OOPS ! and Competency Questions for Evaluating the Intelligent Business Process Management Ontology

Sarra MEJRI
Laboratory RIADI-GDL, ENSI, Manouba 2010, University of Manouba, Tunisia
Higher Institute of Computer Science and Communication Techniques of Hammam Sousse, University of Sousse, Tunisia
e-mail: sarra.mejri.fsm@gmail.com

Sonia AYACHI GHANNOUCHIN
Laboratory RIADI-GDL, ENSI, Manouba 2010, University of Manouba, Tunisia
Higher Institute of Management of Sousse, University of Sousse, Tunisia
e-mail: sonia.ayachi.ghannouchi@gmail.com

***Abstract*— The Intelligent Business Process Management Ontology (IBPMO) models the most important concepts in the context of both Business Process Management (BPM) and Industry 4.0. It ensures the selection of the most suitable technologies 4.0 for Business Processes (BPs). Ontologies have great promise for improving BPM and realizing the Industry 4.0 vision. Ontology Development 101 is the method of ontology modeling. A framework would be helpful to allow the involved actors benefiting from the built ontology and using it for selecting appropriate technologies 4.0 to be integrated in BPs. In this paper, an evaluation framework is proposed to evaluate our IBPM ontology for which existing evaluation methods have been combined into a single framework, dividing the methods used into two phases: verification and validation. The verification of the ontology is concerned with validating whether an ontology was correctly built. It evaluates the structure, functionality and representation of the ontology. It specifically focuses on the validation activity using OntOlogy Pitfall Scanner! (OOPS !) tools. Different metrics and common pitfalls are used to detect errors. The OOPS! tool adopts specific metrics for detecting most anomalies found in the ontology and suggests improvements. Ontology validation is achieved by using Competency Questions (CQs) and expert interviews. This evaluation, which relied on a technology-based approach, using OOPS! tool, and a prototype development, proved the validity of our IBPMO ontology.**

Keywords—ontology; Industry 4.0; Intelligent BPM; ontology evaluation; Competency Questions; OOPS!.

I. INTRODUCTION

We have proposed IBPMO, in a previous work [1], an ontology developed for intelligent BPM, divided into two modules: BPM and Industry 4.0. The use of IBPMO ensures the selection of the most suitable technologies 4.0 for BPs.

This paper aims to assess the quality and the content of the IBPM Ontology (IBPMO) to ensure that it is well built, structured and contains all important concepts and relationships for sufficient reasoning.

Ontologies consist in a formal conceptualization of the knowledge representation and provide the definitions of the concepts and relations capturing the knowledge of a domain in an interoperable way [2]. In recent years, ontology tools have been widely used for representation and reasoning in IBPM, which consists of adding smart technologies and business intelligence to BPM[2] [3].

Semantic Web technologies, especially ontologies, can be connected with logical inferences to enable a common perception of a particular specific domain. Thus, they could facilitate alignment and integration of information entities for Industry 4.0 processes, connecting people, organization of work, and application systems [4]. Ontologies are promising means to improve BPM and to realize the Industry 4.0 vision [5]. Besides, the evaluation of the modeling is an important step in the process of ontology development. This step ensures the adequacy of the ontology and reduces maintenance costs. In fact, ontology evaluation is needed to decide on the quality and content of the ontology by judging it against a reference framework and identifying what the ontology defines correctly, incorrectly or not at all. It is essential for the adoption and improvement of the ontology.

Ontology evaluation is a key ontology engineering activity that can be performed following a variety of approaches and using various tools [6]. It consists of two parts : ontology validation process and verification activity [7]. Ontology validation process checks the correctness of the built ontology and especially investigates the structure, functionality and representation of the ontology with the help of different metrics and quality criteria. Whereas, ontology verification activity checks if the right ontology is built given the suggested application of the ontology [8].

In ontology development 101 (OD 101) method [9], evaluation involves four types of references, which are CQs, application-based, modeling guidelines and expert domain. The first, third and fourth types of references are used during ontology modeling, while the second is used with the application. The Ontology Development 101 (OD 101) is used to model and evaluate ontologies effortlessly and with more flexibility. To the best of our knowledge, the existing research works for example [10] and [11] concentrate on the consideration of OD 101 for evaluating their ontologies. Thereby, in this paper, we considered the ontology evaluation during ontology modeling, which are CQs, application-based evaluation, modeling guidelines.

CQs are used as reference for verification activity. CQs play a crucial role in the ontology development lifecycle, as they represent the ontology requirements [12].

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OOPS ! is used as a tool for validation activity. OOPS ! represents a tool for diagnosing (semi-) automatically in OWL ontologies and targeted at newcomers and domain experts unfamiliar with description logics and ontology implementation languages. This tool operates independently of any ontology development platform and is available online [13].

The contribution of this work is to propose an evaluation framework to evaluate the IBPMO; and thereby refine the IBPMO. The IBPMO has been evaluated using CQs. Then, IBPMO has been verified for its structure using the OOPS ! tool, which was chosen due to its ability to perform both ontology diagnosis and repair activity. The ontology is refined based on the results of this tool. The IBPMO has been validated semantically using various CQs to determine its applicability. The IBPMO has then been put to the said application and the task based evaluation has been carried out. It is found that IBPMO is able to serve its intended purpose after tuning it based on the results of evaluation. After evaluating the IBPMO, we could ensure that the procedure of selecting the most suitable technologies for BPs within the IBPMO is successfully carried out.

