representation of a question answered by a person in a questionnaire on a certain date in which the person has answered "male" to the question "What is your gender?". Furthermore, this question represents a characteristic of a person in a network:

QuestionGender	has_Question_Text	"What is your gender?"
	hasAnswer	AnswerOfGender
	isQuestionOf	QPE01
	isQuestionOfCharacteristicOfPerson	MaleGender
MaleGender	isAnsweredBy	Abott
	hasLabel	MaleLabel
	isAnswerOfPersonToQuestionOf	Answer01OfQPE01toQ01
MaleLabel	has_Value	"Male"

(3) Social Network Analysis: There are sixty-five properties needed to represent all of the relationships between the Social Network Analysis and the other two domains. Five properties are asserted and these properties have been used to represent the value or name of a characteristic in the network, the name of a network or the date of creation of a network from a Social Network Analysis. So, there are sixty properties created to represent the relationships between the Social Network Analysis concepts and the concepts of the Person domain and the Questionnaire domain. An example of a network related to a questionnaire and that related to a person is represented below:

FriendshipNetwork	has_Network_Name	"Friendship relation"
	hasMember	Abott
	isNetworkOfQPE	QPE01
	isNetworkOfTypeOfRelation	FriendshipRelation

3.4. Development of semantic rules

In the task ontology detailed in Table 2, there are 32 inferred properties which are designed as sub-tasks. These properties require semantic rules in SWRL and SPARQL queries to combine the related facts for inference. We collect the practical problem solving experiences before creating semantic rules, and then use the "premise -> conclusion" logic form to describe the solving process [45]. The rules start with the concept to which the property belongs, and then links the concept to other facts in a step-by-step manner until the objective is achieved. Each step is expressed as an atom and the rule is expressed in the form of "(atom$_1$^...^atom$_n$) -> Consequence" to express the cause-effect relationship.

In this study, seven SWRL-based rules and eleven SPARQL queries have been developed to obtain the concepts of the "Personal profile", "Questionnaire" and "Social Network Analysis".

(1) Rule-1: Linking a person with a network and a questionnaire on a certain date:

The first rule (Rule-1) represents the link between three concepts: *Person*, *SNANetwork* and *AnswerOfPersonToQuestionOf*.

Table 2
Task ontology.

Mainly concept	Class	Attribute definition			
		Attribute name	Type	Range	Rules & queries
Personal profile	Person	hasAnsweredToQuestion	Inferred	Question	Rule-1
		hasAnsweredToQuestionnairePastEvent	Inferred	AnswerOfPersonToQuestion	
		hasCharacteristicOfPerson	Inferred	SNACharacteristic	
		hasIndividualBetweenness	Inferred	IndividualBetweenness	
		hasIndividualCloseness	Inferred	IndividualCloseness	
		hasIndividualDegree	Inferred	IndividualDegree	
		hasIndividualEigenvector	Inferred	IndividualEigenvector	
		hasIndividualInDegree	Inferred	IndividualInDegree	
		hasIndividualOutDegree	Inferred	IndividualOutDegree	
		hsIsolateInstanceOfPerson	Inferred	SNAIsolate	
		hasRelation	Inferred	SNARelation	
		isMemberOf	Inferred	SNANetwork	
		isStudentOf	Inferred	ClassOnSchool	
		isTargetOfRelation	Inferred	SNARelation	
	ClassSchoolData	has_Data_Name	Asserted	(string)	
	AcademicCategory	isAcademicCategoryOf	Inferred	ClassOnSchool	
	Course	isCourseOf	Inferred	ClassOnSchool	
	CourseLevel	isCourseLevelOf	Inferred	ClassOnSchool	
	GroupOfClass	isGroupOfClassOf	Inferred	ClassOnSchool	
	School	isSchoolOf	Inferred	ClassOnSchool	
	ClassOnSchool	hasAcademicCategory	Inferred	AcademicCategory	
		hasCourse	Inferred	Course	
		hasCourseLevel	Inferred	CourseLevel	
		hasSchool	Inferred	School	
		hasStudent	Inferred	Person	
Questionnaire	QuestionnairePastEvent	has_Date_Start	Asserted	(datetime)	
		has_Date_End	Asserted	(datetime)	
		has_Event_Id	Asserted	(int)	
		hasAnsweredToQuestionnairePastEvent	Inferred	Person	
		hasAnswerOfPersonToQuestion	Inferred	AnswerOfPersonToQuestion	
		hasCharacteristicOfQPE	Inferred	SNACharacteristic	
		hasNetwork	Inferred	SNANetwork	
		hasQuestionnaire	Inferred	Questionnaire	
		isAnsweredByPerson	Inferred	Person	
	Answer	has_Number_Of_Answer_Label	Asserted	(int)	
		hasLabel	Inferred	Label	
		isAnswerOf	Inferred	AnswerSet	
	AnswerOfPersonToQuestion	hasAnswered	Inferred	Label	
		hasAnsweredTo	Inferred	Question	
		isAnAnsweringRelatingTo	Inferred	Person	
		isAnswerOfPersonOfCharacteristic	Inferred	SNACharacteristic	
		isAnswerOfPersonToQuestionOf	Inferred	Person	
		isAnswerOfQuestionnairePastEvent	Inferred	QuestionnairePastEvent	
	AnswerSet	has_Number_Of_Answers	Asserted	(int)	
		has_Number_Of_Selected	Asserted	(int)	
		hasAnswer	Inferred	Answer	
		isAnswerSetOf	Inferred	Question	

Table 2 (*continued*)

