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Applied Ontology Construction Framework: A methodical approach to enforce collaborative consensus whilst preserving transparency and traceability

Kaneeka Vidanage[1], Noor Maizura Mohamad Noor[2], Rosmayati Mohemad[3], Zuriana Abu Bakar[4]

[1,2,3,4] Faculty of Ocean Engineering Technology and Informatics,University MalaysiaTerengganu –UMT

Corresponding author*:*

Kaneeka Vidanage
Faculty of Ocean Engineering Technology and Informatics,University MalaysiaTerengganu –UMT

Abstract

In collaborative ontology engineering, domain specialists and ontologists should work together with mutual understanding. But there are several barriers hindering this synchrony between both the parties. This could adversely affect to the quality of the applied ontologies designed. Moreover, it will hinder the appropriate and accurate application of those applied ontologies in complex systems (i.e. complex reasoning systems). In this research, a novel framework is proposed to overcome those problems recognized. Framework is tested via applying it on a specific use case and results are evaluated by several parties for the assurance.

Keywords: Applied, Collaborative Consensus, Ontology, Interoperability, Workflow

Introduction

In collaborative ontology engineering, both ontologist and the domain specialist need to work with mutual understanding. However, there are numerous issues which are hindering the common consensus between both these parties (Westerinen et.al, 2017; Neilson et.al, 2019; Weaver et.al, 2019).

Among those issues, one of the critical point is technical knowledge barriers. Ontologists are experts in semantic technologies, but they have no knowledge about the domain of concern. Likewise, domain specialists are experts in the domain of concern, but they have no skills on semantic technologies. Hence, this setting has become a critical bottleneck for the synchrony between two parties (McDaniel et.al, 2019; Façanha et.al, 2019).

The other issue is the absence of a rigid set of guidelines for the collaborative enforcement of the methodologies / frameworks utilized in the collaborative ontology spectrum. Collaborative ontology engineering is a group setup. Hence, if no holistic and rigid set of guidelines are specified, people tempt to work as they want. This hinders the working interoperability of the team (Rajpathak et.al, 2011; Abdullah et.al, 2011). In such circumstance, people in the team tempt to work as they prefer, despite the set of instructions existing. Hence, the knowledge alliance and working interoperability goals in the group environment are hindered and ultimately it will end up in "Tragedy of Commons" state."Tragedy of Commons" state means, though significant time has passed, yet no collective progression is made (Hardin, 1968; Cornish et.al, 1986; Cornish et.al, 1987).

The notions of "Tragedy of Commons" was first introduce by Harding in 1968 associated with group environments' working conditions. The root cause for "Tragedy of Commons" is triggered by "Rational Choice Theory". According to this, during the absence of holistically defined rigid set of guidelines, people tempt to work as they prefer, despite the group`s requirements (Cornish et.al, 1986; Cornish et.al, 1987). Hence, gradually when all members in the group tempts to work as per their individual wishes, it will trigger "Tragedy of Commons".If no proper mechanisms are introduced, this will lead to misunderstandings, opinion mismatches and even unhealthy arguments (Hardin, 1968). This paper`s objective is to propose a theoretical framework to address the aforementioned concerns. It will ensure the deployment of,accurate applied ontology designs, to enforceappropriateoperation of the complex reasoning systems.

Related Work

a) Problem domain

It was already conversed about the problem domain and the impacts of "Rational Choice Theory" and "Tragedy of Commons" (Hardin, 1968; Cornish et.al, 1986; Cornish et.al, 1987) in the introduction section. A conceptual flow diagram can be represented as in figure 1, to elaborate, how those perspectives of the problem domain are linked with each other.

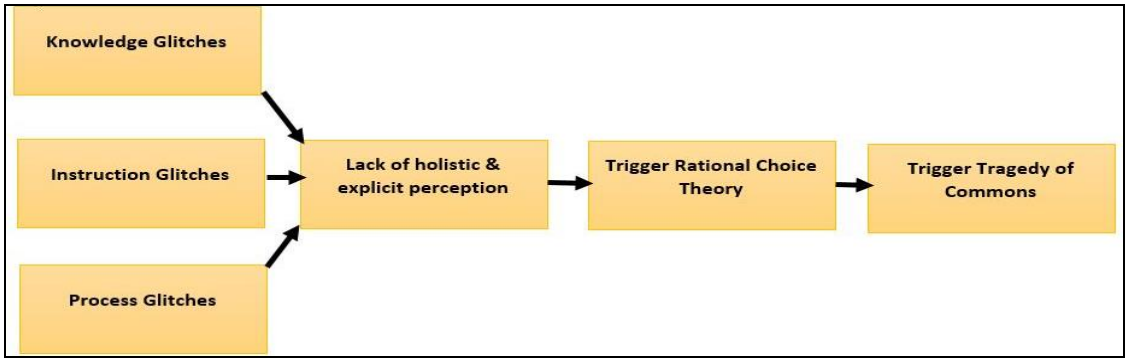

Figure 1. Problem domain`s perspective linkage

b) Technical Issues.

Domain specialists are mostly, non-computing specialists such as lawyers, bankers, medical doctors and etc. It is societally unfair to accept semantic expertise from them. If a domain specialist to effectively contribute for the ontology construction tasks, he/she should cross validate the knowledge embeddings of the ontology increment in each of itsiterations. Because, ontology construction is an iterative and incremental task (Ingram et al, 2019).

Moreover, it is the domain specialists' collective conceptualization modelled in form of an ontology by the ontologists (Saha et.al, 2019; De Nicola et al, 2016; Elgammal et.al, 2015)

Therefore, it is critical to get the opinion of domain specialists` about each ontology increment, before it proceeds to the next iterations. This will prevent unnoticed errors continuing for the future increments, making final ontology erroneous (Ingram et al, 2019; Simperl et al, 2013; Strohmaier et al, 2013)

In inquiring about the knowledge embeddings stored inside an ontology, SPARQL or SQWRL querying skillset is a vital necessity. But as already elaborated, societally it is unacceptable from a non-computing domain specialists' to expect such expertise. Therefore, an alternative mechanism has to be introduced to overcome this problem (Trokanas & Cecelja, 2016; Munir et.al, 2018; Elve & Presig, 2018).

Another perspective of the problem is the transparency and traceability. The existing methodologies and frameworks fail to insist on documenting the transition decisions from one phase to another in amethodicalmanner. Therefore, in the event of an unexpected flaw, auditing and traceability will not be practical, as the followed process is not transparently documented (Abdelghany et.al, 2019; Gómez-Pérez et.al, 2009; Fernández-López, 1997)

c) Methodological / Framework issues

In the "Appendix Section-A" of the paper comprehensive assessment is conducted on second, third generation methodologies and frameworks. It isevident, none of those methodologies or frameworks are emphasizing on the collaborative insights such as knowledge alliance, working interoperability, transparency and traceability aspects (Westerinen et.al, 2017; Neilson et.al, 2019; Weaver et.al, 2019).

d) Reflection

As reflected in the tabular comparison of the methods and frameworks (i.e. in "Appendix Section-A"), it`s evident that the existing methodologies and frameworks have not concerned about the collaborative challenges described above. Therefore, the objective of this research is to resolve the afore-mentioned gaps by proposing an appropriate conceptual framework.

Methodology

Design science research methodology (McCarthy, 1980) is selected for the current research. In literature it is stated design science research methodology is appropriate to solve human-centered issues(Sarkar et al, 2004; Hybs, 1996). The problem investigated in this research also has human centered characteristics. Therefore, it isdecided, design science research methodology is appropriate for the current research. High level flow of the design science research methodology is depicted in figure 2A and refined version customized to suite with the current research is depicted in figure 2B.