The goal in this paper is mainly to adopt an evaluation process in order to improve the IBPMO. For this purpose, it is worth noting that considering CQs, the OOPS ! tool and the application-based evaluation can help us to successfully evaluate our IBPMO.

The rest of this paper is structured as follows: Section 2 presents related work on ontologies evaluation. Regarding the third section, it deals with our research methodology. Section 4 briefly explains the implementation of the evaluation process in IBPMO. Section 5 concludes the findings.

II. Related work on ontologies evaluation

Many researchers have worked on ontology evaluation. Jain et al. [14] proposed an evaluation framework to evaluate the Emergency Situation Ontology (ESO), in which existing evaluation methods have been combined into a single framework, dividing the methods used into two phases: verification and validation. Richard, et al. [15] proposed the LOVMI(Ontologies Validated by Interactive Method) method in order to validate ontologies and in particular their developed ontology ONTOPSYCHIA, which is an ontology for psychiatry in three modules: social and environmental factors of mental disorders, and treatments. LOVMI validation is performed in six steps: validation (1) of consistency, (2) of other structural aspects, (3) of labels, (4) of choices of label and (5) of semantic with experts and (6) of semantic in an application. On the other hand, Kalita, et al. [16] presented an evaluation of the developed ontology on traditional dances (OTD), which divides the evaluation methods into two critical steps : First, the syntactic correctness and internal consistency of the ontology were checked via the HermiT reasoner and the OOPS! tool, and, in the second step, the ontology has undergone a competency check via the CQs scenarios. In their work, Chansanam, et al. [10] presented an evaluation of The COviD-19 Ontology for Cases and Patient information (CODO) focused explicitly on the validation operation using OOPS! tools. Moreover, Yusof, et al. [11] discussed the manual approach, i.e., modeling guidelines and automatic approach, i.e., OOPS! for validating the Malaysian food composition ontology (MyFCO). In addition, Bezerra, et al. [12] proposed a mechanism to support evaluating whether the ontology follows their correspondent CQs. Pizzuti, et al. [17] validated and interrogated the MEat Supply Chain Ontology (MESCO), that is an ontology developed for supporting the management of meat traceability along the whole supply chain, through the formulation of several queries expressed in Description Logic (DL), executed using the Pellet reasoner, to deal with different scenarios and problems of traceability.

We can conclude that to the best of our knowledge rare are the approaches that have used the different types of references of the OD 101 during ontology evaluation. In our research work, we focus on CQs, application-based evaluation, modeling guidelines.

III. Presentation of our IBPMO Ontology

Semantic Web technologies, especially ontologies, are promising means to improve BPM and to realize the Industry 4.0 vision. In this scope, we presented the IBPM ontology that we have created with Protégé 5.5.0. Every IBPM ontology element is inserted as a class; the full hierarchy is shown in Figure 1 (75 classes). The IBPM ontology is an important part of our BPIGuide approach, which ensures the selection of the most suitable technologies 4.0 for BPs.

Regarding the first step, the scope of our ontology is to develop an ontology for IBPM. Basically, a number of methodologies have been used for developing ontologies, such as the methodology defined in [18], [19], [20] and [21], [22], [23]. In our research work, we have selected the methodology Ontology Development 101 defined by Noy and McGuinness's in [21] because we have exploited an existing ontology.

Concerning the second step, we have selected the existing BPM ontology presented in (von Rosing, Laurier and Polovina, 2015a), which is an empiric ontology, meaning that its roots lie in practice, as it was developed by practitioners documenting their practical knowledge of the field rather than having originated from theory and academics specialized in a restricted area of business. The selected BPM Ontology offers a set of principles, views, artefacts, and templates that have detailed metaobject relations and rules that apply to them, such as how and where can the process objects be related (and where not) (von Rosing, Laurier and Polovina, 2015a).

In order to consider the Industry 4.0 main concepts, we have been inspired from [24]. New classes were added to present the industry 4.0 concepts such as Sensor, Location, Machine, Workstation, Line, Technology4.0. The Machine has been defined with the device that performs a task by itself or by human intervention. The Workstation refers to

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small integrated physical groupings of machines. The Cell is a set of combined workstations for a particular complex task; and the Line is a group of cells. Consequently, new relations were added. A sensor is located in a location. A process happens in a location. A workstation contains a Machine. A machine can be an assembling machine, a testing machine and a processing machine. A business process adopts a technology 4.0.

3D printing, Augmented reality/simulation, Big data, Biomedical/digital sensor, Blockchain, Cloud computing, Collaborative robots, IoT, Machine/deep learning, Remote control or monitoring and SOA are introduced as sub-classes of Technology 4.0. A business process can be linked to a business resource through the transforms property. Besides, the hasSensor property is used to affirm that sensors are attached to a business resource. In addition, the happensIn property is used to stand for the location where a business process takes place. Moreover, the measuredBy property is used to associate a business process to the process measurement. The business process can be linked to the technology 4.0 through the adopts property.