Mainly concept	Class	Attribute definition			
		Attribute name	Type	Range	Rules & queries
	Domain_Class	isDomainClassOf	Inferred	Domain_Ontology	
	Domain_Ontology	has_Domain_IRI	Asserted	(string)	
		has_Domain_Name	Asserted	(string)	
		hasDomainClass	Inferred	Domain_Class	
		isDomainOntologyOf	Inferred	Question	
	Answer_Label	has_Value	Asserted	(string)	
		isAnswerOfCharacteristicValue	Inferred	SNACharacteristicValue	
		isAnswerOfTypeOfRelation	Inferred	SNATypeOfRelation	
		isLabelOf	Inferred	Answer	
	Question	has_Question_Text	Asserted	(string)	
		hasAnswerSet	Inferred	AnswerSet	
		hasDomainOntology	Inferred	Domain_Ontology	
		hasMergedDomainClass	Inferred	Domain_Class	
		isQuestionOf	Inferred	Questionnaire	
		isQuestionOfCharacteristicOfPerson	Inferred	SNACharacteristic	
		isQuestionOfTypeOfCharacteristic	Inferred	SNATypeOfCharacteristic	
		isQuestionOfTypeOfRelation	Inferred	SNATypeOfRelation	
	Questionnaire	hasQuestion	Inferred	Question	
		isQuestionnaireOf	Inferred	QuestionnairePastEvent	
Social Network Analysis	SNACharacteristic	has_Characteristic_Name	Asserted	(string)	
		has_Characteristic_Value	Asserted	(string)	
		hasCharacteristicValue	Inferred	SNACharacteristicValue	
		isAnCharacteristicOfPersonOfQuestion	Inferred	Question	
		isCharacteristicOfAnswerOfPerson	Inferred	AnswerOfPersonToQuestion	Rule-5
		isCharacteristicOfNetwork	Inferred	SNANetwork	Rule-3
		isCharacteristicOfPerson	Inferred	Person	Rule-3 and 4
		isCharacteristicOfQPE	Inferred	QuestionnairePastEvent	Rule-3 and 4
		isCharacteristicOfType	Inferred	SNATypeOfCharacteristic	Rule-3 and 4
	SNACharacteristicValue	isCharacteristicValueOf	Inferred	SNACharacteristic	Rule-3
		isCharacteristicValueOfAnswer	Inferred	Answer_Label	
		isPossibleCharacteristicValueOf	Inferred	SNATypeOfCharacteristic	
	SNAIndice	has_SNA_Value	Asserted	(float)	Query-1 to 11
	IndividualBetweenness	isIndividiualBetweennessOfPerson	Inferred	Person	Rule-6
	NetworkBetweenness	isNetworkBetweennessOfNetwork	Inferred	SNANetwork	Rule-7
	IndividualCloseness	isIndividualClosenessOfPerson	Inferred	Person	Rule-6
	NetworkCloseness	isNetworkClosenessOfNetwork	Inferred	SNANetwork	Rule-7
	IndividualInDegree	isIndividualInDegreeOfPerson	Inferred	Person	Rule-6
	NetworkInDegree	isNetworkInDegreeOfNetwork	Inferred	SNANetwork	Rule-7
	IndividualDegree	isIndividualDegreeOfPerson	Inferred	Person	Rule-6
	NetworkDegree	isNetworkDegreeOfNetwork	Inferred	SNANetwork	Rule-7
	IndividualOutDegree	isIndividualOutDegreeOfPerson	Inferred	Person	Rule-6
	NetworkOutDegree	isNetworkOutDegreeOfNetwoerk	Inferred	SNANetwork	Rule-7
	DensityOfNetwork	isDensityOfNetworkOf	Inferred	SNANetwork	Rule-7
	IndividualEigenvector	isIndividualEigenvectorOf	Inferred	Person	Rule-6
	NetworkEigenvector	isNetworkEigenvectorOf	Inferred	SNANetwork	Rule-7
	NumberOfActors	isNumberOfActorsOf	Inferred	SNANetwork	Rule-7
	NumberOfActorsInvolvedInARelation	isNumberOfActorsInvolvedInARelationOf	Inferred	SNANetwork	Rule-7
	NumerOfObjectActors	isNumberOfObjectActorsOf	Inferred	SNANetwork	Rule-7

Table 2 (*continued*)

Mainly concept	Class	Attribute definition			
		Attribute name	Type	Range	Rules & queries
	NumberOfRelations	isNumberOfRelationsOf	Inferred	SNANetwork	Rule-7
	NumberOfSubjectActors	isNumberOfSubjectActorsOf	Inferred	SNANetwork	Rule-7
	SNAIsolate	isIsolateInstanceOfNetwork	Inferred	SNANetwork	
		isIsolateInstanceOfPerson	Inferred	Person	
	SNANetwork	has_Date	Asserted	(datetime)	
		has_Network_Name	Asserted	(string)	
		hasCharacteristicOfNetwork	Inferred	SNACharacteristic	
		hasDensityOfNetwork	Inferred	DensityOfNetwork	
		hasIsolateInstanceOfNetwork	Inferred	SNAIsolate	
		hasMember	Inferred	Person	Rule-1
		hasNetworkBetweenness	Inferred	NetworkBetweenness	
		hasNetworCloseness	Inferred	NetworkCloseness	
		hasNetworkDegree	Inferred	NetworkDegree	
		hasNetworkEigenvector	Inferred	NetworkEigenvector	
		hasNetworkInDegree	Inferred	NetworkInDegree	
		hasNetworOutDegree	Inferred	NetworkOutDegree	
		hasNumberOfActors	Inferred	NumberOfActors	
		hasNumberOfActorsInvolvedInARelation	Inferred	NumberOfActorsInvolvedInARelation	
		hasNumberOfObjectActors	Inferred	NumberOfObjectActors	
		hasNumberOfRelations	Inferred	NumberOfRelations	
		hasNumberOfSubjectActors	Inferred	NumberOfSubjectActors	
		hasRelationOfPerson	Inferred	SNARelation	
		isNetworkOfQPE	Inferred	QuestionnairePastEvent	
		isNetworkOfTypeOfRelation	Inferred	SNATypteOfRelation	
	SNARelation	isRelationOfNetwork	Inferred	SNANetwork	Rule-2
		isRelationOfPerson	Inferred	Person	Rule-2
		isRelationOfType	Inferred	SNATypeOfRelation	Rule-2
		isRelationWith	Inferred	Person	Rule-2
		isRelationOfQpe	Inferred	QuestionnairePastEvent	Rule-2
	SNATypeOfCharacteristic	hasPossibleCharacteristicValue	Inferred	SNACharacteristicValue	
		isCharacteristicOfQuestion	Inferred	Question	
		isTypeOfCharacteristicOf	Inferred	SNACharacteristic	
	SNATypeOfRelation	hasAnswerOfTypeOfRelation	Inferred	Answer_Label	
		hasQuestionOfTypeOfRelation	Inferred	Question	
		isTypeOfRleationOfNetwork	Inferred	SNANetwork	
		isTypeOfRelationOf	Inferred	SNARelation	

