

Evaluating the Progress of PhD Students using Ontology

Laxmi Verma Arya

Department of Physics and Computer Science
Dayalbagh Educational Institute
Agra, Uttar Pradesh, India
lakshmiarya5@gmail.com

Preetvanti Singh

Department of Physics and Computer Science
Dayalbagh Educational Institute
Agra, Uttar Pradesh, India
preetvantisingh@gmail.com
ORCID: 0000-0002-4575-195

Abstract—For academic institutions to guarantee research productivity, assessing PhD students' progress is essential. It is a complex problem that calls for a mix of quantitative and qualitative factors. A PhDProgressEvaluation Model is developed in this paper with the goal of classifying the progress of PhD students. This model combines SWRL reasoning and ontology to classify the performance of doctoral students based on parameters such as student feedback, scholarly skills, supervisor opinion, and publications. The model enables automated decision-making and provides a transparent evaluation framework.

Keywords— Ontology, SWRL, SPARQL, Doctoral Study, Progress Evaluation

I. INTRODUCTION

Ontology represents a powerful tool for knowledge representation and management, and retrieval of knowledge in a specific domain. It consists of concepts, relationships between concepts, and instances. These are used to model real-world domains in a way that both humans and machines can understand.

Saranya, Gomathi & Chinnasamy (2021) developed an ontology-based and IoT health preventive management system for patient information discovery. Bughio, Cook & Shah (2024) presented an internet of medical things-enabled remote patient monitoring system using ontology. Croce et al. (2024) developed an ontology-based system to manage and prepare healthcare data. A mental health ontology was developed by Hastings et al. (2024). Hu et al. (2024) developed a health ontology to diagnose diabetes mellitus. Guo, Scriney & Liu (2024) developed an ostensive information architecture for enhancing semantic interoperability in healthcare information systems. Ontology-based data management in a cardiology information system was developed by Raboudi et al. (2024). Zafeiropoulos, Bitilis, Tsekouras, & Kotis (2024) presented an ontology-based system to monitor Parkinson disease. Aktaş (2024) designed an ontology-driven career planning system to assist individuals in making informed career decisions. Tseng, Yang, Shih & Shan (2024) developed a self-evolving iMonsters board

game designed for cybersecurity education, offering an innovative approach to interactive learning. Wang, Haudek, Manzanares, Romulo & Royse (2024) extended BERT using an ontological perspective to classify students' scientific expertise level based on their written responses. Bhattacharya & Pandey (2024) developed ontology for agriculture to extract relationships from texts using natural language processing and artificial intelligence for enhancing semantic understanding. Cornei, Cornei & Foşalău (2024) proposed a model to capture spatial and temporal dynamics in agriculture. Saravanan & Bhagavathiappan (2024) developed a question answering system for improving the information retrieval from the agricultural text documents.

This paper presents an ontology for evaluating the progress of the PhD students during their doctoral degree. The PhD ontology enables effective decision making by providing flexible and complex knowledge representation and reasoning in complex domain.

II. MATERIALS AND METHODS

Ontology and Rule Markup (RuleML) is used to perform classification. Rule Markup is a markup language for publishing and sharing rule bases on the World Wide Web. It focuses on rule interoperability between industry standards. RuleML builds a hierarchy of rule sublanguages upon RDF and OWL. Semantic Web Rule Language (SWRL) is an example of RuleML.

SWRL is used to express rules and logic. It includes a high-level abstract syntax for horn-like rules. All rules are expressed in terms of OWL concepts (classes, properties, individuals). SWRL rules are defined using the *if...then...* structure and can be integrated into ontologies.

III. THE MODEL

For academic institutions to guarantee research productivity, assessing PhD students' progress is essential. It is a complex problem that calls for a mix of quantitative

and qualitative factors. A PhD Progress Evaluation (PPE) Model is developed in this paper with the goal of classifying the progress of PhD students.

A. Participants and Data collection

The data of 33 full-time doctoral students of the Physics and Computer Science department, Dayalbagh Educational Institute, Agra is considered in this study. 13 students were enrolled in their first year of doctoral study, 7 were in their second year, and 12 were in their third year of the study. 8 students among these three categories were considered for detailed study.