IV. RESEARCH METHODOLOGY

This section briefly explains the activities that were carried out for ontology evaluation process. The evaluation framework is proposed to evaluate our IBPM ontology for which existing evaluation methods have been combined into a single framework, dividing the methods used into two phases: verification and validation [25].

The verification of the ontology is concerned with building an ontology correctly. It evaluates the structure, functionality and representation of the ontology. It specifically focused on the validation activity using OOPS ! tools. Different metrics and common pitfalls are used to detect errors. The validation of the ontology ensures that the right ontology for the given application is built. This is achieved by CQs and expert interviews. In particular, we focus (1) on verifying whether the developed IBPMO is correct according to three evaluation metrics [26], namely completeness, conciseness and consistency, and (2) on checking how effective the ontology is in the context of different applications. In this regard, the IBPMO is evaluated by using three approaches: CQs, technology-based, and application-based evaluations. Figure 2 shows the evaluation process of the IBPMO.

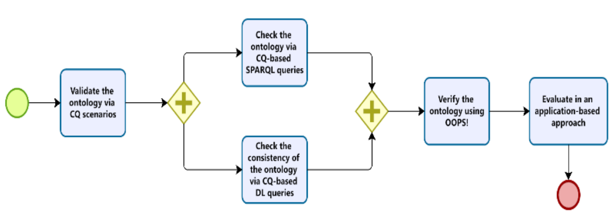

Figure 2. The proposed Evaluation Process

Figure 1. Class hierarchy of the IBPMO

V. EVALUATION OF OUR IBPMO

In this section, we represent the evaluation of our IBPMO, which focuses on the CQs, the technology-based evaluation and the application-based evaluation.

A. *Competency Questions evaluation*

For the present evaluation, CQs as a qualitative measure is the most effective and reliable way to check if all important information are included in the ontology [27]. The CQs pertain to various aspects, including class hierarchy, individuals, disjoint classes, intersections and unions of classes, equivalent classes, universal and existential quantification, as well as restrictions related to has-value and cardinality [12]. Thus, this evaluation focuses on reformulating CQs as queries to retrieve data from the ontology and to verify whether the CQs are answered or not. In this sense, queries are written in Description Logic (DL) and SPARQL language, which is a semantic query language used for describing and even worse checking the fulfillment of OWL CQs [12].

1) Consistency check via CQ-based DL: For syntactic correctness and consistency check of our IBPMO, we rely on "consistency checkers". For this task, we have used the Hermi reasoner, implemented in Protege as an external plug-in. The goal is to verify the ability of the ontology and check its consistency. The reasoner is known as a classifier and used for consistency checking as well as to compute the inferred class hierarchy (Natschläger, 2011). HermiT 1.4.3 is an OWL 2 reasoner compatible with Java. HermiT 1.4.3 provides functionalities to verify the validation, check consistency of the ontology and answer a subset of several queries expressed in DL. The evaluation process has been executed considering the monitoring of chronic disease BP, the food selection and guidance for diabetic and hypertensive patients BP and the monitoring of COVID 19 patients BP. We have considered these different BPs to elaborate our validation, but only the individuals of COVID BP will be detailed next. The monitoring of chronic disease BP concerns the continuous monitoring of patients with chronic disease to effectively manage disease. The food selection and guidance for diabetic and hypertensive patients BP concerns the Classification of Food according to patients' health. The monitoring of COVID 19 patients BP concerns the monitoring of COVID-19 patients or persons under investigation in the COVID-19 crisis unit at CHU Farhat Hached Sousse. The BP and the elaborated ontology were elaborated using various surveys and investigation. It consists of BPCOVID; Covid19CrisisCell; Physician; HealingTime; Home; IoTTech; Oximeter; Patient; QualityOfService; SensorOxygenSaturation; SensorTemprature; Thermometer; beurer HealthManager; MeasuringSpO2; RecoveringPatients; RegainingAnAcceptableTemperature; Treatment_Cost; WorkDoneByPhysician; CheckHealthStatus; CovidTreatmentProcesses; CrisisComityPerformanceIndicator; InfectiousDiseaseDepartment which are defined to represent different individuals. SensorTemperature and SensorOxygenSaturation represents the individuals of the same class Sensor. Thermometer and Oximeter are individuals of the same class ProcessingMachine. Patient and Physician are instances of the same class BusinessRole. BPCOVID is an instance of the class HumanOperation. HomeMonitoring is an individual of the class Sit-Monitoring. Covid19CrisisCell is an instance of the class ProcessOwner. We have also defined the individuals for both the monitoring of chronic disease BP and the food selection and guidance for diabetic and hypertensive patients BP. The query formulated for the identification of the BPs that have adopted the IoT Technology is showed in Fig. 2. It was applied for all the individuals of the three considered BPs.

Two examples of CQs, which cover the IBPMO, are provided along with their corresponding DL queries and results. The fact that the obtained results are conform to the expected results contributes to proving the validity of our ontology.

- CQ1 : What are the BPs that have adopted the IoT Technology ? The results of this DL query, that corresponds to this CQ1, show that it is possible to easily access to most important information related to the monitoring of chronic disease BP, the food selection and guidance for diabetic and hypertensive patients BP and the monitoring of COVID 19 patients BP in a short time, as shown in Figure 3.