Person(?p) ^ SNANetwork(?net) ^ AnswerOfPersonToQuestion(?aoptq) ^ isAnswerOfQuestionnairePastEvent (?aoptq, ?qpe) ^ hasNetwork(?qpe, ?net) -> **hasMember(?net, ?p)** ^ **hasAnsweredToQuestionnaire PastEvent (?p, ?qpe)**	**Rule-1**

(2) Rule-2: A rule used to create instances of relationships between different people in a network

The Rule-2 searches to see whether an answer is of type "Answer Of Type Of Relation" (*isAnswerOfTypeOfRelation*) and it adds a relationship with the corresponding person of the corresponding type. For example, the answer "I'm always with Juan" answered by Laura implied that:

- I am always with => it is an answer to a relationship of friendship, partnership and acquaintance.
- So, in this case, three instances of class SNARelation will be created between Laura and Juan. These instances represent the three relationships between both.

This creation of a new instance is possible thanks to *swrlx:makeOWLThing,* belonging to the *ExtensionsBuiltInLibrary*. Once the instance is generated, initially in class *Thing*, in the consequent class, it is indicated that the instance is of type *SNARelation*.

isAnswerOfTypeOfRelation(?al, ?tor) ^ isTypeOfRelationOfNetwork(?tor, ?net) ^ swrlx:makeOWLThing(?rel, ?p, ?q) ^ isAnswerOfPersonToQuestionOf(?a, ?p) ^ Person(?q) ^ isAnswerOfQuestionnairePastEvent(?a, ?qpe) ^ Person(?p) ^ hasAnswered(?a, ?al) ^ SNANetwork(?net) ^ isNetworkOfQPE(?net, ?qpe) ^ isAnAnswerRelatingTo(?a, ?q) ^ differentFrom(?p,?q) -> **isRelationOfType(?rel, ?tor)** ^ **isRelationOfNetwork(?rel, ?net)** ^ **isRelationWith(?rel, ?q)** ^ **SNARelation(?rel)** ^ **isRelationOfQPE(?rel, ?qpe)** ^ **isRelationOfPerson(?rel, ?p)**	**Rule-2**

(3) Rule-3: this rule assigns a characteristic to a person within a network in relation to his or her answer to a questionnaire.

Some answers give value to a characteristic of a member within a network. This rule analyses whether the answer gives value to a characteristic of a person in a network and, if so, this rule generates a new instance of type characteristic, giving it the properties necessary to relate a person in a network with a type of characteristic.

Person(?p) ^ hasAnsweredToQuestion(?p, ?atoq) ^ hasAnswered(?atoq, ?al) ^ isAnswerOfCharacteristicValue(?al, ?av) ^ isPossibleCharacteristicValueOf(?av, ?atype) ^ isAnswerOfQuestionnairePastEvent(?a, ?qpe) ^ hasNetwork(?qpe, ?net) ^ swrlx:makeOWLThing(?aop, ?av, ?p) -> **SNACharacteristic(?aop)** ^ **isCharacteristicOfNetwork(?aop, ?net)** ^ **isCharacteristicOfPerson(?aop, ?p)** ^ **isCharacteristicOfQPE(?aop, ?qpe)** ^ **isCharacteristicValueOf(?av, ?aop)** ^ **isCharacteristicOfType(?aop, ?atype)**	**Rule-3**

(4) Rule-4: this rule creates an instance of class SNACharacteristic. This instance is a characteristic of a person that corresponds to the answer of this person to a question in a questionnaire answered at a certain time so later, through a SPARQL query, it will be possible to add the value corresponding to the sum of these answers, that it to say:

- If Juan is member of a network *Friendship* and there is a characteristic, for example *AuditValue*, that has an integer value, a new instance will be generated.
- This instance *AuditOfJuanInFriendship* has a relationship with an instance of an SNACharacteristic and this characteristic belongs to a type of characteristic, to a person, to a network and to a questionnaire at a certain time.

Person(?p) ^ SNACharacteristicValueInteger(?av) ^ isPossibleCharacteristicValueOf(?av, ?toa) ^ hasMember(?net, ?p) ^ hasAnsweredToQuestionnairePastEvent(?p, ?qpe) ^ swrlx:makeOWLThing(?aop, ?p, ?av) -> **SNACharacteristic(?aop)** ^ **isCharacteristicOfType(?aop, ?toa)** ^ **isCharacteristicOfPerson(?aop, ?p)** ^ **isCharacteristicOfNetwork(?aop, ?net)** ^ **isCharacteristicOfQPE(?aop, ?qpe)**	**Rule-4**

(5) Rule-5: after Rule-3 has been applied, thanks to this new rule, it is possible to find out which answer of a person is related to this new characteristic, for example:

- Juan has a characteristic *Gender* in a network called *Friendship*.
- This network *Friendship* is related to questionnaire answered at a certain time called *QPE01*.
- So, there is an answer of Juan in questionnaire *QPE01* which is related to the characteristic *Gender*.

SNACharacteristic(?aop) ^ isCharacteristicOfPerson(?aop, ?p) ^ isCharacteristicOfType(?aop, ?toa) ^	**Rule-5**

SNACharacteristicValueInteger(?av) ^ isPossibleCharacteristicValueOf(?av, ?toa) ^
isCharacteristicOfQuestion(?toa, ?q) ^ isAnswerOfPersonToQuestionOf(?aoptq, ?p) ^ hasAnsweredTo(?
aoptq, ?q) -> **isCharacteristicOfAnswerOfPerson(?aop, ?aoptq)**

(6) Rule-6: this rule creates the SNAConcepts of a person in a network. Thanks to this rule it is possible to create all instances relating a person with a network in terms of Social Network Analysis, concepts such as: *IndividualBetweenness, IndividualCloseness, IndividualDegree*, etc.