Literature was reviewed to identify the following components that a student should have to function as a researcher:

- *Primary research skills:* These skills include the ability to efficiently carry out data collection, to identify an appropriate method for interpreting data, and applying appropriate tools for understanding the data.
- *Information Pursuing Skills:* These involve understanding the way to explore information sources in the areas relevant to the study and to evaluating the reputation of the searched information.
- *Methodological Skills:* These skills include identifying and designing appropriate research procedures to understand the limitations and scope of research design.
- *Communication and Time Management Skills:* Communication skills include the ability to effectively present research findings and tailor communication to the audience. Time management skills include the ability to complete the task on time.
- *Advisor-student relationship:* This parameter is considered to understand the relationship of students with their supervisors as it enables enhancing the academic and professional growth of students.

The first four skills, termed scholarly skills, are developed during the doctoral study of a student for his academic success and future career.

B. Analyzing the Performance of Questionnaire Items

These identified components were used to generate a PhDProgress questionnaire for evaluating the progress of PhD students based on student feedback, scholarly skills, and the supervisor's opinion. This questionnaire was filled by scholars using the 5-point scale (1-very poor and 5-

excellent). The internal consistency of the performance questionnaire is analyzed using Cronbach's Alpha (Sharma & Singh, 2025).

C. Designing the PhD Ontology

A PhDOnto is developed next to provide efficient knowledge sharing and interoperability across system. This ontology includes the PhDStudent class as a subclass of Student. The other classes, object properties, and data properties related to PhDStudent are shown in Tables I to III. The conceptual framework for the ProgressEvaluation model is shown in Figure 1.

TABLE I. OWL CLASSES OF PHD ONTOLOGY RELATED TO PROGRESS EVALUATION

Class	Description
PhDStudent	A subclass of student
PerformanceSatisfactory	Categorizes the performance of a PhD student as satisfactory. The class is created after executing the SWRL rules.
PerformanceGood	Categorizes the performance of a PhD student as good. The class is created after executing the SWRL rules.
PerformanceUnsatisfactory	Categorizes the performance of a PhD student as unsatisfactory. The class is created after executing the SWRL rules.
PerformanceMetricPhD	Represents various performance metrics of PhD students.
RACCommittee	The RAC members for each PhD student.
Supervisor	Supervisor of PhD student.
Achievements	Contains subclasses Award, CommunPaper, PublishedPapers, Visits.

TABLE II. OBJECT PROPERTIES OF PHD ONTOLOGY RELATED TO PROGRESS EVALUATION

Object Properties	Domain	Range
hasPublishedPapers	PhDStudent	PublishedPapers
hasCommunicatedPapers	PhDStudent	CommunPaper
hasPerformanceMetric (<i>inverse</i>)	PhDStudent	PerformMetricPhd
hasLABAttendance	PhDStudent	LabMeets
has Award	PhDStudent	Award
hasPresent	PhDStudent	LabMeet
hasRacM	PhDStudent	RACCommittee
hasSupervisor (<i>inverse</i>)	PhDStudent	Supervisor
ofPhDStud (<i>inverse</i>)	PerformMetricPhd	PhDStudent
Supervises (<i>inverse</i>)	Supervisor	PhDStudent

D. Generating Rules

In this study, SWRL rules are generated after discussing with expert to classify the progress of PhD students as *satisfactory*, *unsatisfactory*, and *good*.