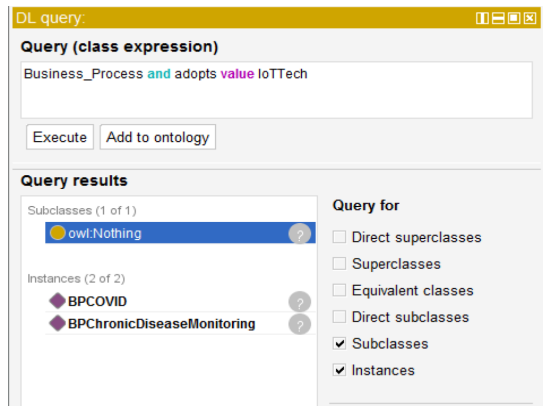

Figure 3. Query for the identification of the BPs that have adopted the IoT Technology

- CQ2: What are the BPs that have adopted the Big data Technology ? The result of this DL query, that corresponds to this CQ2, shows the instance of the BusinessProcess concept that have adopted the Big data Technology, as shown in Figure 4.

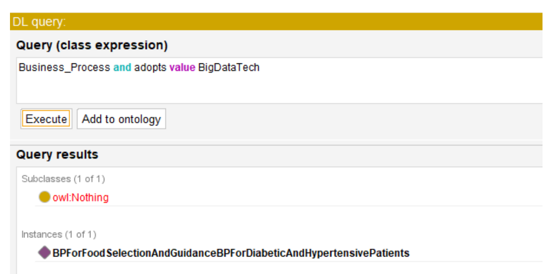

Figure 4. Query for the identification of the BPs that have adopted the Big data Technology

The phase of the internal consistence check ensures that our IBPMO does not contain any contradictory facts. In fact, The internal consistency check in ontology is performed by automated reasoners, which use formal language representation and axiomatic definitions to detect contradictions within the ontology [28].

Besides by this phase, we have checked that the model is a correct rendering of the idea we wanted to express.

2) CQ-based SPARQL: In this paper, each question is translated into SPARQL queries and implemented in Protégé using the SPARQL QUERY plugin.

Four examples of CQs, which cover the IBPMO, are provided along with their corresponding SPARQL queries and results.

- CQ1: What are the Business Processes contained in the ontology? The SPARQL query, that corresponds to this CQ1 to retrieve all instances of the BusinessProcess concept, is presented in Fig. 4. The result of this query, as illustrated in the Figure 5, contains the BPs modeled in the IBPM Ontology.

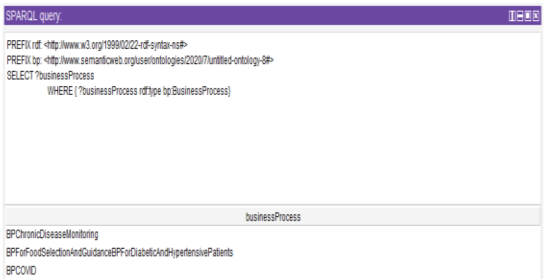

Figure 5. SPARQL query results for CQ1

- CQ2: What are the concepts represented in the ontology that model a Business Process? Figure 6 displays the formal representation of this CQ using SPARQL query. The query asks for the subclasses of the class BusinessProcess. Consequently, the result of this query as shown in the Figure 6 contains all instances of the BusinessProcess.

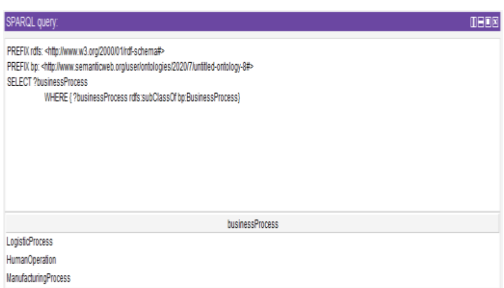

Figure 6. SPARQL query results for CQ2

- CQ3: What are the concepts modeled in the ontology that can be used to be applied to Business Processes? Fig. 6 presents the SPARQL query formalizing CQ3 to retrieve the subclasses of the class BusinessProcess that are linked to the BusinessResource/Actor class via the object property appliesTo. The result of this query, as shown in the Figure 7, contains the business resource/actor for each business process modeled in the IBPMO.

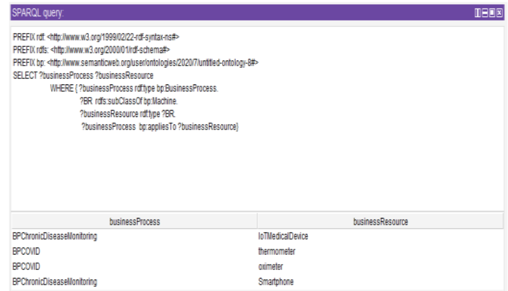

Figure 7. SPARQL query results for CQ3

- CQ4 : What are the concepts modeled in the ontology that can be used to be applied to Business Processes in a specific (particuler) domain? Figure 8 presents the SPARQL query formalizing CQ3 to retrieve the subclasses of the class BusinessProcess that are linked to the BusinessResource/Actor class via the object property appliesTo. The result of this query, as shown in the Figure 8, contains the business resource/actor and the domain for each business process modeled in the IBPMO.