Rule-6

Person(?p) ^ SNANetwork(?net) ^ hasMember(?net, ?p) ^ swrlx:makeOWLThing(?bw, ?p, ?net) ^
swrlx:makeOWLThing(?cn, ?p, ?net) ^ swrlx:makeOWLThing(?dg, ?p, ?net) ^ swrlx:makeOWLThing(?in, ?
p, ?net) ^ swrlx:makeOWLThing(?ou, ?p, ?net) ^ swrlx:makeOWLThing(?ei, ?p, ?net) ->
**IndividualBetweenness(?bw) ^ isIndividualBetweennessOfPerson(?bw, ?p) ^
isIndividualBetweennessOfNetwork(?bw, ?net) ^ IndividualCloseness(?cn) ^
isIndividualClosenessOfPerson(?cn, ?p) ^ isIndividualClosenessOfNetwork(?cn, ?net) ^
IndividualDegree(?dg) ^ isIndividualDegreeOfPerson(?dg, ?p) ^ isIndividualDegreeOfNetwork(?dg, ?
net) ^ IndividualInDegree(?in) ^ isIndividualInDegreeOfPerson(?in, ?p) ^
isIndividualInDegreeOfNetwork(?in, ?net) ^ IndividualOutDegree(?ou) ^
isIndividualOutDegreeOfPerson(?ou, ?p) ^ isIndividualOutDegreeOfNetwork(?ou, ?net) ^
IndividualEigenvector(?ei) ^ isIndividualEigenvectorOfPerson(?ei, ?p) ^
isIndividualEigenvectorOfNetwork(?ei, ?net)**

(7) Rule-7: this rule creates the SNAConcepts of a network. Thanks to this rule it is possible to create all instances relating a network to the different terms of Social Network Analysis, concepts such as: *NetworkBetweenness, NetworkDegree,NetworkInDegree* etc.

Rule-7

SNANetwork(?net) ^ isNetworkOfQPE(?net, ?p) ^ swrlx:makeOWLThing(?bw, ?p, ?net) ^
swrlx:makeOWLThing(?cn, ?p, ?net) ^ swrlx:makeOWLThing(?dg, ?p, ?net) ^ swrlx:makeOWLThing(?in, ?
p, ?net) ^ swrlx:makeOWLThing(?ou, ?p, ?net) ^ swrlx:makeOWLThing(?ei, ?p, ?net) ^
swrlx:makeOWLThing(?noa, ?p, ?net) ^ swrlx:makeOWLThing(?noair, ?p, ?net) ^ swrlx:makeOWLThing(?
nooa, ?p, ?net) ^ swrlx:makeOWLThing(?nosa, ?p, ?net) ^ swrlx:makeOWLThing(?nor, ?p, ?net) ^
swrlx:makeOWLThing(?don, ?p, ?net) -> **NetworkBetweenness(?bw) ^ hasNetworkBetweenness(?net, ?
bw) ^ NetworkCloseness(?cn) ^ hasNetworkCloseness(?net, ?cn) ^ NetworkDegree(?dg) ^
hasNetworkDegree(?net, ?dg) ^ NetworkInDegree(?in) ^ hasNetworkInDegree(?net, ?in) ^
NetworkOutDegree(?ou) ^ hasNetworkOutDegree(?net, ?ou) ^ NetworkEigenvector(?ei) ^
hasNetworkEigenvector(?net, ?ei) ^ hasNumberOfActors(?net, ?noa) ^ hasNumberOfSubjectActors(?
net, ?nosa) ^ hasNumberOfObjectActors(?net, ?nooa) ^ hasNumberOfRelations(?net, ?nor) ^
hasNumberOfActorsInvolvedInARelation(?net, ?noair) ^ hasDensityOfNetwork(?net, ?don)**

Once the SWRL-based rules have been implemented in the ontology and applied to a particular case, this would become an ontology in which there would be instances that represent the values of a Social Network Analysis, such as:
  Intermediation level: represented by the NetworkBetweenness and IndividualBetweenness classes.
  - Sum of all relationships in a network: represented by class *NumberOfRelations*.
  - Sum of all members: represented by the *NumberOfActors, NumberOfObjectActors, NumberOfSubjectActors, NumberOfActorsInvolvedInARelation*.
  - Density of a network: represented by the class *DensityOfNetwork*.
  - Sum of all isolated members: represented by the class *SNAIsolate*.
  - Closeness level: represented by the *NetworkCloseness* and I*ndividualCloseness* classes.
  - Degree of entry: represented by the *NetworkInDegree* and *IndividualInDegree* classes.
  - Degree of output: represented by the *NetworkOutDegree* and *IndividualOutDegree* classes.
  - Complete degree: represented by the *NetworkDegree* and I*ndividualDegreee* classes.
  - Own vector: represented by the *NetworkEigenvector* and *IndividualEigenvector* classes.

Each of the instances will have a numerical value, represented by the data property *has_SNA_Value*. To make these calculations, it has been necessary to generate a series of queries in SPARQL Update, which can be processed later with environments such as Apache Fuseki Server, Stardog or Virtuoso. All of the queries are described in Appendix A and these are available at https://doi.org/10.21227/z6pj-je73.

4. Experimental validation and case study

4.1. Introduction to a case study

The line of work that gives rise to this research is based on the fact that alcohol consumption among adolescents is a social and public health problem [6]. Research so far has found that contacts between adolescents can influence the habit of consumption. Specifically, the adolescent's social network includes diverse contact patterns in the classroom, which pose a risk in the consumption of drugs, such as the negative influence of peers, social norms that govern relationship groups, or the position they occupy within the social network. However, there is a lack of studies that look into how educational leaders and other multidisciplinary collectives perceive these contacts, in order to obtain useful information to transfer ethnographic information to the quantitative analysis of the SNA and design strategies in which the stakeholders are incorporated.

The objective of the case study was to analyze the perspective of teachers as to the position and pattern of behavior that adolescents occupy in the classroom and their relationship with the high risk of alcohol intake.

In this research, a study based on mixed methods was carried out in two schools of Compulsory Secondary Education, using random sampling according to inclusion criteria, with a total of 10 teachers. The methodology used was quantitative for the analysis of the structural data of the networks of contacts through an Analysis of Social Networks (self-administered questionnaire) and qualitative, through discussion groups, with the education officer responsible for the classrooms.

After obtaining the data through the questionnaires, the next step is to analyze the "raw" data to later reach a series of conclusions. The justification of this research begins in this step of the project.