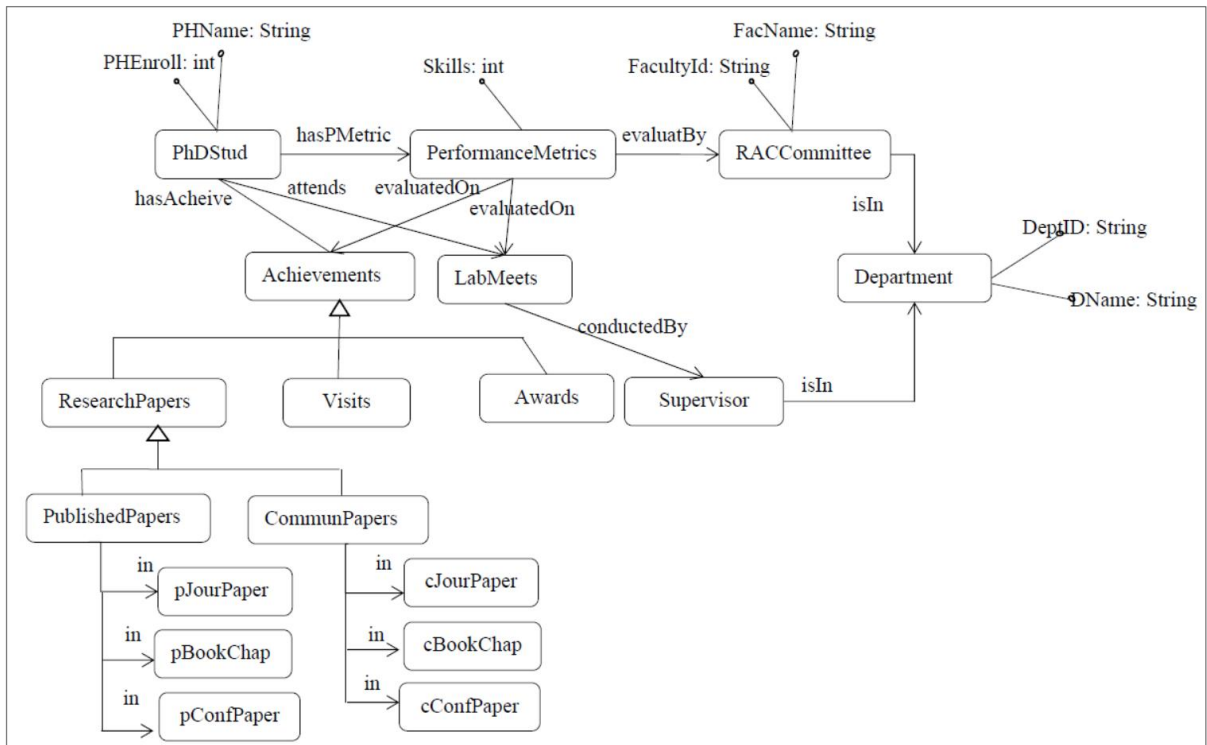


Fig. 1. Conceptual Framework for PPE Model

TABLE III. DATA PROPERTIES OF PHD ONTOLOGY RELATED TO PROGRESS EVALUATION

Data Properties	Domain	Type
AcadEngage	PerformMeticPhd	(xsd:integer)
AwardName	Award	(xsd:string)
AwardYr	Award	(xsd:integer)
VisitPlace	Visit	(xsd:string)
VisitPurpose	Visit	(xsd:string)
VisitYr	Visit	(xsd:integer)
PaperJC	ResearchPaper	(xsd:string)
PaperYr	ResearchPaper	(xsd:integer)
Member1Designation	RACCCommittee	(xsd:string)
Member1Name	RACCCommittee	(xsd:string)
Member2Designation	RACCCommittee	(xsd:string)
Member2Name	RACCCommittee	(xsd:string)
NoAward	PerformMeticPhd	(xsd:integer)
NoCommPaper	PerformMeticPhd	(xsd:integer)
NoPubpapers	PerformMeticPhd	(xsd:integer)
PHEnroll	PerformMeticPhd	(xsd:integer)
PHName	PerformMeticPhd	(xsd:string)
PHLabAttd	PerformMeticPhd	(xsd:integer)
PHResearchTopic	PerformMeticPhd	(xsd:string)
PHRegistrationDate	PerformMeticPhd	(xsd:string)
ResearchQuality	PerformMeticPhd	(xsd:integer)
ScholarlySkills	PerformMeticPhd	(xsd:integer)
SupName	Supervisor	(xsd:string)
SupDesignation	Supervisor	(xsd:string)
YearsRegistered	PerformMeticPhd	(xsd:integer)

Table 4 shows the generated rules in mathematical form as well as their corresponding SWRL rules. For example rule S1 says that let s be the student, k be the scholarly skills score of s , q be the research quality score of s , lab attendance during lab meets be att of s and years of registration in PhD programme be y , then the progress of student s is satisfactory if $(3.0 \leq k < 3.5 \text{ and } q \geq 3.5 \text{ and } att \geq 75 \text{ and } y = 1)$.