By providing a set of CQs for the validation purpose, the completeness of the ontology is evaluated. Each query is run on the IBPMO to test if all requirements can be met and the correct answers can be inferred. For those queries that fail to run, the missing concepts or relations are added in the IBPMO. Nonetheless, one of the main problems that hamper the proper use of CQs lies on the completeness of the ontology that can never be proved and constant enhancement of the IBPMO needed.

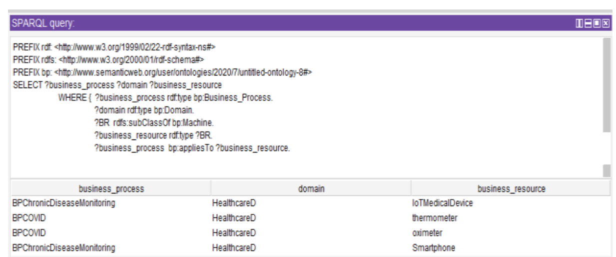

Figure 8. SPARQL query results for CQ4

B. Technology-based evaluation

The present evaluation is concerned with the structural characteristics of an ontology. It investigates the syntax, consistency and formal semantics and thereby aims to ensure the correctness and usability of the ontology. Different tools have been developed to support the technology-based evaluation. In this study, our IBPMO is evaluated through the OOPS ! tool, which is a web-based evaluation tool used for the detection of common pitfalls or anomalies in ontologies according to a pitfall catalogue currently containing 41 errors. This tool helps developers to improve ontology quality by automatically detecting potential errors [13].

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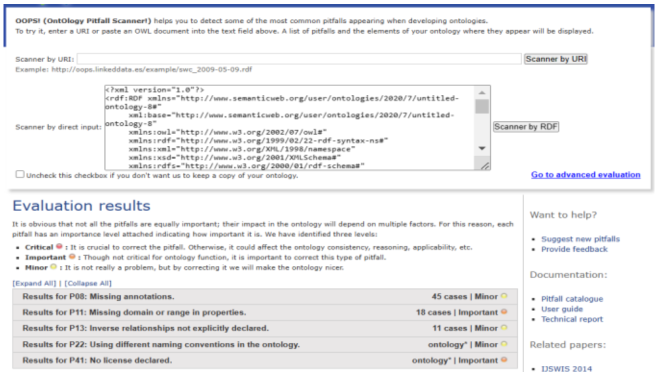

Figure 9. The OOPS! Validation results.

After executing the online tool reliably OOPS ! with the IBPMO, a summary of the pitfalls encountered is generated as shown in Figure 9. The diagnosis results obtained from OOPS! were manually revised. In fact, the OOPS! tool detects most anomalies found in the ontology and suggests improvements. Nonetheless the modifications of the ontology needs to be done manually. OOPS ! classified the results for each pitfall into three levels: critical, important, and minor levels. Priority was given for the critical level first. The minor level was not mandatory since it was not counted as a problem; however, by doing so, it will improve the IBPMO performance. Fig.8 shows the validation results for our IBPMO. It achieved two important and three minor pitfalls. It attains zero critical pitfalls. The three minor pitfalls resulted from missing annotations (P08), Inverse relationships not explicitly declared (P13) and using different naming conventions in the ontology (P22). The two important pitfalls in the opposite are caused by missing domain or range in properties (P11) and the absence of a declared license (P41). The pitfalls detected by OOPS ! can also be classified by the following evaluation criteria : consistency, completeness, and conciseness. The obtained results show that no consistency nor conciseness pitfalls are detected. Nevertheless, other pitfalls are detected (P08, P22,P41) and two of them (P11, P13) are related to the ontology completeness. Table 1 presents the five pitfalls encountered.

TABLE I. IBPMO PITFALLS DETECTED BY OOPS

Criteria	**Pitfall Description**	**Importance level**	**Cases**
Consistency	No detected pitfalls that correspond to consistency	–	0
Completeness	P11 : Missing domain or range in properties	Important	18
	P13 : Inverse relationships not explicitly declared	Minor	11
Conciseness	No detected pitfalls that correspond to conciseness	–	0
Other Pitfalls	P08 : Missing annotations	Minor	45
	P22 : Using different naming conventions in the ontology	Minor	The pitfall applies to the ontology in general
	P41 : No license declared	Important	The pitfall applies to the ontology in general

Figure 10 shows an excerpt of the first important pitfall (P11: Missing domain or range in properties). It shows a missing domain and range for some properties. But this pitfall was reported for the properties which were already mentioned as inverse properties in the IBPMO. Eighteen cases were detected for this pitfall as they represented 18 object properties without domain and range. The OD101 provided the guidelines regarding this property's facet. The effect of range and domain constraints as axioms is the most common problem in OWL [29] [30]. In IBPMO, the domain and range of properties are not assigned to avoid the above problems. Thus, no ontology repair action was carried out for this pitfall.

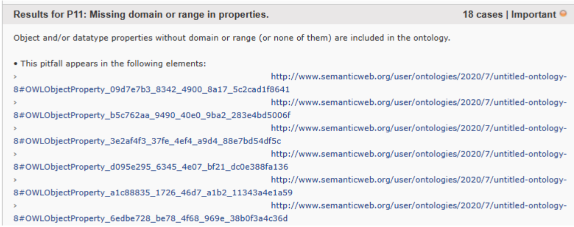

Figure 10. An excerpt from the first important pitfall.