All of the ontology explained throughout this document, as well as the SWRL rules and SPARQL queries, can and has helped to carry out this research, saving time for the health expert in drawing up the questions and allowing the values and conclusions to be obtained with a reduced error as it is an automated process, eliminating human error in the reading and transcription of data, among others. Another important feature is that it is now possible to visualize and obtain a result from the social network analysis.

4.2. Web-based application development using the ontology

For the primary purpose of testing the conceptual model generated in this research, a web application has been made that makes use of it. This web solution is mainly aimed at research experts, mainly from the health field, who wish to carry out studies on a population group based on personalized surveys. This application will allow the user to carry out the following functions:

- To create personalized surveys to send to a certain group of people.
- To carry out the Social Network Analysis on the data obtained through the surveys of the different users.
- To obtain an approximate interpretation of the data obtained in the Social Network Analysis carried out.

The proposed application has a Login System, through which the researcher will access a personalized control panel in which he or she will be able to carry out the necessary tasks for his or her research. This Login system has been made in the PHP programming language, using programming oriented objects, MySQL database and HTML5, Javascript (jQuery, AJAX) and CSS3 has been made use of for the web interface. It is also worth mentioning the use of the Apache Jena Fuseki Server to make direct queries to the ontology, as well as its repopulation from the administrator and manager environment.

Furthermore, it has been necessary to use specific libraries to manage the creation of different graphs, specifically the SigmaJS library (http://sigmajs.org/) used in other studies of interest [46], as well as its different plugins, highlighting especially the Louvain statistics manager, based on this algorithm [47].

The application initially has three roles:

- Super administrator: they have full permission to manage validated questionnaires, as well as users, pollsters and respondents.
- Surveyor: they can add validated questionnaires, under review by a super administrator, and you can only access your questions, surveys and interviewers.
- Surveyed: they only have access to the platform to carry out the questionnaires that their interviewer needs.

The interface is friendly and simple, without needing to have a high level of computer knowledge at the programming level. We came to this conclusion after obtaining a positive response from fourteen researchers from different scientific branches, all different from engineering: nursing, psychology, anthropology and pharmacy.

With this application, the researcher can carry out the following tasks:

- Manage validated questionnaires
- Manage questions for questionnaires
- Manage questionnaires
- Manage pollsters
- Analyze data from surveys conducted

The respondents will only access a control panel where they can see the surveys that have been assigned to them to answer.

This application has the following functionalities, based on the type of information that can be obtained from the data from the questionnaires that have been inserted into it in this research and the aforementioned requirements.

- Load the set of data from the answers to the questionnaire and show the different networks that can be useful to find out the habit of alcohol consumption in relation to friendship (at school level) and family networks.
- Show the data graphs and the results of the analysis on the social patterns of alcohol consumption taking into account the different levels of relationship with a partner (acquaintance, partner and friend) and also within the family environment, as well as basic information on the relationships with the individuals outside the school / class and the family circle.
- Show basic data and a description similar to a report on any individual in the network as to their alcohol consumption status, especially in relation to the risk of alcohol consumption disorder or any type of relevance within the network that the individual may experience (be it a mediator, an influencer for others, etc.). This report will be the result of different calculations carried out by SNA and other techniques.
- Show, for each individual, who can act as an influence on him / her.
- Show a description similar to the aforementioned report, but for social networks and entire groups that can be found.
- Show and study the level of alcohol consumption in relation to gender and the environment.
- Show and report the relationship that may exist between alcohol consumption, socioeconomic status, self-perception and self-efficacy.
- Show and report factors that may be related to the level of alcohol consumption, such as the use of politoxicomaniacs and the consumer and relationship environments.

4.3. Description of validation method to the case study

In the previous section, the web application that makes use of the ontology developed throughout this research has been explained [48]. However, what is really interesting and what determines whether the model works and that the data shown are valid, is the comparison of said data with an environment that has already been validated previously in the carrying out of the SNA.

For this reason, it was decided to carry out the social network analysis on the particular case study with the UCINET tool, Cytoscape, Pajek and Gephi, so that by making the aforementioned relevant SPARQL queries, it is possible to make a comparison of whether the results are exactly the same or if there are discrepancies in the system that has been generated.

Next, we will describe the data obtained using the UCINET tool in the particular case that arose in this research, as well as the data obtained through the ontology generated and populated with the data in question.

4.4. Introduction to the social network analysis to be applied

The particular case to which the generated conceptual model would be applied, as well as the aforementioned system, had as its main objective to analyze the perspective of the teaching staff as to the position and pattern of behavior that adolescents occupy in the classroom and their relationship with the high risk of alcohol consumption.

For this, a survey was carried out that included a total of 252 fixed generic questions and a variable number of questions related to social networks. This variability depended on the number of respondents, since there were two questions in this questionnaire that related the respondents to each other. If the questionnaire was completed by a group of forty people, for example, forty students in a school class, the total number of questions would be 252 + 80 = 332. However, if the same questionnaire had been completed by a group of eighty people, there would have been the 252 common questions plus the 2 questions related to the eighty people, which would make a total of 252 + 160 = 412 questions in total.

This questionnaire was carried out for the first time by different students aged 16 and 17 in 9 different classes, with a total of 214 people surveyed, with a total of 14,555 answered questions to be analyzed. These 214 people represent several classrooms from different schools. To carry out our study we have selected a classroom of 38 people. The first step in the research was carried out manually, that is, the research group asked the different students to answer a survey using an online form.

This form stored the answers on a spreadsheet. This questionnaire had different standardized forms, specifically the following: AUDIT, FAS II, KIDSCREEN 27, STUDES.

The research group, once the data was obtained, took an average of 15 min per respondent to obtain the sum of the individual values of the questions corresponding to these forms.

Subsequently, they used Social Data Analysis tools for specific data blocks, including: GEPHI [49], Pajek [50] and UCINET [10]. With this methodology, an average of two hours was necessary to be able to obtain graphs in each of the 9 classes surveyed, having to analyze the meaning of the different data later.

In a second phase, they returned to carry out the data collection from the aforementioned questionnaire with the tool developed and explained in this article. Although the creation of the survey took them a total of 14 h, including the involvement of the 38 users who had to carry out the survey, once all the users filled out their respective questionnaires, they obtained the results class by class immediately.

Next, we will detail the results of the analysis of a social network belonging to one of the nine classes at the school through UCINET, Cytoscape, Pajek, Gephi and through the application developed in this research that makes use of the generated ontology.