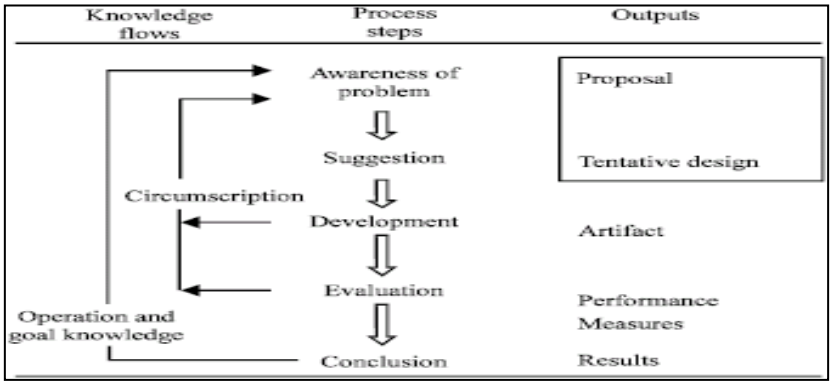

Figure 2A. High Level Flow of the Design Science Research Methodology

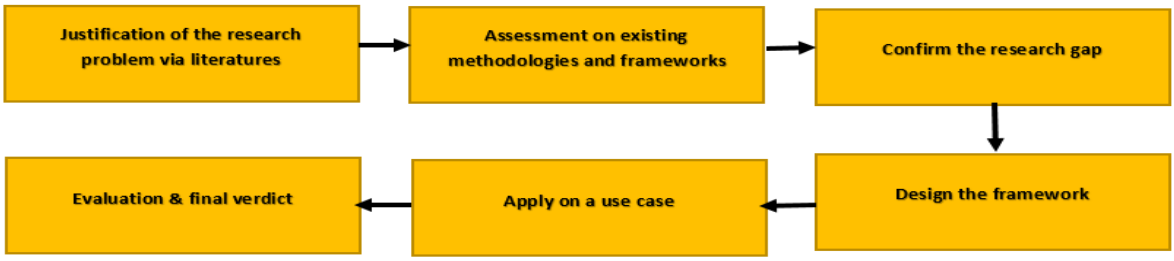

Figure 2B. Customized version of the Design Science Research Methodology

Results and Discussion

High level overview of the proposed framework is as depicted in figure 3. The framework comprises of multiple modules. Each module has its own task specification.

Pool formation module

First important task is to define the team composition. As suggested by Nielsen et.al (2019), larger team sizes will reduce the effectiveness. Team size exceeding 08 is defined as too much, as it creates complex interactions. Hence, in this research also, maximum team size is defined as 08. From this team size of 08, a count of 03 members are allocated to be ontologists. Among them, one more experienced ontologist has to be appointed as the convener of the meeting sessions to be conducted. From the remaining 02, one can act as a time keeper and the other one is for the documentation needs which arises throughout the process. Therefore, as per the remaining balance, maximum of 05 domain specialists are allowed to be in the team and minimum should be 02.

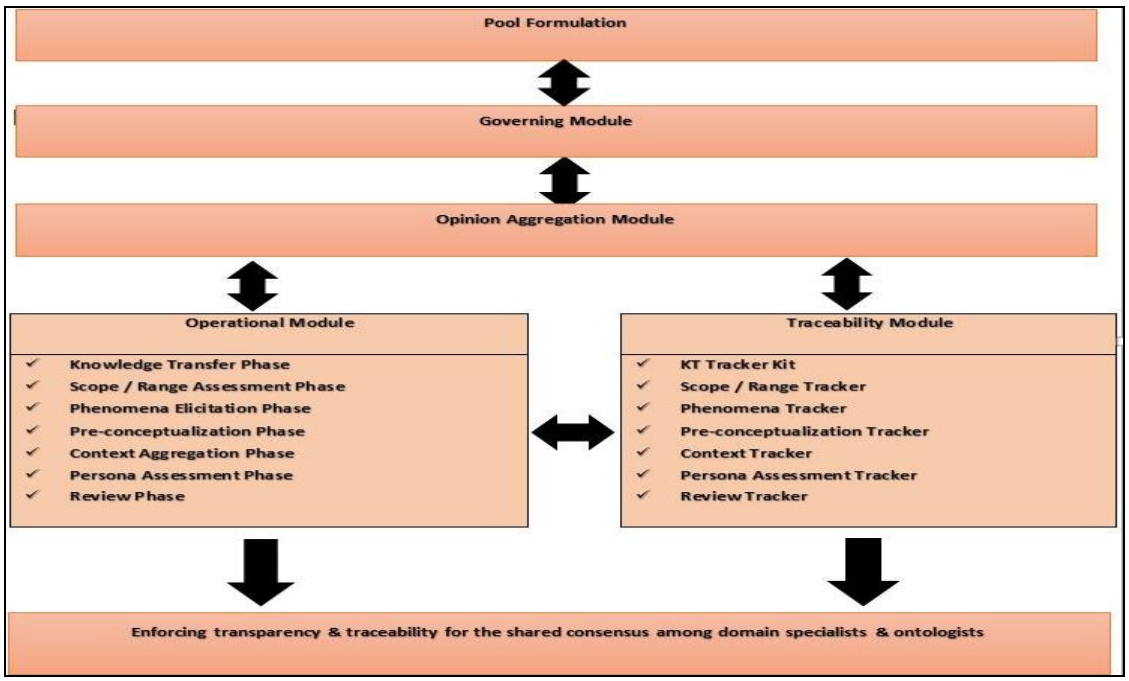

Figure 3. Proposed framework

Governing module

This is a very significant module of the framework. The main goal of this module is to emphasize on the interoperability and knowledge alliance aspects. Because those aspects are crucial in reaching to a shared consensus, which is a dire requirement to be fulfilled in collaborative ontology construction. Internal work-flow of the governing module is depicted in figure 4 below. Governing module comprise of with two phased "synchronized action plan meets". Holistic set of instructions are provided in those two phases to enforce the work-flow by eliminating the ambiguity (Rajpathak et.al, 2011; Abdullah et.al, 2011).

Execution time lapse of each synchronized action plan meet is defined as maximum of 1.5 hours, which is equivalent into two sprints in Scrum Agile methodology (Carneiro et.al, 2018). Because very lengthy meetings are not productive and the effective concentration of the stakeholders will not last for longer hours. Additionally, there need to be a proper hold and control over the meeting to ensure it is not going out of scope and effective engagement is maintained (Ozoliņš et.al, 2018). Hence, the duration of the synchronized action plan meet execution is time-boxed for a maximum of 1.5 hours.

a.) Purposive Awareness:

The first step in the "Phase -01 of the Synchronized Action Plan Meet" is purposive awareness. During this step, stakeholders need to be notified about the purpose of the meeting series, topic of concern, and the processes to be followed with instructional-guidelines (i.e. video recording of the entire session as necessary). It`s suggested at the time when the meeting request email is sent, a brief description needs to be shared with the stakeholders. Convener of the meeting can initiate this activity. It is always recommended an ontologists to be the convener because the purpose of the meeting is to create an applied ontology collaboratively.

b.) Individual brain storming:

The second step is “Individual brain storming”.This operates at the meeting day. Before the commencement of the second step, maximum of 08 minutes are given (i.e. time keeper to log the time) for the panelists to individually brainstorm about their perspectives on the problem of concern. Henceforth, they should be informed to finalize on their top 05 perspectives of the problem. As a mechanism of dimensionality reduction, it is advised not to exceed the top 05 perspectives in order to avoid a situation of information overloading.

c.) Individualized perspective projection

The third step is “Individualized perspective projection”. In this step, the respective individual can pitch his/her perspectives to the audience. Henceforth, the individual needs to submit his/her top 05 perspectives to the convener through a previously created Google form link shared with the participants (i.e. handled by the documentation assistant). This step, should repeat for all stakeholders. It is recommended not to exceed the time of 8 minutes which is allotted for perspective projection. When multiple domain specialists are waiting to present, yet the “Phase-1 Synchronized Action Plan Meet” duration should not be extended beyond allotted 1.5 hours. An agenda can be produced stating who will be presenting in the first iteration of the “Phase-1 Synchronized Action Plan Meet”. This iteration`s outcomes can be logged as, “Phase-1-[A]” in the perspective tracker (depicted in table-1). The balance domain specialists’ perspective projections can be arranged in another iteration (i.e. “Phase-1-[B”]) of the “Phase-1 Synchronized Action Plan Meet”.