Figure 11 shows the second and the last important pitfall in IBPMO (P41: No license declared). It reports about uses of no license agreement in the IBPMO. The pitfall concerns the ontology metadata aspect, which does not have any guidelines in OD 101. The repair recommendation by OOPS! was to include a statement containing the license information using any of the following properties: dc:rights, dcterms:rights, dcterms:license, cc:license or xhv:license.

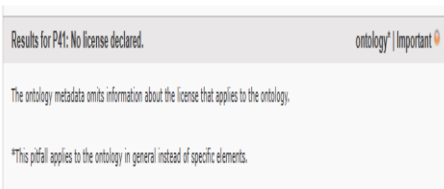

Figure 11. Second important pitfall.

In Protégé, the metadata annotations are under the ontology header view. Figure 12 shows the interface of metadata annotations where the license of the IBPMO is declared. The predicate for the license declaration of the IBPMO was taken from the dcterms:license and assigned to the CC-BY license [31], which is the most popular open Creative Commons Attribution License.

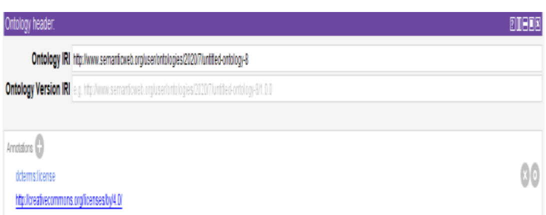

Figure 12. License declaration.

The IBPMO has three minor pitfalls. Figure 13 shows the first minor pitfall (P08: Missing annotations). The description of this pitfall was in creating an ontology element, human readable annotations have failed to be attached to it. The label annotation properties (rdfs:label) and the description annotation properties (rdfs:comment) were considered to define annotations of the IBPMO elements. These are the two most commonly used annotation properties, besides owl:versionInfo [32]. This pitfall will be repaired for further reuse.

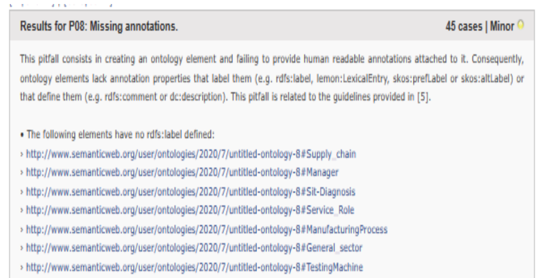

Figure 13. First minor pitfall.

The second minor pitfall is P13 : Inverse relationships not explicitly declared. It suggested some object properties which can be declared as inverse. The description of this pitfall was when any relationship (except for those that were defined as symmetric properties using owl:SymmetricProperty) did not have an inverse relationship (owl:inverseOf) defined within the ontology. OOPS! listed all of the object properties in IBPMO, which did not have the inverse relationship (see Figure 14). OD 101 provided the guidelines regarding inverse relationships. Poveda-Villalón et al. [33] stated that the specification of the inverse properties is needed for completeness.

Figure 14. Second minor pitfall.

The final minor pitfall is P22: Using different naming conventions in the ontology (see Figure 15). It detected uses of different naming conventions in the IBPMO. This was reported because for some long class names the symbol "-" (dash) was used, but for short class names, it was not used. A modification was not necessary. OD 101 provided guidelines on naming conventions. It emphasized consistency with the chosen naming conventions. The benefits from the consistency help to avoid modeling mistakes, improve readability, and ease the understanding of the ontology.

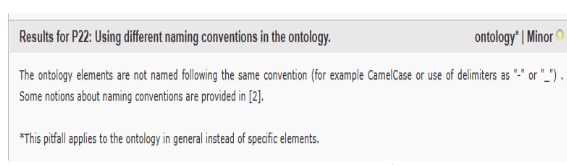

Figure 15. Third minor pitfall.

After correcting the observed errors, the pitfall scanner is run again to ensure all errors are corrected and no new ones are detected. OOPS! plays a significant role in ensuring the ontology is free from the common pitfall by double checking the modeling guidelines provided by the Ontology Development 101. For example, it supports the latest common modeling errors that are not listed in the Ontology Development 101, such as the annotation issue. The main advantage of OOPS! is the repair recommendation made by it. It shows how the ontology element can be repaired to improve the ontology technical quality. In the IBPMO, the evaluation results from OOPS! have improved the inferencing, understanding, clarity and metadata aspects. Nevertheless, OOPS! has a limitation. It still needs to be revised manually in some cases of the pitfall.

C. Application-based evaluation

The last step of the evaluation process consists of using the ontology in a dedicated application. In the present evaluation approach, the IBPMO is evaluated by providing an application-based approach to assess the ability of the IBPMO to serve as a knowledge base for a computer system. The effectiveness of the IBPMO has been assessed by putting it to the real application. It was designed to work for as a knowledge base. The IBPMO is validated by providing the following applications.

- **IBPMO database and interface:** A standalone application, which enables the visualization of knowledge modeled in the IBPMO, was developed. The interfaces provided by the application are designed to configure user needs on selection criteria. In order to provide an easy means to configure each criterion, three User Interface (UI) components can be used, which allow modifying a criteria's configuration. The UI components concern the performance criteria, the BP languages and the application fields. Such interfaces display the selection criteria. Figure 16-18 show interface examples of the application : interface for performance criteria (Figure 16), interface for BP languages (Figure 17) and interface for application fields (Figure 18).