5. Results

As mentioned above, the model, through the use of different SPARQL queries, is able to obtain different significant measurements when carrying out a personal social network analysis. That is why the results obtained through the different SNA programs (UCINET, Cytoscape, Pajek and Gephi) that determine the following values of a social network analysis are shown below:

Measurements from each network:
- Total number of relationships in a network
- Total number of stakeholders within a network
- Total number of members subject within a network
- Total number of total members within a network
- Total number of members that have at least one relationship within a network
- Average degree of a network
- Density of a network
- Total number of nodes without connection within a network

Measures obtained for each actor within the network:
- Degree of each actor within a network
- Indegree of each actor within a network
- Outdegree of each actor within a network

Within the study carried out by the population group made up of thirty-eight students aged 16 and 17 from a school, three networks have been differentiated according to the following criteria:
- One of the questions included in the questionnaire was responsible for how much time the respondent and his classmates spent together.
- There were five possible answers: never, almost never, sometimes, almost always, always.
- Each response had a numerical value of between 1 and 5 according to the previously expressed request and that can be seen in the table shown below in Table 3:
- Based on this weighting, three types of relationships have been determined. Table 4 shows these relationships.

Once the three networks chosen for the validation of the model have been explained, as well as the different values to be compared, a series of comparative tables between the values obtained by SNA Standard Tools (UCINET, Cytoscape, Pajek, Gephi) and the system created in this research through SPARQL queries will be presented below.

The results of the Social Network Analysis using SNA Standard Tools and our web-based application that uses the ontology is represented in the following table (Table 5):

6. Discussion

Once the different comparative tables of results from the particular case study have been obtained, the system generated as a result of the ontology developed throughout this research, shows coherent and correct results when carrying out a social network analysis on three different networks.

These data are those used by the application generated and explained previously in this document, thanks to which, not only are the measures obtained at the SNA level, but real conclusions and an interpretation of the measures obtained in the SNA are obtained.

Thanks to the conclusions resulting from the implementation of the application used, the expert in drawing up the questions can, without having knowledge of SNA, obtain an interpretation of one or several social networks without needing knowledge of Social Network Analysis.

For this reason, this tool seems to facilitate the collection of data and their analysis in the field of research and in different domains, but especially in the field of medicine. Although it still needs improvements and solutions to small operating errors, it really fulfills the purpose of improving the handling of data by researchers and saves time both for the researchers and the respondents since it offers the opportunity to carry out surveys from any place where there is an Internet access point.

Table 3
List of labels with the value in a questionnaire.

Answer	Value
Never	1
Almost never	2
Sometimes	3
Almost always	4
Always	5

Table 4
Values needed to consider a relation between two people in a network.

Relationship	Value
Friendship	4 and 5
Workmate	3, 4 and 5
Acquaintance	2, 3,4 and 5

Table 5
Results of the Social Network Analysis carried out using SNA Standard Tools and using KBS.

SNA Measures tested	Equivalent results
Friendship network measurements (density, members, isolated…)	Yes
Classmate network measurements	Yes
Acquaintance network measurements	Yes
Measurements of members in a friendship network	Yes
Measurements of members in a classmate network	Yes
Measurements of members in an acquaintance network	Yes

7. Conclusions

As final conclusions to this research, we can say that it has been possible to define a conceptual model within the scope of Social Network Analysis, which in turn is adaptable to any domain of structured content in which an SNA is applied. This has been possible using semantic technologies, learning techniques and information filtering processes within the Semantic Web.

Furthermore, a development environment has been designed and developed that allows semantic technologies to be applied and making use of the conceptual model generated as the basis of a Knowledge Based System useful for multiple domains.

In a new step in the research, the generated conceptual model has been implemented, making use of the knowledge base generated on the basis of a series of data obtained through surveys or questionnaires and able to reach conclusions thanks to a series of SPARQL queries on the said model.

Based on some data, it has been possible to draw conclusions on an SNA in the field of health. This has been possible thanks to the rules and queries generated for that particular domain. However, the system allows the adaptation or use of the said system in any other domain, by previously inserting the specification of the particular knowledge for the domain in which it is required to apply the said System Based on Knowledge.

In this research, it has also been possible to obtain a characterization of the structured and semantic content common to any SNA, and which can also be applied indifferently in any domain.

Finally, thanks to the generation of semantic rules in the SWRL language, applying these with a semantic reasoning, in the case of this particular Pellet research, as well as thanks to the SPARQL queries, it has been possible to obtain the necessary base of an SBC to generate conclusions from a different Social Network Analysis, without the need to apply it to a single domain.

CRediT authorship contribution statement

José Alberto Benítez-Andrades: Methodology, Software, Writing - original draft. **Isaías García-Rodríguez:** Conceptualization, Supervision. **Carmen Benavides:** Investigation. **Héctor Aláiz-Moretón:** Resources, Methodology. **José Emilio Labra Gayo:** Supervision, Project administration.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgments

Appendix A. SPARQL Update queries.

This section completes the ontological model of this system. In this part of the document SPARQL Update queries will be shown. These queries have been necessary to achieve some of the objectives of this research.

(1) Relationship counter in a network

```
Query-1
PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX owl: <http://www.w3.org/2002/07/owl#>
PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>
PREFIX xsd: <http://www.w3.org/2001/XMLSchema#>
PREFIX jisnaqa: <http://www.jabenitez.com/ontologias/jisnaqa#>
INSERT{
  ?nor jisnaqa:has_SNA_Value ?tot
}
WHERE{
  SELECT ?net ?nor (count(distinct ?rel) as ?tot) WHERE {
    ?net a jisnaqa:SNANetwork .
    ?net jisnaqa:hasNumberOfRelations ?nor .
    ?rel jisnaqa:isRelationOfNetwork ?net
    ?rel jisnaqa:isRelationOfPerson ?p .
    ?rel jisnaqa:isRelationWith ?q
    # FILTER (?p != ?q)
  } GROUP BY ?net ?nor
}
```