d.) Rational Break

Once designated count of domain specialists have pitched their perspectives of the problem (according to the agenda), the fourth step of “Rationale Break” commences. In this step, stakeholders need to be provided with tea/ snacks whilst the captured responses from the Google form, has to be projected to a screen as in a form visible to the entire audience. All the perspectives submitted by the panelists should be presented in form of a list. It is expected during this time span, individuals can modify their viewpoints, refinements can be noted and overall retrospect about the points collected can be formulated and shared.

e.) Healthy Debate

After the break, healthy debate commences about the points already collected and projected to the screen. As the name implies, this is a collective rational discussion on the points elicited.

f.) Reflection Collection

During and after the debate, convener can include refinements or new additions to the earlier collected points. Frequentlythis reflection collection step occurs in parallel to the healthy debate. After the healthy debate completion, maximum of 08 minutes are available to log and finalize the refinements emerged.

g.) Heuristic Assessment via opinion aggregation module

In step “g” new Google form link has to be shared by the documentation assistance to all the panelists. This new Google form contains all the refined choices as the options to vote. For the completion of the voting process, time-span of 03 minutes are provided.

h.) Graphical representation of the top 05 opinions

Once the voting is completed, immediately pie chart breakdown of the option-wise voting segments needs to be projected to the screen.

i.) Review phase

In this phase, more in detailed and collective discussions will take place about the top 05 perspectives chosen by the collective opinions of the panelist. These perspectives will ultimately become the competency scopes of the ontology to be constructed. Once the ontology is constructed, it should be answerable to those top 05 perspectives collectively recognized.

j.) Sharing of video footage

This will allow a second chance to recall about the decisions taken and to testify whether those are reasonable or not. Video footage has to be shared among all the panelist.

"Phase-02 of the Synchronized Action Plan Meet" commences, maybe after two, three days' break, as necessary. This phase two commences with the projection of the finally agreed top 5 topics. The intention of the phase 02 of the synchronized action plan meet, is to give chances for any new rectifications emerged, after going through the recorded video footage or post thinking about the results captured in the phase-01. If there are significant new rectifications to be discussed, convener can raise the healthy debate again and necessary updating can be made to the finalized points collected. Eventually, finalization of the point's discussion can be conducted and the top 5 perspective lists can be signed off. Signed off details needs to be logged in the perspective tracker work sheet depicted in table 1.

Depending on the pool size of the stakeholders / experts, disagreements among the panelist, the work-flow of the governing module can be iterated. However, it should not continue beyond for two weeks, in order to provide a time-boxed control for the entire process.

It should be noted that, the impact of 'Governing Module' is applicable across all the phases of the framework, with slight updates. For an example, it will not be always the perspectives to be collaboratively assessed and it is not always the perspectives tracker to be updated. There will be slight alterations in those aspects as per the goal to be accomplished by the designated step. Otherwise, all other sequences remain the same. All opinions finalized needs to be logged into the perspective tracker work-sheet as visible in table 1.

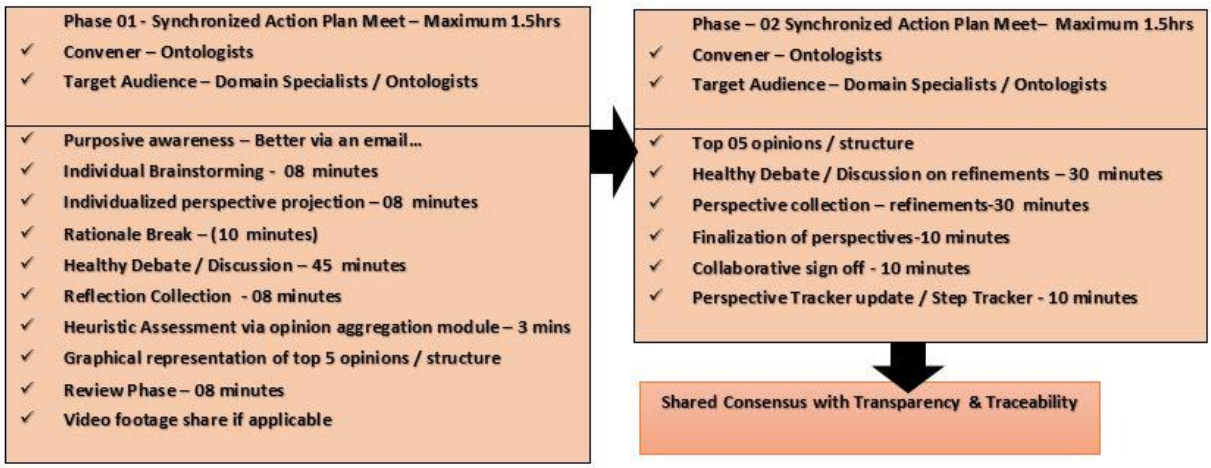

Figure 4. Governing Module`s workflow

Perspective Tracker			
Domain of Concern :			
Audience : [Mainly targeted for domain specialists]		Iteration Info :	
Convener :	Date:	Version :	
Consent (%) & Remarks :			
List of perspectives	Panelist Name - Signature	Version details – Sign off Date	Special Remarks

Table 1. Perspective Tracker worksheet

Opinion Aggregation Module

This module determines the necessity for the iterative execution of the steps, in fulfilling collaborative consensus requirements. As already elaborated in the "Governing Module" panelist preferences will be collected via Google forms for specified purposes. Then those preferences will be presented graphically as a pie / bar chart. Henceforth, convener can initiate the discussion to get finalizing remarks on the points recognized in a collaborative setting. The outcome of this discussion would be finalizing and signing off on the perspectives collectively agreed or taking decision to iterate the process again with the triggered recommendations.

Statistically, a portion of more than 80% of majority vote is required for the transition into the next phase. If the majority vote is less than 80%, concerns should be collaboratively discussed (e.g. domain specialists from several other related disciplines are also required – pool formulation update) and required steps need to be iterated.

Eventually, the details of the vote percentage and special remarks associated with the collaborative decision needs to be updated inside the "Perspective Tracker's "Consent (%) & Remarks" field (i.e. table 1). This mechanism is significant in accomplishing the ideology alliance and working interoperability needs. Because those are vital aspects which needs to be addressed in a collaborative applied ontology construction atmosphere.

Operational Module

This module is controlled by both Governing module and the Opinion Aggregation modules. Governing module should be executed in accordance with each step residing inside the operational module to ensure the ideology alliance and working interoperability aspects are addressed. Impact of Opinion Aggregation module is also critical, because this module's outcomes decides whether there is going to be a transition to the next step or the same step is iterated.

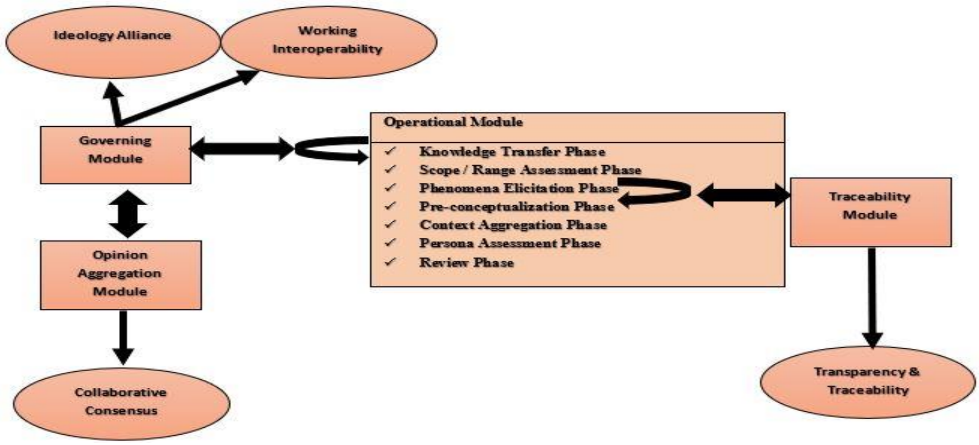

Figure 5. Module interaction objectives

Figure 5above depicts, detailed interaction requirements of each of the modules and the expected objectives from those interaction (i.e. represented in ovals)

Traceability Module

As already discussed in the introduction section, among the un-addressed shortages in existing methodologies and frameworks, the traceability and transparency issues are prominent. Decisions associated with transitioning from one step to another is not documented and maintained. Traceability module is introduced to address that shortcoming.