TABLE IV. SWRL RULES (CORRESPONDING SWRL RULES ARE SHOWN IN FIGURE 2)

R. No.	Mathematical Representation of the Rule
S1	$\forall_s (3.0 \leq k_s < 3.5) \wedge (3.5 \leq q_s < 4.0) \wedge (75 \leq att_s < 80) \wedge (y_s = 1) \Rightarrow \text{Satisfactory}$
S2	$\forall_s (q_s \geq 4.0) \wedge (e_s \geq 4.0) \wedge (y_s \geq 1) \wedge (c_s \geq 1) \Rightarrow \text{Good}$
S3	$\forall_s (y_s \geq 1) \wedge (c_s \geq 1) \Rightarrow \text{Good}$
S4	$\forall_s (k_s \leq 3.5) \wedge (75 \leq att_s < 80) \wedge (y_s = 1) \Rightarrow \text{Unsatisfactory}$
S5	$\forall_s (k_s \leq 3.5) \wedge (q_s \leq 3.5) \wedge (att_s \leq 75) \wedge (y_s \geq 1) \Rightarrow \text{Unsatisfactory}$
S6	$\forall_s (k_s \geq 3.5) \wedge (q_s \geq 3.5) \wedge (e_s \geq 3.5) \wedge (att_s \geq 75) \wedge (y_s = 2) \Rightarrow \text{Satisfactory}$
S7	$\forall_s (k_s \leq 3.5) \wedge (e_s \geq 3.5) \wedge (att_s \geq 75) \wedge (y_s \leq 2) \Rightarrow \text{Satisfactory}$

Total seven rules are created after discussing with experts. The rules are implemented using the SWRL structure in protégé (Figure 2.) to achieve the goal. The

rules are executed using the HerMiT reasoner in Protégé. When student data is entered into the ontology, the reasoner infers the appropriate performance category

based on the defined SWRL rules (Figure 2 through Figure 4).