(2) Object actors counter in a network

```
Query-2
PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX owl: <http://www.w3.org/2002/07/owl#>
PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>
PREFIX xsd: <http://www.w3.org/2001/XMLSchema#>
PREFIX jisnaqa: <http://www.jabenitez.com/ontologias/jisnaqa#>
INSERT{
  ?noa jisnaqa:has_SNA_Value ?tot
}
WHERE{
  SELECT ?net ?noa (count(distinct ?p) as ?tot) WHERE {
    ?net a jisnaqa:SNANetwork.
    ?net jisnaqa:hasNumberOfActorsInvolvedInARelation ?noa
    ?p jisnaqa:isMemberOf ?net.
    ?rel jisnaqa:isRelationOfPerson ?q .
    ?rel jisnaqa:isRelationWith ?p .
    ?rel jisnaqa:isRelationOfNetwork ?net
  } GROUP BY ?net ?noa
}
```

(3) Subject actors counter in a network

```
Query-3
PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX owl: <http://www.w3.org/2002/07/owl#>
PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>
PREFIX xsd: <http://www.w3.org/2001/XMLSchema#>
PREFIX jisnaqa: <http://www.jabenitez.com/ontologias/jisnaqa#>
INSERT{
```

```
    ?nosa jisnaqa:has_SNA_Value ?tot
}
WHERE{
   SELECT ?net ?nosa (count(distinct ?p) as ?tot) WHERE {
      ?net a jisnaqa:SNANetwork .
      ?p jisnaqa:isMemberOf ?net .
      ?net jisnaqa:hasNumberOfSubjectActors ?nosa .
      ?rel jisnaqa:isRelationOfPerson ?p .
      ?rel jisnaqa:isRelationWith ?q .
      ?rel jisnaqa:isRelationOfNetwork ?net
   } GROUP BY ?net ?nosa
}
```

(4) Total actors counter in a network

```
Query-4
PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX owl: <http://www.w3.org/2002/07/owl#>
PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>
PREFIX xsd: <http://www.w3.org/2001/XMLSchema#>
PREFIX jisnaqa: <http://www.jabenitez.com/ontologias/jisnaqa#>
INSERT{
   ?noa jisnaqa:has_SNA_Value ?tot
}
WHERE{
   SELECT ?net ?noa (count(distinct ?p) as ?tot) WHERE {
      ?net a jisnaqa:SNANetwork .
      ?p jisnaqa:isMemberOf ?net .
      ?net jisnaqa:hasNumberOfActors ?noa .
   } GROUP BY ?net ?noa
}
```

(5) Total actors counter with at least one relationship in a network

```
Query-5
PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX owl: <http://www.w3.org/2002/07/owl#>
PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>
PREFIX xsd: <http://www.w3.org/2001/XMLSchema#>
PREFIX jisnaqa: <http://www.jabenitez.com/ontologias/jisnaqa#>
INSERT{
   ?noai jisnaqa:has_SNA_Value ?tot
}
WHERE{
   SELECT ?net ?noai (count(distinct ?p) as ?tot) WHERE {
      ?net a jisnaqa:SNANetwork .
      ?net jisnaqa:hasNumberOfActorsInvolvedInARelation ?noai .
      ?p jisnaqa:isMemberOf ?net .
      ?rel jisnaqa:isRelationOfPerson | jisnaqa:isRelationWith ?p .
      ?rel jisnaqa:isRelationOfPerson | jisnaqa:isRelationWith ?q .
      ?rel jisnaqa:isRelationOfNetwork ?net
      # FILTER (?p != ?q)
   } GROUP BY ?net ?noai
}
```

(6) Total degree of each actor in a network

Query-6
```
PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX owl: <http://www.w3.org/2002/07/owl#>
PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>
PREFIX xsd: <http://www.w3.org/2001/XMLSchema#>
PREFIX jisnaqa: <http://www.jabenitez.com/ontologias/jisnaqa#>
INSERT{
  ?deg jisnaqa:has_SNA_Value ?val
}
WHERE{
  SELECT ?p ?net ?deg (count(?rel) as ?val) WHERE {
    ?p jisnaqa:isMemberOf ?net .
    ?p jisnaqa:hasRelation ?rel .
    ?rel jisnaqa:isRelationWith ?q .
    ?deg jisnaqa:isIndividualDegreeOfPerson ?p .
    ?deg jisnaqa:isIndividualDegreeOfNetwork ?net .
    ?rel jisnaqa:isRelationOfNetwork ?net
    #FILTER (?p != ?q)
  } GROUP BY ?p ?net ?deg
}
```

(7) Total indegree of each actor in a network

Query-7
```
PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX owl: <http://www.w3.org/2002/07/owl#>
PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>
PREFIX xsd: <http://www.w3.org/2001/XMLSchema#>
PREFIX jisnaqa: <http://www.jabenitez.com/ontologias/jisnaqa#>
INSERT{
  ?indg jisnaqa:has_SNA_Value ?val
}
WHERE{
  SELECT ?p ?net ?indg (count(?rel) as ?val) WHERE {
    ?p jisnaqa:isMemberOf ?net .
    ?p jisnaqa:isTargetOfRelation ?rel .
    ?rel jisnaqa:isRelationOfNetwork ?net .
    ?indg jisnaqa:isIndividualInDegreeOfPerson ?p .
    ?indg jisnaqa:isIndividualInDegreeOfNetwork ?net .
    ?rel jisnaqa:isRelationOf ?q
    # FILTER (?p != ?q)
  } GROUP BY ?p ?net ?indg
}
```

(8) Total outdegree of each actor in a network

Query-8
```
PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX owl: <http://www.w3.org/2002/07/owl#>
PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>
PREFIX xsd: <http://www.w3.org/2001/XMLSchema#>
PREFIX jisnaqa: <http://www.jabenitez.com/ontologias/jisnaqa#>
INSERT{
  ?oudg jisnaqa:has_SNA_Value ?deg
}
```

```
WHERE{
    SELECT ?p ?net ?oudg (count(?rel) as ?deg) WHERE {
        ?p jisnaqa:isMemberOf ?net .
        ?p jisnaqa:hasRelation ?rel .
        ?rel jisnaqa:isRelationOfNetwork ?net .
        ?oudg jisnaqa:isIndividualOutDegreeOfPerson ?p .
        ?oudg jisnaqa:isIndividualOutDegreeOfNetwork ?net .
        ?rel jisnaqa:isRelationWith ?q
        # FILTER (?p != ?q)
    } GROUP BY ?p ?net ?oudg
}
```