According to the proper functioning of the traceability module, all collaborative decisions associated with step-wise transitions need to be clearly documented. Hence, in an event of a conflict, auditing requirements can be initiated assuring transparency and traceability, with the help of the information tracker templates introduced inside the traceability module.

Knowledge Transition Phase – Operational Module

Before commencing the discussions on the agreed perspectives resulted from the governing module, mutual understanding needs to be strengthened in between the ontologists and domain specialists. Then only, key contributions can be expected from each parties. Refer the workflow depicted in figure 6 for clear understanding.

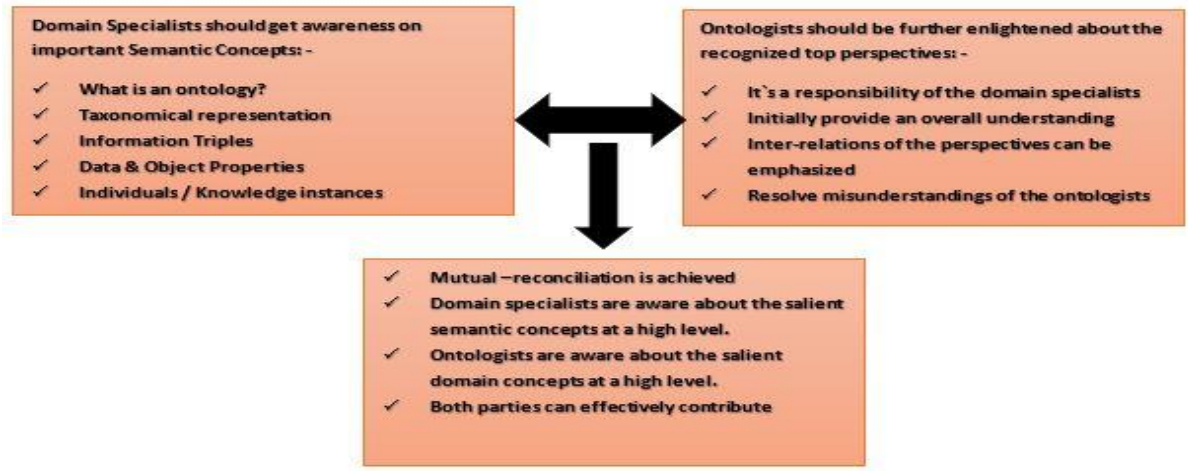

Figure. 6 Knowledge Transfer Work-Flow

The ultimate goal of the knowledge transfer phase is to strengthen the purposive mutual understanding between the ontologists and domain specialists. Both parties do not need to understand all advanced topics attached with each disciplines. Comprehension of what is required to complete the task is the expectation. The convener appointed from each party (i.e. domain specialists / ontologists) can discuss and conclude about the topics to be discussed in the knowledge transfer sessions. This will improve the clarity of the problem of concern for both the parties. This is very important for the rapport development among the panelist, which is crucial for the effective engagement leading into expert contributions. In order to prevent the process going out of control, this is time-boxed for maximum of 03 days.

After completion of the aforementioned process defined in figure 6, convener can initiate the Governing module`s workflow again. As depicted in table 2, if the comprehension percentage is more than 80%, according to the logic sequence elaborated in the opinion aggregation module, it can be concluded as knowledge transition phase is successful. Unless, convener has to initiate a discussion and iterate the process in figure 6, as necessary. Ultimately conclusions need to be logged in the KT tracker worksheet in table 2, to fulfil transparency and traceability needs.

KT Tracker			
Audience : [ontologists / domain specialists] ** strikethrough whatever inappropriate			
Convener : Date: Version :			
Consent / Comprehension (%) & Remarks :			
List of concepts	**Panelist Name - Signature**	**Version details – Sign off Date**	**Special Remarks**

Table 2. KT Tracker worksheet

Scope / Range Assessment Phase – Operational Module

During the initial execution of the Governing module, perspectives are logged in the perspective tracker, depicted in table 1. The goal of this phase is to collaboratively determine, what is in-scope is and what is out-scope of the finalized perspectives. Work-flow defined in figure 7 can be carried out to fulfil the goal of the specified operational phase. Ultimately finalized results can be logged in the scope / range tracker worksheet as in table 3.

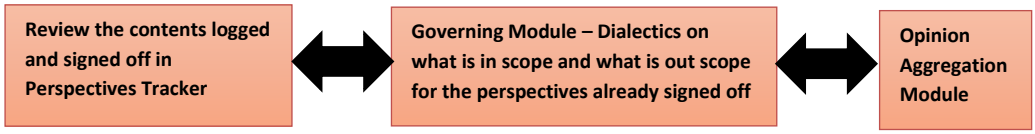

Figure. 7 Scope / Range Assessment Work-Flow

Scope / Range Tracker					
Audience: [ontologists / domain specialists] ** strikethrough whatever inappropriate **Convener:** **Consent / Comprehension (%) &Remarks:** **Date: Version :**					
Perspectives	**Scope / Range**		**Panelist Name - Signature**	**Version details – Sign off Date**	**Special Remarks**
	In-scope	**Out-Scope**			

Table. 3 Scope/Range Tracker

Phenomena Elicitation Phase – Operational Module

One of the important goal to be accomplished in this phase is the extraction of phenomena. Phenomena is a specific occurrence relevant and attached with a perspective. Hence the boundary lines of the perspectives are defined, phenomena extraction will be much more realistic and easy. One perspective can have multiple interconnected phenomena. All elicited phenomena need to be recorded in the Phenomena Tracker worksheet, depicted in table 4.

Rationale to Understand

a) Domain Specialists Viewpoints

For an example if we take the perspective as "Good habits for COVID – 19", a list of potential phenomena would be "wearing of masks", "social distancing", "washing of hands". By coupling the phenomena elements with competency questions, further descriptive information can be derived. For an example "What is the recommended distance to be made in public gatherings?" The answer for that is 1 meter. Further, "what are the suggested mediums to wash the hands?" The answers are soap, sanitizers and high percentage alcohol. "What is the best mask type to be used?" The answer is N95 respirator masks. Likewise, this combination of perspective associated phenomena and competency questions will be significant in deriving the entity classes and it`s descriptive data properties.

b) Ontologists Viewpoints

When all those information is logged into the Phenomena tracker work-sheet, from the ontologists' perspective, they should interpret it as, a taxonomic linkage with an inheritance relationship. Because all 03 solutions, "wearing of masks", "social distancing", "washing of hands" can be mapped as sub-classes to the super class of "Good Habits for COVID-19". Additionally, "washing of hands" can be divided into another three sub-classes as "washing from soap", "washing from sanitizers" and "washing from high percentage alcohol". Type of sanitizers, names of alcoholic solutions, duration of hand washing, distance to be kept in social-distancing, best mask-types becomes descriptive knowledge attributes associated with the phenomena. Therefore, data properties need to be defined in such a way to accommodate these requirements. The high-level process to be followed is depicted in figure 8.