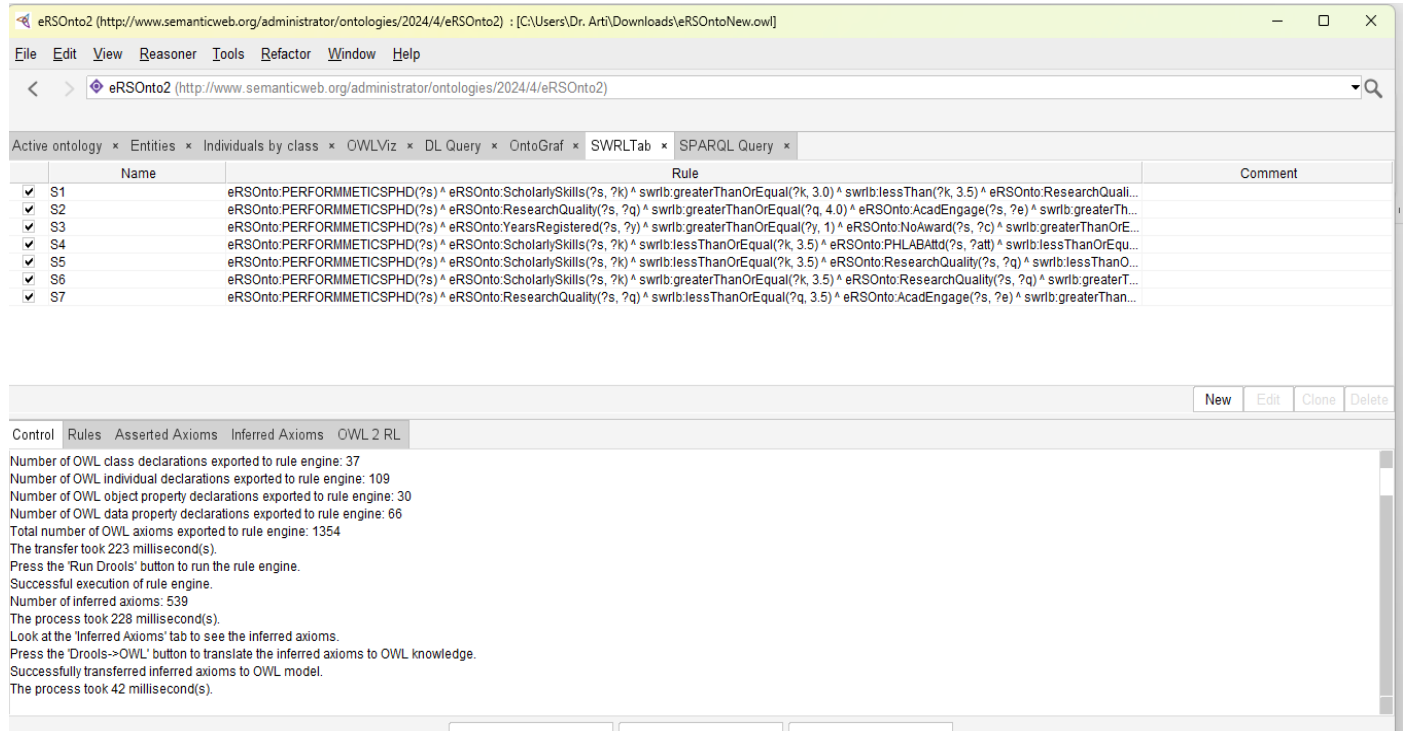


Fig. 2. The SWRL Tab in Protégé

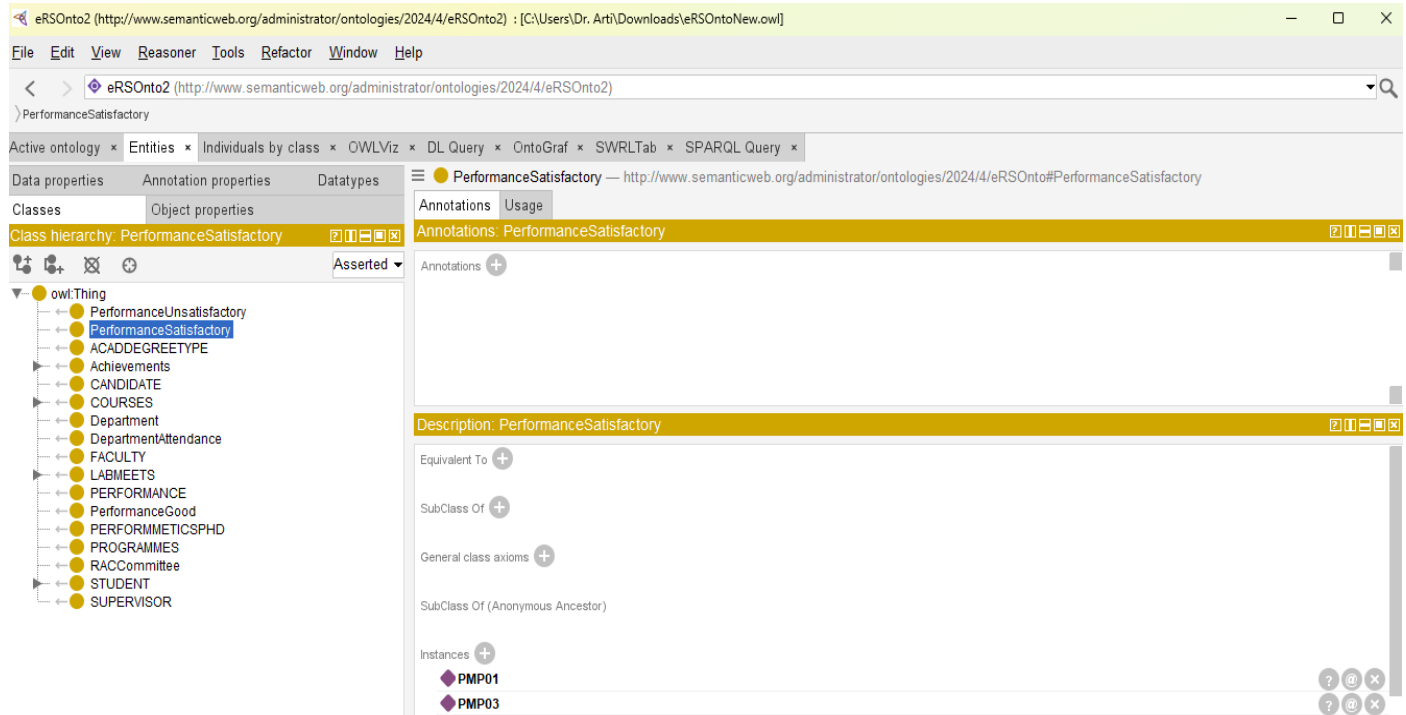


Fig. 3. The generated PerformanceSatisfactory Class

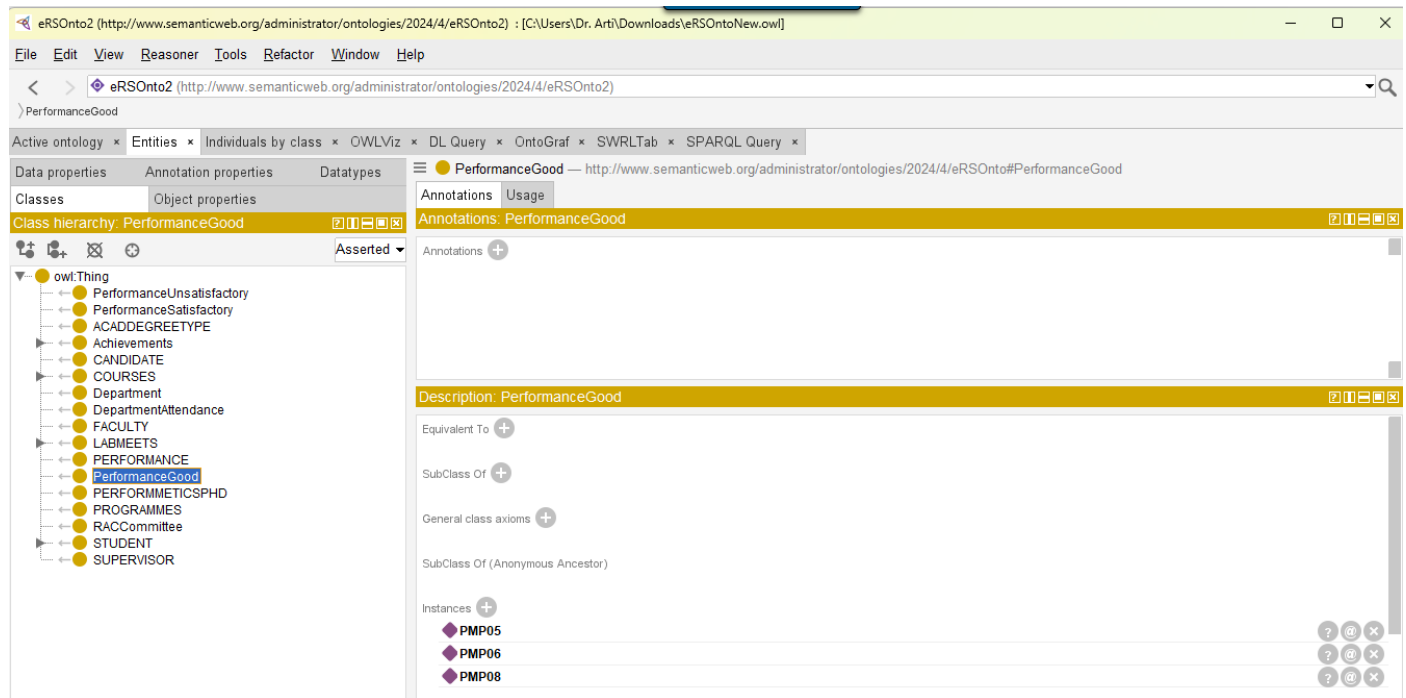


Fig. 4. Generated *PerformanceGood* Class

IV. RESULTS

Table 5 displays the α values for each QI. As the value is greater than 0.7 for all the categories, the performance questionnaire is consistent internally.