- **BPIGuide tool:** The IBPMO is used in conjunction with the BPIGuide tool decribed in previous works. The BPIGuide enables the decision rules represented in the IBPMO to be automatically infered. Since, using the ontology-based engine, the result of the execution of these rules are the rank of the recommended technologies 4.0 which will be presented to users and could be used to redesign and implement optimized BPs 4.0. Besides, our validated ontology was used in the context of patient care in the healthcare field. We applied the different rules that we extracted from IBPMO in the surgical monitoring business process.

Figure 16. Interface for performance criteria

Figure 17. Interface for BP languages

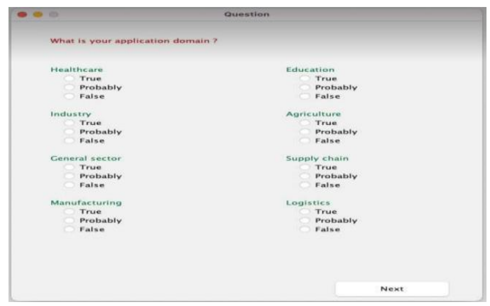

Figure 18. Interface for application fields

VI. DISCUSSION

The evaluation of the IBPMO indicates that the ontology is well-designed and suitable for its application. Only minor changes and adaptations regarding the lexical and structural layer are made. The conducted evaluation revealed that the developed IBPMO is : correct since it meets the completeness, conciseness, and consistency standards, and effectiveness since it can be used concretely in a variety of applications. Nevertheless, evaluating the IBPMO demonstrated that most probable no automatic method will ever be enough to perform a complete ontology evaluation. The evaluator has to decide on the criteria relevant for the evaluation, has to evolve the CQs and has to make decisions based on the evaluation results over each metric. But as good science should exclude subjectivity, it is advisable that more than one person performs the evaluation. Experts should be included for a satisfactory result in the evaluation.

VII. CONCLUSION AND FUTURE WORK

Ontology evaluation is a main task in the process of ontology development that takes a lot of effort and thought-process as each ontology needs an individual approach for evaluation adapted to the intended application of the ontology. The ontology evaluated in this study, IBPMO, has been developed to select the most suitable technologies 4.0 for BPs. We mainly focused on the end-to-end evaluation methodology. First, the IBPMO is evaluated against CQs. This first phase focuses on reformulating CQs as queries, which are expressed in DL and SPARQL language to retrieve data from the ontology and to verify whether the CQs are answered or not. During the second phase, a technology-based evaluation approach is addressed to specify quality criteria in order to ensure that the IBPMO is rid from pitfalls. At last, the ontology is evaluated using an application-based approach to assess the effectiveness of the IBPMO. For future work, the IBPMO will be upgraded with linked open data to enable domain knowledge sharing and reuse.

REFERENCES

[1] S. Mejri and S. Ghannouchi. "Towards a New Approach for Intelligent BPM Based on Technologies 4.0". New Trends in Intelligent Software Methodologies, Tools and Techniques: Proceedings of the 20th International Conference on New Trends in Intelligent Software Methodologies, Tools and Techniques (SoMeT_21). vol. 337, pp. 313-326, September 2021. https://doi.org/10.3233/FAIA210030.

[2] V. R. Sampath Kumar, et al. "Ontologies for Industry 4.0". The Knowledge Engineering Review. vol. 34, pp. e1-e17, November 2019. https://doi.org/10.1017/S0269888919000109.

[3] S. Jaskó, A. Skrop, T. Holczinger, T. Chován, and J. Abonyi. "Development of manufacturing execution systems in accordance with Industry 4.0 requirements: A review of standard-and ontology-based methodologies and tools". Computers in Industry. Vol. 123, pp. 1-18, December 2020.

[4] C. Kaar, J. Frysak, C. Stary, U. Kannengiesser, and H. Müller. "Resilient Ontology Support Facilitating Multi-Perspective Process Integration in Industry 4.0". Proceedings of the 10th International Conference on Subject-Oriented Business Process Management. pp. 1–10, April 2018.

[5] A. Annane, N. Aussenac-Gilles, and M. Kamel. "BBO: BPMN 2.0 Based Ontology for Business Process Representation." 20th European Conference on Knowledge Management (ECKM 2019). pp. 49–59, September 2019.

[6] M. Poveda-Villalón, MC. Suárez-Figueroa, and A. Gómez-Pérez. "Validating ontologies with oops!" Knowledge Engineering and Knowledge Management: 18th International Conference, EKAW 2012. Galway City, Ireland, pp. 267–81, October 2012.

[7] A. A. Alsanad, A. Chikh, and A. Mirza. "A Domain Ontology for Software Requirements Change Management in Global Software Development Environment". IEEE Access. vol. 7, pp. 49352-49361, January 2019. https://ieeexplore.ieee.org/abstract/document/8684236/ (accessed January 30, 2023).

[8] A. Abdelghany, N. Darwish, and H. Hefni. "An Agile Methodology for Ontology Development". IJIES 2019. Vol. 12, pp. 170–181, April 2019. https://doi.org/10.22266/ijies2019.0430.17.