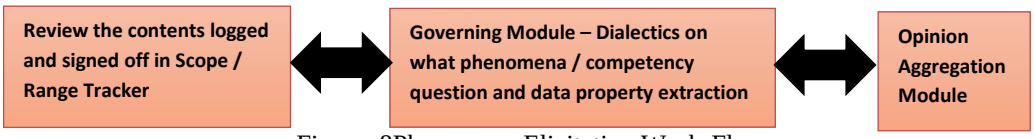

Figure. 8Phenomena Elicitation Work-Flow

Phenomena Tracker						
Audience : [ontologists / domain specialists] ** strikethrough whatever inappropriate **Consent / Comprehension (%) &Remarks:** **Convener:** **Date:** **Version :**					**Panelist Name - Signature**	**Version details – Sign off Date**	**Special Remarks**
Perspectives	**Scope / Range**		**Phenomena**	**Competency Questions**	**Entity / Class**	**Data Properties – Data Type**	
	In-scope	**Out-Scope**					

Table. 4 Phenomena Tracker

Pre-conceptualized Phase – Operational Module

The goal of this phase is to construct the initial taxonomy. Ontology creation is an iterative and incremental task. This activity should commence from the pre-conceptualized version. This is the first and most primitive version of the ontology skeleton. The inputs for the primitive version construction are obtained from the perspectives and associated phenomena related information logged in phenomena tracker (i.e. table 4). Information elicited from the domain specialists need to be coherently modelled by the ontologists. Protégé can be used for the construction of the premature version. Once all important information logged in the phenomena tracker is conceptually modelled, it needs to be presented to the domain specialists in a formal meeting via projecting the taxonomy structure in a larger screen. Domain specialists can examine the taxonomic structure (i.e. they have already gone through the basics of semantic-web in knowledge transfer phase) and can verify whether the ontologists have accurately modelled the conceptual structure elaborated to them. To further assist the domain specialists` knowledge verification role, specialized tool support will be provided from this phase onwards. Intended tool support will be multi-varied. It will be drill-down enabled visualization support, verbalization support and natural language-based question and answering support

a) Drill-Down Enabled Visualization Support:

Protégé will anyway depict the high-level taxonomic structure. But when the taxonomic structure become gradually complex (i.e. inheritance relationships, individuals with data and object property mappings) it will be cognitively difficult for the non-computing domain specialists to comprehend. But with the new drill-down visualization support introduced, it will prevent the information overload for non-computing specialists by enabling representation of the facts in a layered formulation, whist reducing the dimensions and improving the abstraction and simplicity.

b) Verbalization Support:

This feature will represent the semantic information modeled by the ontologists about the domain of concern, in simpler English for the easier realization (i.e. process of verbalization).

c) Natural Language-Based Question and Answering:

This will allow the non-computing domain specialists to query the premature versions of the ontology in simple English, in form of asking general questions to verify, whether the conceptual space is accurately modelled by the ontologists. Need for SPARQL / SQWRL literacy is eliminated.

Continuous verification assistance of the domain specialists is extremely important throughout the overall collaborative ontology construction process. As depicted in figure 9, by facilitating the comprehension challenges of domain specialists via multi-varied mechanisms, comprehension efficacy of the domain specialists will be enforced. This is very significant and a crucial necessity in determining the ultimate success of the ontology to be constructed. Their final reflections can be logged in the pre-conceptualized tracker (i.e. table 5). The high-level process associated with the pre-conceptualized phase is depicted in figure 10.

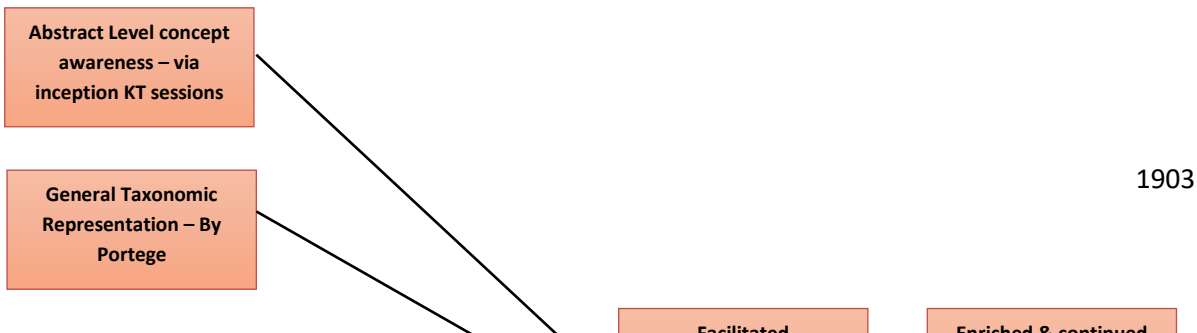

Figure. 9 Process to boost the comprehension of domain specialist

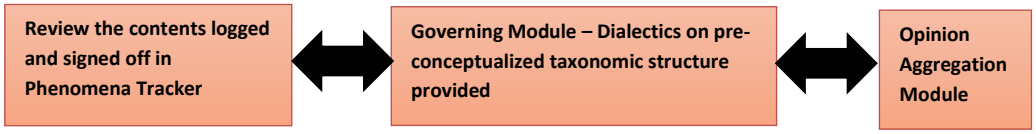

Figure. 10 Pre-Conceptualized Work-Flow

Pre-conceptualized Tracker						
Audience : [ontologists / domain specialists] ** strikethrough whatever inappropriate **Date: Version:** **Consent / Comprehension (%) &Remarks:** **Convener :**				**Panelist Name - Signature**	**Version details – Sign off Date**	**Special Remarks**
Perspectives	**Scope / Range**		**Phenomena**	**Competency Questions**	**Taxonomic Arrangement with Data Properties**	**Review Comments**
	In-scope	**Out-Scope**				

Table. 5 Pre-conceptualized Tracker

Context Aggregation Phase – Operational Module

The goal of this phase is to inter-connect classes to represent important contexts residing in the conceptual phase. Recognized classes are already included in the pre-conceptualized taxonomy. Contexts denote significant circumstances living inside the domain of concern. Object properties are introduced as the contextual labels.

Rationale to Understand

a) Domain Specialists Viewpoints

Governments all over the world has taken several measures to prevent the spread of the "COVID-19". Hence, a perspective can be derived as a "Government Measures to prevent spread of COVID-19". From this perspective multiple phenomena can be elicited as, curfew, travel bans, lock-downs, fining and etc. In the previous example relate with "Phenomena Elicitation Phase" perspective "Good Habits for COVID-19" was identified. In contextual linking, domain specialists can collectively brainstorm and derive a new relationship as, "Government Measures to prevent spread of COVID-19" enforces the "Good Habits for COVID-19". Here, the label "enforces" can be introduced as contextual label to aggregate two important perspectives residing in the COVID-19 conceptual phase.

b) Ontologists Viewpoints

The notions raised by the domain specialists needs to be conceptually modelled in the semantic space by the ontologists. They can introduce another super class as "Government Measures" and assign inherited sub-classes, "Curfew", "Travel Bans", "Lock Downs", "Fines" and etc. Further, by conducting competency question inquiries, knowledge scope of the phenomenas can be further enriched. (i.e. "What are the curfew timings?", "To which districts curfew operates?", "What are the fine amounts?").

It will facilitate the proper introduction of the data properties to store that information to describe the instances derived from those classes with more clarity. For contextual integrations, ontologists can link sub-class "Curfew" via an object property label introduced as "enforces" with another sub-class, "Social Distancing".

Likewise, ontologists can critically analyze the knowledge provided by the domain specialists and can introduce more new contextual aggregations inform of object property label to enrich the ontology even more domain rich. Domain experts' involvement for the accomplishment of this phase can be further enriched by the process-flow depicted in figure 9. High level work-flow functioning inside the "Contextual Aggregation Phase" can be represented in figure 11 below. The team`s finalized decisions on contextual introduction to the pre-conceptualized version of the ontology can be logged into Context Tracker in table 6 and signed off.