TABLE V. THE CRONBACH’S ALPHA VALUE FOR EACH QI

S. No.	Quest. Categories	No. of QIs	α value
1.	Core research skills	10	0.8053
2.	Information seeking skills	10	0.7028
3.	Research methodology skills	10	0.7977
4.	Communication and time management skills	10	0.7891
5.	Advisor-supervisor relationship	10	0.8391

As the Cronbach’s Alpha value is more than 0.7, it shows an internal consistency among the QIs.

A. Analyzing the Progress of Students

The background of the students is described through graphs. All the 8 students are self-disciplined, dedicated and motivated towards their doctoral study. None of these students had any health issues or any kind of stress. The students had a good relationship with their supervisor and could manage time efficiently.

The developed questionnaire is analyzed to determine the progress of students in terms of scholarly skills, student feedback, and supervisor’s opinion. Average score is computed for each student.

Analyzing their skills, it is observed that the primary research skills of most of the students are above average. However, information seeking skills, research methodology skills, and communication and time management skills are rated below average for some of the students (Figure 5).

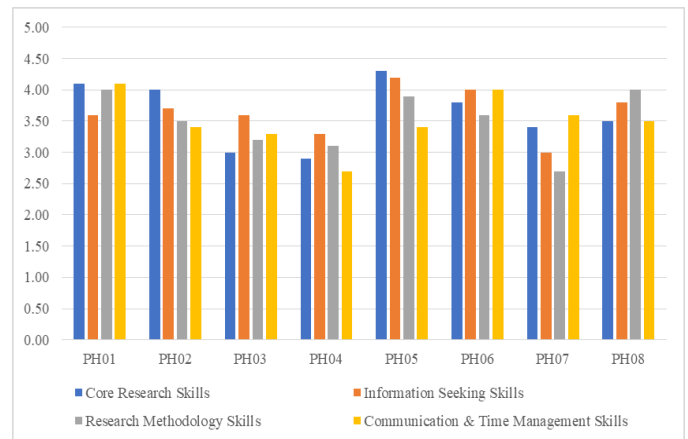


Fig. 5. Scholarly Skills Scores of Students

According to the supervisors’ opinion (Figure 6), the research quality of the students ranged from good to below average. This indicates that most of the students were able to understand the significance of research questions and were clear about the research methodology. However, few of these students lack in generating novel ideas, and in effectively presenting their work to audiences.

Academic engagement of each individual is however good meaning that they were able to take active participation in academic discussion, and attend conferences and workshops/research seminars.

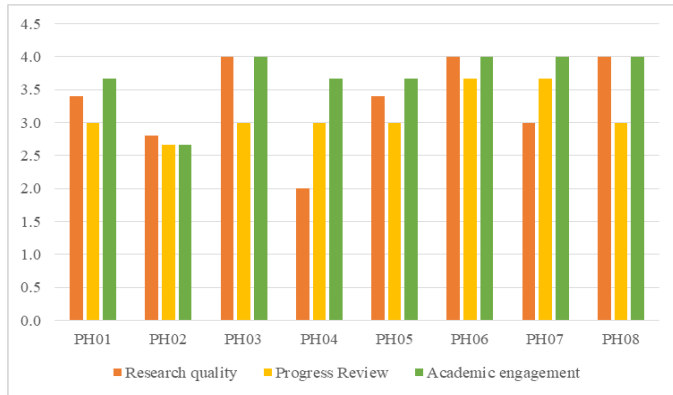


Fig. 6. Supervisors' Opinion Score

All students are on average able to complete the milestones timely and adhere to their plan. Mostly the students in their first year and second year of doctoral studies were not able to present their research plans efficiently and discuss the feasibility of it.

B. Generating Recommendations

Upon analyzing the scholarly skill scores of the student PH01, it can be observed that she has shown progress in enhancing the core research skills, research methodology

skills and communication and time management skills. However, she needs to improve information seeking skills. Here she lacks in evaluating the quality and reliability of information. This can be improved by suggesting ways to improve evaluation skills. Possible solutions can be to learn to determine who created the information and why, look for the credentials, affiliations, and reputation of the author, look for data governance framework, and consider data quality dimensions, i.e., the data accuracy, completeness, consistency, timeliness, and validity.