[9] N. Noy and DL. McGuinness. "Ontology development 101". Knowledge Systems Laboratory, Stanford University 2001. vol. 2001, pp. 1-18, January 2001.

[10] W. Chansanam, K. Suttipapa, and A.R. Ahmad. "COVID-19 ontology evaluation". International Journal of Management. vol. 11, pp. 47-57, October 2020.

[11] N. M. Yusof and S. A. M. Noah. "Malaysian food composition ontology evaluation". International Journal of Machine Learning and Computing. vol. 9, pp. 700–705, October 2019.

[12] C. Bezerra, F. Freitas, F. Santana da Silva. "Evaluating Ontologies with Competency Questions". pp. 284-285, November 2013. https://doi.org/10.1109/WI-IAT.2013.199.

[13] M. Poveda-Villalón, A. Gómez-Pérez, and MC. Suárez-Figueroa. "Oops!(ontology pitfall scanner!): An on-line tool for ontology evaluation". International Journal on Semantic Web and Information Systems (IJSWIS). vol. 10, pp. 7–34, April 2014.

[14] S. Jain, V. Meyer. "Evaluation and refinement of emergency situation ontology". Int J Inform Educ Technol. vol. 8, pp. 713–719, July 2018.

[15] M. Richard, X. Aimé, M.C. Jaulent, M.O. Krebs, and J. Charlet. "From Patient Discharge Summaries to an Ontology for Psychiatry". MEDINFO 2017: Precision Healthcare through Informatics, IOS Press. pp. 930–934, June 2017.

[16] D. Kalita, and D. Deka. "Ontology for preserving the knowledge base of traditional dances (OTD)". The Electronic Library. vol. 38, pp. 785–803, October 2020.

[17] T. Pizzuti, G. Mirabelli, Grasso G, and G. Paldino. "MESCO (MEat Supply Chain Ontology): An ontology for supporting traceability in the meat supply chain". Food Control. vol. 72, pp. 123–133, Février 2017.

[18] M. Uschold and M. King. "Towards a methodology for building ontologies". Citeseer. pp. 1-13, July 1995.

[19] M. Gruninger. "Methodology for the design and evaluation of ontologies". Proc. IJCAI'95, Workshop on Basic Ontological Issues in Knowledge Sharing. April 1995.

[20] M. Fernández-López, A. Gómez-Pérez, and N. Juristo. "Methontology: from ontological art towards ontological engineering". pp. 33-40, March 1997.

[21] N. F. Noy, and D. L. McGuinness. "Ontology development 101: A guide to creating your first ontology". Stanford knowledge systems laboratory technical report KSL-01-05. pp. 1-25, March 2001.

[22] H. S. Pinto, S. Staab, and C. Tempich. "DILIGENT: Towards a fine-grained methodology for DIstributed, Loosely-controlled and evolvInG Engineering of oNTologies". ECAI. vol. 16, pp. 1-393, January 2004.

[23] M. C. Suárez-Figueroa, A. Gómez-Pérez, and M. Fernández-López. "The NeOn methodology for ontology engineering. Ontology engineering in a networked world". pp. 9–34, Springer; December 2011.

[24] F. Giustozzi, J. Saunier, C. Zanni-Merk. "Context modeling for industry 4.0: An ontology-based proposal". Procedia Computer Science. vol. 126, pp. 675–684, January 2018.

[25] H. Hlomani and D. Stacey. "Approaches, methods, metrics, measures, and subjectivity in ontology evaluation: A survey". pp. 1-11, August 2014.

[26] Z. C. Khan.” Evaluation metrics in ontology modules”. pp. 1-13, April 2016.
[27] Kurukshetra, S. Jain S, and V. Meyer. “Evaluation and Refinement of Emergency Situation Ontology”. IJIET. vol. 8, pp. 713–719, January 2018. https://doi.org/10.18178/ijiet.2018.8.10.1127.
[28] J. D. Warrender and P. Lord . "How, What and Why to test an ontology". pp. 1-4, Mai 2015.
[29] A. Rector, et al. “OWL pizzas: Practical experience of teaching OWL-DL: Common errors & common patterns”. Engineering Knowledge in the Age of the Semantic Web: 14th International Conference, EKAW. Whittlebury Hall, UK, pp. 63–81, October 2004. Proceedings 14, Springer.
[30] D. Allemang and J. Hendler. “Semantic web for the working ontologist: effective modeling in RDFS and OWL”. pp. 1-510, May 2011.
[31] M. Poblet, et al. “Assigning Creative Commons Licenses to Research Metadata: Issues and Cases”. In: Pagallo U, Palmirani M, Casanovas P, Sartor G, Villata S, editors. AI Approaches to the Complexity of Legal Systems, vol. 10791, pp. 245–256, October 2018. https://doi.org/10.1007/978-3-030-00178-0_16.
[32] M. Horridge, et al. “A practical guide to building owl ontologies using protégé 4 and co-ode tools edition1”. vol. 2. pp. 1-107, March 2011.
[33] A. Gangemi, C. Catenacci, M. Ciaramita, and J. Lehmann. “Modelling ontology evaluation and validation”. The Semantic Web: Research and Applications: 3rd European Semantic Web Conference, ESWC. Budva, Montene, pp. 140–154, June 2006.