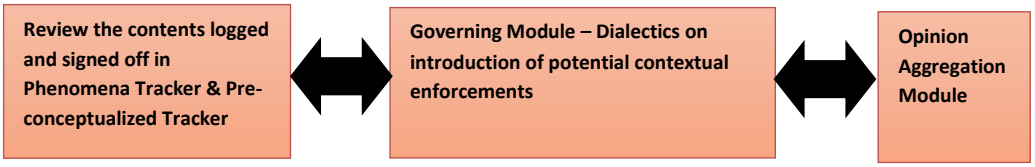

Figure. 11 Contextual Aggregation Workflow

Context Tracker						
Audience : [ontologists / domain specialists] ** strikethrough whatever inappropriate **Consent / Comprehension (%) & Remarks:** **Convener:** **Date:** **Version :**					**Panelist Name - Signature**	**Version details – Sign off Date**	**Special Remarks**
Perspectives	**Scope / Range**		**Phenomena**	**Competency Questions**	**Entity / Class mappings** **i.e. Student - Module**	**Context Name / Object Property Label** **i.e. studies**	
	In-scope [Domain]	**Out-Scope [Range]**					

Table. 6 Context Tracker

Persona Assessment Phase – Operational Module

Personas are specific user experiences. Convener of the team should provide a chance to each individual domain specialist to share his/her domain related experiences with the panelist. The intension of that is to extract more and more valid use cases associated with the domain. Once a domain specialist shares his/her specific persona, other domain specialists / panelist can question on it, add more value to it, pitch new ideas on different angles associated with the persona and etc. Whist, ontologists, can initiate video recordings of the discussions as quick note taking amidst the discussion could be erroneous.

This exercise will create a platform to extract more and more domain associated use cases. Alternatively, information gathering can be further enriched through the variable viewpoints associated with the panelists. Therefore, the goals of this phase would be to verify the adequacy and accuracy of the current mappings introduced to the ontology increments. Apart from that, by investigating deeply on the personas / use cases shared by the domain specialists, individuals / instances can be introduced for the class structures already recognized. New contexts can be defined by making new object property mappings. This is a critical phase where both ontologists and domain specialists needs to work synchronously.

High level work-flow functioning inside the “Persona Assessment Phase” can be represented in figure 12 below.

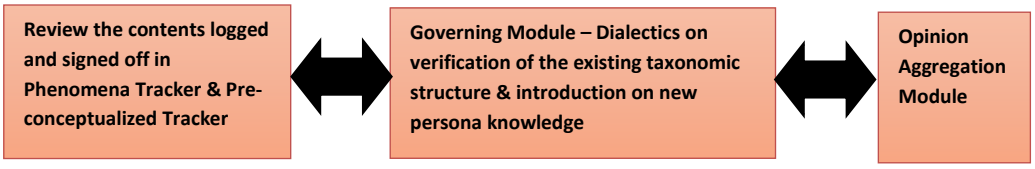

Figure. 12Persona Assessment Workflow

As elaborated in detail inside the Governing module, phase 1 and phase 2 synchronized action plan meets can be iterated as necessary depending on the collaborative percentage turnovers, returned by the Opinion Aggregation module.

In each iteration salient information can be logged in the persona tracker as depicted in table 7. Persona tracker work-sheet has four main sections as depicted in different colors. Those are to log necessary facts with a segmentation of ontologists’ viewpoints and domain specialists’ viewpoints.

Test & Review Phase – Operational Module

Once all afore-mentioned phases of the collaborative ontology construction is completed, as if all panelists have reached to a satisfactory state, this final phase can be executed. Test & Review phase can comprise with multiple sub-facets to make the goal accomplishment of this phase more methodical. Those aspects are elaborated in below.

a) Black-box Test

Domain specialists can play a lead role in this. They are provided with specialized tool support for visualization, verbalization, as well as English based question and answering. They can refer to the axioms brainstormed in Pre-conceptualized tracker, Context Tracker and Persona Tracker by traversing through those worksheets maintained for traceability purposes. Henceforth, they can verify the accuracy of the knowledge representations deployed in the latest ontology increment by, referring to the verbalized contents generated by the verbalizer and English based question and answering on the current ontology increment. Panelist can collectively engage in this investigation. Eventually, they can log their comments in the Black-box tracker worksheet, depicted in table 8. Logging of the verification method is also important as then ontologists can re-generate the error to further witness on it. High-level process followed in Black-boxed test phase is depicted in figure 13.

b) While-box Test

In this facet, structural contents, mapping sequences of the latest ontology increment need to be verified. Ontologists have to play a lead role in this step whilst gaining the required collaborative verification assistance from the domain specialists. It`s suggested to have a methodical walk-through on the structural aspects and elements of the latest ontology increment.

Then, ontologists can select structural components, one by one and verify the contents residing inside it. This will prevent, structural components being un-noticed from the white-boxed verification. Review fragments functioning inside the white-boxed verification phase is depicted in figure 14.

Persona Tracker						
For Domain Specialists :- Verification of the existingTaxonomic Structure			**For Domain Specialists :- Introduction of newpersonas**			
Perspective / Phenomena	**Adequacy – vote (%) & remarks**	**Accuracy- vote (%) & remarks**	**Panelist**	**Persona / use case**	**Special Remarks**	
For Ontologists : Verification of the existingTaxonomic Structure				**For Ontologists : Introduction of newpersonas**		
Perspective /Phenomena	**Data property adjustments**	**Object property adjustments**	**Individuals / Instances associated remarks**	**Persona / use case**	**Data property adjustments/ inclusions**	**Object property adjustments / inclusions**	**Individuals / Instances associated remarks**
Audience : [ontologists / domain specialists] ** strikethrough whatever inappropriate				**Panelist Name -**	**Version details – Sign off Date**		**Special Remarks**

Consent / Comprehension (%) & Remarks : **Convener :** **Date:** **Version :**	**Signature**		

Table. 7 Persona Tracker

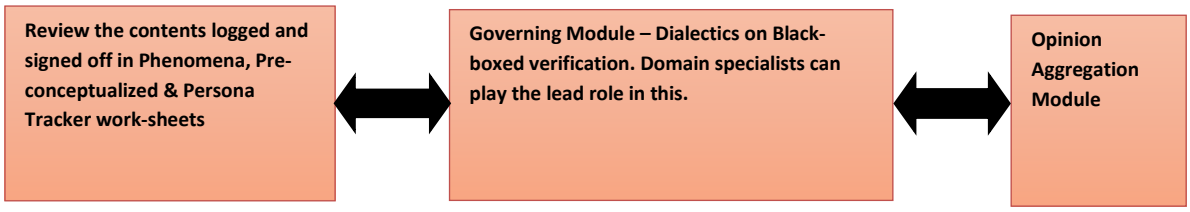

Figure. 13 Black-boxed verification Work-Flow

Black-box Tracker						
Audience : [ontologists / domain specialists] ** strikethrough whatever inappropriate **Consent / Comprehension (%) & Remarks:** **Convener:** **Date:** **Version :**				**Panelist Name - Signature**	**Version details – Sign off Date**	**Special Remarks**
Perspectives	**Scope / Range**		**Phenomena**	**Competency Questions**	**Verification methods used [Visualization / Verbalization / Question & Answer]**	**Comments on Ambiguous Conceptualizations**
	In-scope [Domain]	**Out-Scope [Range]**				

Table. 8 Black-box Tracker

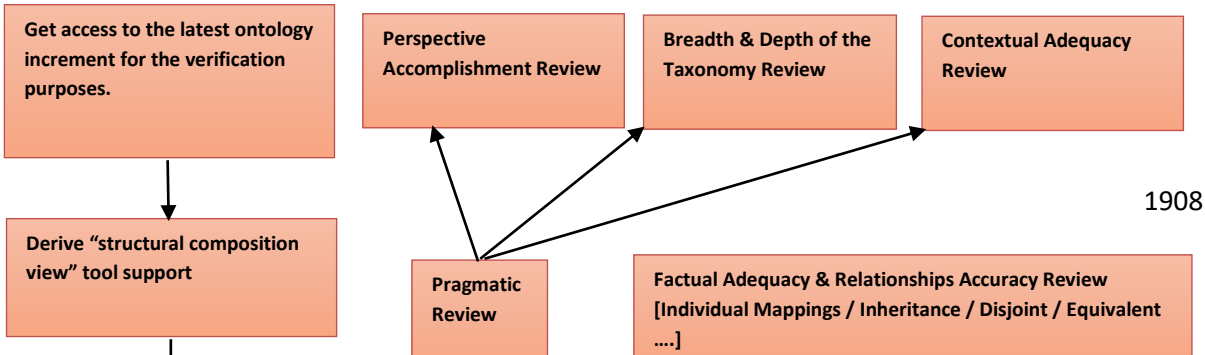

Figure. 14 Review Fragments Work-Flow

High-level process followed in while-boxed test phase is depicted in figure 15 below.