(9) Average degree of a network

Query-9
```
PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX owl: <http://www.w3.org/2002/07/owl#>
PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>
PREFIX xsd: <http://www.w3.org/2001/XMLSchema#>
PREFIX jisnaqa: <http://www.jabenitez.com/ontologias/jisnaqa#>
INSERT{
    ?dg jisnaqa:has_SNA_Value ?deg
}
WHERE{
    SELECT ?p ?net ?dg (count(?rel) + count(?relout) as ?deg) WHERE {
        ?p jisnaqa:isMemberOf ?net .
        ?p jisnaqa:isTargetOfRelation ?relin .
        ?relin jisnaqa:isRelationOfNetwork ?net .
        ?p jisnaqa:hasRelation ?relout .
        ?relout jisnaqa:isRelationOfNetwork ?net .
        ?dg jisnaqa:isIndividualDegreeOfPerson ?p .
        ?dg jisnaqa:isIndividualDegreeOfNetwork ?net .
        ?relin jisnaqa:isRelationOf ?q .
        ?relout jisnaqa:isRelationWith ?q
        # FILTER (?p != ?q)
    } GROUP BY ?p ?net ?dg
}
```

(10) Density of a network

Query-10
```
PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX owl: <http://www.w3.org/2002/07/owl#>
PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>
PREFIX xsd: <http://www.w3.org/2001/XMLSchema#>
PREFIX jisnaqa: <http://www.jabenitez.com/ontologias/jisnaqa#>
INSERT{
    ?don jisnaqa:has_SNA_value ?tot
}
WHERE{
    SELECT ?net ?don (count(distinct ?rel) as ?tot) (count(distinct ?p) * (count(distinct ?p)-1) as ?totactors)
    (?tot/?totactors as ?density)
    WHERE {
        ?net a jisnaqa:SNANetwork .
        ?net jisnaqa:hasDensityOfNetwork ?don
    {
        ?rel jisnaqa:isRelationOfNetwork ?net
    } UNION {
```

```
        ?p jisnaqa:isMemberOf ?net
    }
    }GROUP BY ?net ?don
}
```

(11) Isolates in a network

Query-11
PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX owl: <http://www.w3.org/2002/07/owl#>
PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>
PREFIX xsd: <http://www.w3.org/2001/XMLSchema#>
PREFIX jisnaqa: <http://www.jabenitez.com/ontologias/jisnaqa#>

DELETE { ?isol jisnaqa:has_SNA_Value ?val}
INSERT { ?isol jisnaqa:has_SNA_Value '1' }
WHERE{
    SELECT ?p ?net
    WHERE{
        ?p a jisnaqa:Person .
        ?p jisnaqa:isMemberOf ?net .
        ?isol jisnaqa:isIsolateInstanceOfNetwork ?net .
        ?isol jisnaqa:isIsolateInstanceOfPerson ?p .
        ?isol jisnaqa:has_SNA_Value ?val
        FILTER NOT EXISTS {
    ?rel jisnaqa:isRelationOfNetwork ?net .
    ?rel   jisnaqa:isRelationOfPerson|jisnaqa:isRelationWith ?p
    }
    }group by ?p ?net
}
```

## Appendix B. Tables of results

Results of the measures the three of different networks are listed below:

*Friendship network measures*

### B.1.Social Network Analysis of Friendship network

| Network Measures | UCINET | Pajek | Cytoscape | Gephi | OntoSNAQA |
|---|---|---|---|---|---|
| Total relations | 116 | 116 | 116 | 116 | 116 |
| Total actors | 38 | 38 | 38 | 38 | 38 |
| Total object actors | 32 | 32 | 32 | 32 | 32 |
| Total subject actors | 32 | 32 | 32 | 32 | 32 |
| Actors with any relation | 32 | 32 | 32 | 32 | 32 |
| Average degree | 2.342 | 2.342 | 2.342 | 2.342 | 2.342 |
| Density of network | 0.063 | 0.063 | 0.063 | 0.063 | 0.0633 |
| Isolate nodes | 6 | 6 | 6 | 6 | 6 |

*Classmate network measures*

### B.2. Social Network Analysis of Classmate network

| Network Measures | UCINET | Pajek | Cytoscape | Gephi | OntoSNAQA |
|---|---|---|---|---|---|
| Total relations | 178 | 178 | 178 | 178 | 178 |
| Total actors | 38 | 38 | 38 | 38 | 38 |
| Total object actors | 37 | 37 | 37 | 37 | 37 |

**Classmate network measures** (*continued*)

*B.2. Social Network Analysis of Classmate network*

| Network Measures | UCINET | Pajek | Cytoscape | Gephi | OntoSNAQA |
|---|---|---|---|---|---|
| Total subject actors | 33 | 33 | 33 | 33 | 33 |
| Actors with any relation | 37 | 37 | 37 | 37 | 37 |
| Average degree | 3.947 | 3.947 | 3.947 | 3.947 | 3.947 |
| Density of network | 0.107 | 0.107 | 0.107 | 0.107 | 0.107 |
| Isolate nodes | 1 | 1 | 1 | 1 | 1 |

*Acquaintance network measures*

*B.3. Social Network Analysis of Acquitance network*

| Network Measures | UCINET | Pajek | Cytoscape | Gephi | OntoSNAQA |
|---|---|---|---|---|---|
| Total relations | 404 | 404 | 404 | 404 | 404 |
| Total actors | 38 | 38 | 38 | 38 | 38 |
| Total object actors | 38 | 38 | 38 | 38 | 38 |
| Total subject actors | 38 | 38 | 38 | 38 | 38 |
| Actors with any relation | 38 | 38 | 38 | 38 | 38 |
| Average degree | 9.816 | 9.816 | 9.816 | 9.816 | 9.816 |
| Density of network | 0.265 | 0.265 | 0.265 | 0.265 | 0.265 |
| Isolate nodes | 0 | 0 | 0 | 0 | 0 |

The Social Network Analysis of the actors was also carried out, obtaining, from each of the three networks, the following values of each of the actors:

- Indegree of each actor within a network
- Outdegree of each actor within a network

No significant differences were found between any of the values obtained by each of the programmes used to compare the efficiency of KBS.

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