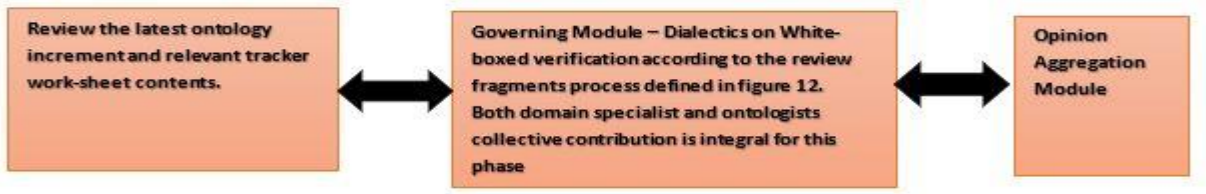

Figure. 15 High-level process of the white-boxed phase

Finalized decisions, which are collectively agreed need to be logged in the White-boxed tracker worksheet, as depicted in table 9.

White-box tracker work-sheet is segmented into four sections for extraction and logging of pragmatic concerns, empirical concerns and proposed pragmatic resolutions and empirical resolutions. All these needs to be collaborative decisions derived after executing the steps of the Governing module. Collaborative agreement percentages also need to be logged in the white-box tracker, depicting the collective consensus impacts on issues recognized and resolutions proposed

White-Box Tracker – Issues						
Collaborative consent on issues identified (%) & Remarks: **Convener:** **Date:** **Version :**						
Collaboratively Agreed Pragmatic Concerns				**Collaboratively Agreed Empirical Concerns**		
Perspective Accomplishments - Reviews	**Breadth / Depth Taxonomy -Reviews**	**Contextual Adequacy - Reviews**	**Need for new individual mappings**	**Relationship Review**	**Property review**	**Introduce New individuals as necessary**
White-Box Tracker – Resolutions						
Collaboratively Agreed Resolutions for Pragmatic Concerns				**Collaboratively Agreed Resolutions for**		

				Empirical Concerns		
Perspective Accomplishments - Reviews	**Breadth / Depth Taxonomy -Reviews**	**Contextual Adequacy - Reviews**	**Need for new individual mappings**	**Relationship Review**	**Property review**	**Introduce New individuals as necessary**
Collaborative consent on resolutions introduced (%) & Remarks :						

Table. 9 White-box Tracker

Evaluation

For the evaluation of the proposed framework, a psychotherapeutic ontology construction case was selected. A pool of 08 members took part for this experiment. 03 ontologists and 05 consultant psychologists and psychiatrists. Experiment ran for about 03 months, until satisfactory ontology increments are derived.

By following the instructions given in the framework, collaboratively domain specialists and ontologists created multiple ontology increments. Henceforth, their insights and exposures were interrogated and analyzed. Formulation of the overall experiment can be depicted from the below figure 16.

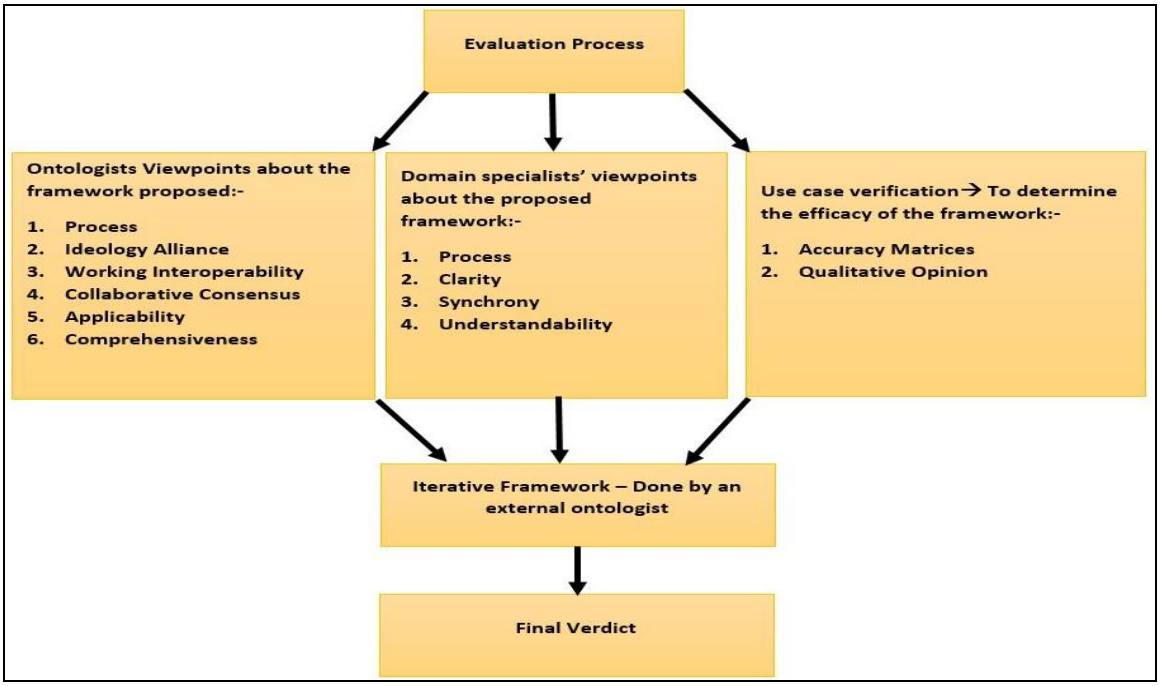

Figure. 16 Overall Evaluation Process

After completion of the experiment, all panelists were given a specifically designed rating grid. They had to provide their honest opinion via selecting the appropriate region of the grid which they think as suitable. Ontologists has to go through 06 facets as mentioned in the figure 16 and domain specialists needs to go through 04 facets. For both, same rating grid was used, but the facets were different.

Because, ontologists were mainly compelled to assess the technical aspects of the framework, whilst domain specialists are required to assessthe application side of the framework. The used rating grid structure is depicted in figure 17 below.

1	2	3	4	5	6	7	8	9	10
Very Poor	Fairly OK, but major flaws visible				Good and acceptable – Only few minor revisions			Exceptional	

Figure. 17 Rating Grid Structure

Tables 10 and 11 are respectively showing the opinions provided by the ontologists and domain specialists, for the sections there were interrogated.

Ontologist	**Process**	**Ideology Alliance**	**Working Interoperability**	**Collaborative Consensus**	**Applicability**	**Comprehensiveness**
A	80%	90%	90%	80%	80%	70%
B	70%	90%	80%	90%	70%	80%
C	80%	80%	80%	70%	80%	80%
AVG	77%	87%	83%	80%	77%	77%

Table. 10 Quantitative opinions of the ontologists

Domain Specialist	**Process**	**Clarity**	**Synchrony**	**Understandability**
A	80%	80%	80%	70%
B	90%	70%	80%	70%
C	80%	80%	70%	70%
D	80%	80%	80%	80%
E	80%	70%	70%	70%
AVG	82%	76%	76%	72%

Table. 11 Quantitative opinions of the domain specialists

By analyzing the overall averages, domain specialists` combined average is 77% and ontologists combined average is 80%. Therefore, it can be concluded the proposed framework is working accurately with no major flaws.

In addition to this, qualitative feedbacks were also derived from (via a controlled interview session), both domain specialists and ontologists. Those are reflected in table 12.

Ultimately, an external ontologist is invited to go through the available quantitative and qualitative feedbacks and he is requested to apply iterative framework to derive a final verdict on the evaluation experiment. The iterative framework is a very effective and famous evaluation assessment framework proposed by Srivastava and Hopwood (Srivastava et.al, 2009).

Here in this research, the steps of the iterative framework and, mapping of each step with the research`s outcomes are elaborated in Table 13.

Reflection

As depicted in figure 16, evaluation phase comprises of 03 main sections. First is the ontologists assessment, then the domain specialists' assessment and finally assessing the application of the designed ontology increments (i.e. designed using the proposed framework) for the psychotherapeutic use case and test the designed ontologies functional accuracy. Details and statistics associated with the first two steps are already discussed in the evaluation section.

Psychotherapeutic aspect of the experiment is not discussed in detailed as it`s out of the scope of this research. But the accuracy of the defined ontology increments has yielded satisfactory outcomes. It can be considered as another evidence to prove the accuracy and functional adequacy of the proposed framework. Because those ontology increments were derived by following the proposed framework and it`s steps.

Therefore, a triangulation approach has been utilized to evaluate the effectiveness of the proposed framework. Eventually, iterative framework is applied to derive the final verdict of the entire evaluation experiment. In order to overcome any biases, iterative framework is applied by an external ontologist who is not involved in the process. He was provided with a clear briefing about the entire process, purpose and steps of the iterative framework as well. Eventually, he was exposed to all quantitative and qualitative results yielded from the experiments and requested to apply the iterative framework on it. Ultimately, he was asked to document the reflections as already tabulated in table 13.

Facet	Comments	Ontologists qualitative feedback
Process	• Holistic guidelines are provided. • Rigid process with a strong hold. • Transparency is addressed	
Ideology Alliance	• Accomplished • Opinion Aggregation module does this task. • Fair representation.	
Working Interoperability	• Good rapport • Mutual understanding enforced • Synchronized operation	
Collaborative Consensus	• Governing module + Opinion aggregation modules addressed the requirements • Satisfactory and very much synced operation	
Applicability	• Vital for collaboration aspects • Will be useful to function inside	

	collaborative ontology engineering • Has a scope of expanding to other domains as well	
Comprehensiveness	• Very comprehensive. • Detailed instructions are provided • Co-ordinated operation	
Process	• Strong process • Instructions are rich • Organized	Domain specialists qualitative feedback
Clarity	• Cleary guidelines are provided. • Some sections are bit challenging, but can manage • Time spans are good, but suggest to expand more	
Synchrony	• Good coordination • Idea sharing is a strong point • All are treated equally	
Understandability	• Good • Opportunity to learn new skills • Iterations is helpful to strengthen the understanding	

Table 12. Qualitative summary of the feedbacks derived

Iterative Framework Step	Justification Elaborations
01 – What are the data telling me ?	In quantitative experiment conducted, domain specialists have given a 77% of consent for the process and the steps in the proposed framework. Ontologists have looked at the framework in a more technical perspective and they also have given an overall consent of 80% for the proposed framework. Additionally, the qualitative feedback provided (i.e. summary is documented in table 12) by both domain specialist and ontologists also depicts positive

	attributes about the entire framework, and it`s workarounds.
02- What do I want to know ?	How effective is the proposed framework in terms of accomplishing collaborative requirements stipulated in the research ?
03 – Is there a dialectical relationship in step 01 and step 02 ?	Yes. Both qualitative and quantitative results yielded has depicted the efficacy of the proposed framework, in terms of the research objective to be addressed. Therefore, it can be concluded the proposed solution is satisfactory at its current state.

Table 13. Iterative framework

Conclusion

There`re shortages in existing methodologies and frameworks on enforcing the collaborative aspects, which is a dire necessity to be fulfilled in collaborative ontology engineering niche. In overcoming that shortage, as the objective of this research, a novel framework is proposed and it`s evaluated in numerous techniques. According to the final verdict derived as per the outcomes of the iterative framework, research objective has been effectively accomplished.

In future, it`s decided to apply this framework on several more diverse domains and to derive cross-domain oriented results.

Appendix – Section A

[Comparative analysis on several of the most popular existing ontology development methodologies and frameworks]

Methodology	Generation	Collaboration Perspectives		
		Interoperability	Ideology Alliance	Traceable & Transparent workflow
Methontology (Fernández-López, 1997)	02	N/A	N/A	No
Tove (Fox, 1998)	02	N/A	N/A	No
IDEF5 (Peraketh et.al ,1994)	02	N/A	N/A	No
OTKM (Sure et.al, 2004)	02	N/A	N/A	No
Diligent (Vrandecic et.al ,2005)	03	No	No	No
RapidOWL (Auer et.al, 2006)	03	N/A	N/A	No

NeOn (Gómez-Pérez et.al, 2009)	03	No	No	No
Upon-Lite (De Nicola et.al, 2016)	03	No	No	No
AMOD (Abdelghany et.al, 2019)	03	No	No	No

Appendix [A] - Table 1- Tabular comparison of ontology development methods

Framework	Category	Pros	Cons	Special Remarks
Semiotic (Toppano et.al, 2009)	Ontology Communication	✓ Consider ontology construction as a communication pipeline in-between sender and receiver.	✓ The learning curve is high as the user should be familiar with Peirce theory triadic relations and speculative grammar ✓ High subjectivity and ambiguity as mainly a symbolic representation ✓ No notion on ontology increments	No, emphasize for interoperability and alliance facets (Collaboration perspectives)
Generic Ontology Development Framework (Rajpathak et.al, 2011)	Ontology	✓ Workflow to followed in properly elaborated with a proper breakdown of phases and sub-phases	✓ No notion on ontology increments ✓ Evaluation of the ontology is done, after full completion of the development. This allows unforeseen errors to	No, emphasize for interoperability and alliance facets (Collaboration perspectives)

				accumulate	
Industry Relevant Ontology Development Framework (Abdullah, et.al, 2011)		Ontology	✓ Has introduced index-coded thematic analysis to assess qualitative information extracted from the expert interview. ✓ Explore relevant scholarly articles and incorporate knowledge accordingly with expert insights.	✓ No notion on ontology increments	No, emphasize for interoperability and alliance facets (Collaboration perspectives)
Platform Independent Ontology Development Framework (Sanya et.al, 2014)		Ontology	✓ Use case-oriented ontology comprehension projection ✓ Specify finalized requirements through formal representations (i.e. FOL) ✓ Fine-tuning of platform-independent meta-model to a platform-specific version via configuring the formal representations	✓ No notion on ontology increments	No, emphasize for interoperability and alliance facets (Collaboration perspectives)
Systemology Framework (Rousseau et.al, 2018) This framework is a composition of	GIF (Rousseau et.al, 2018)	Communication	✓ Provide a solid baseline for knowledge acquisition	✓ General communication framework with cross-disciplinary applications. Not fine-tune for ontology domain	✓ No, emphasize for interoperability and alliance facets (Collaboration perspectives) ✓ Lack of a governing workflow

GIF, DSRP and Dialectics concepts					visible
	DSRP (Cabrera et.al, 2017)	Communication	✓ Provide a solid baseline for brainstorming on acquired facts	✓ General communication framework with cross-disciplinary applications. Not fine-tune for ontology domain	✓ No, emphasize for interoperability and alliance facets (Collaboration perspectives) ✓ Lack of a governing workflow visible
	Dialectics(Levins, 2008)	Communication	✓ To govern argumentation of pros and cons associated with an axiom	✓ General communication concept with cross-disciplinary applications. Not fine-tune for ontology domain	✓ No, emphasize for interoperability and alliance facets (Collaboration perspectives) ✓ Lack of a governing workflow visible

Appendix [A] -Table 3- Tabular comparison of ontology development frameworks

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