Considering student PH04, he is yet not able to develop his core research skills and communication and time management skills. He must improve writing skills, oral communication, practice to engage audience, and learn to structure the research documents. He also has to work for improving problem-solving skills, analytical skills, work on effeciently analyzing and summarizing key ideas from articles, and learn to make critical relections while reading the research articles. SPARQL queries are generated to display the details of the PhD students. Figure 7, Figure 8 and Figure 9 show the details of student PH01 working under the supervision of Dr. PVSingh.

Referring to Figure 7, progress of student PH01 is categorized as satisfactory. But this student had a low progression in information seeking skills. Thus, student PH01 was recommended various solutions to improve information seeking skills.

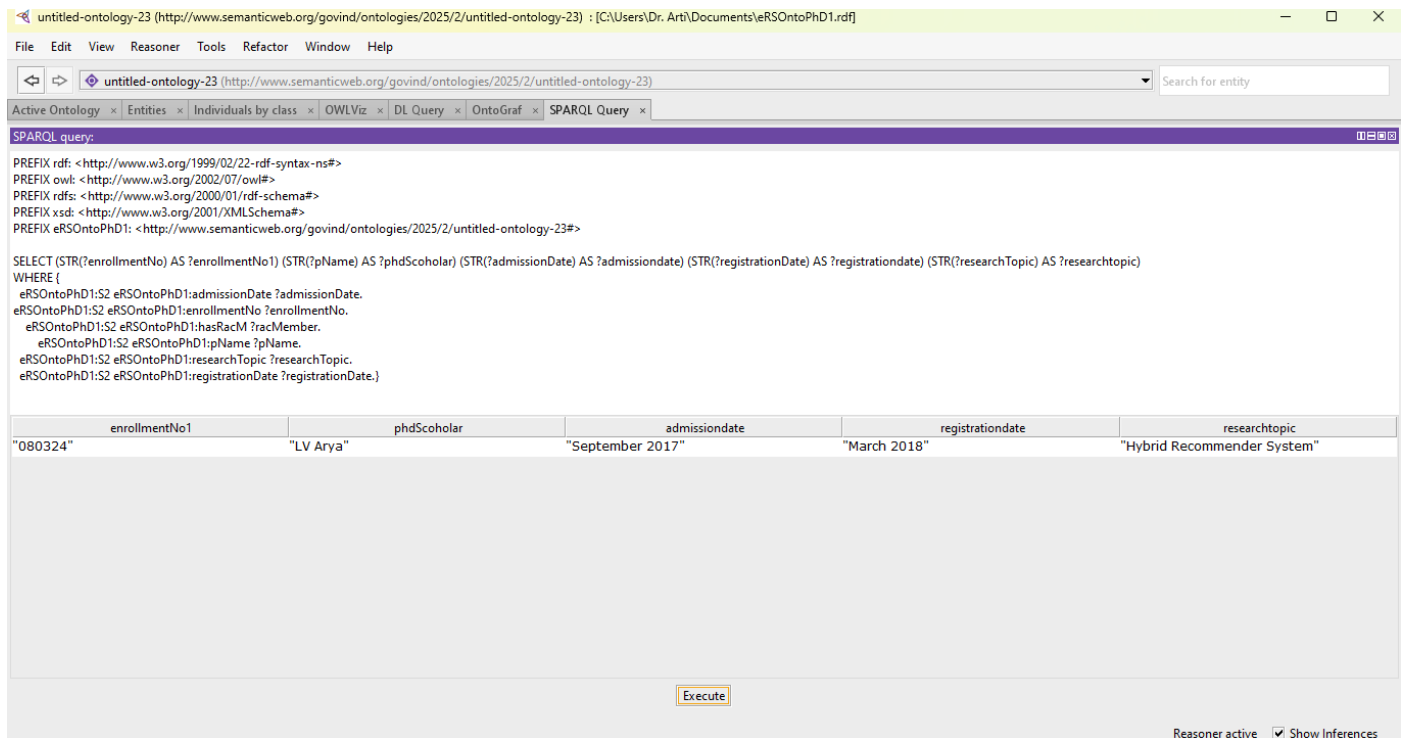


Fig. 7. Research Topic and registration date of PH01

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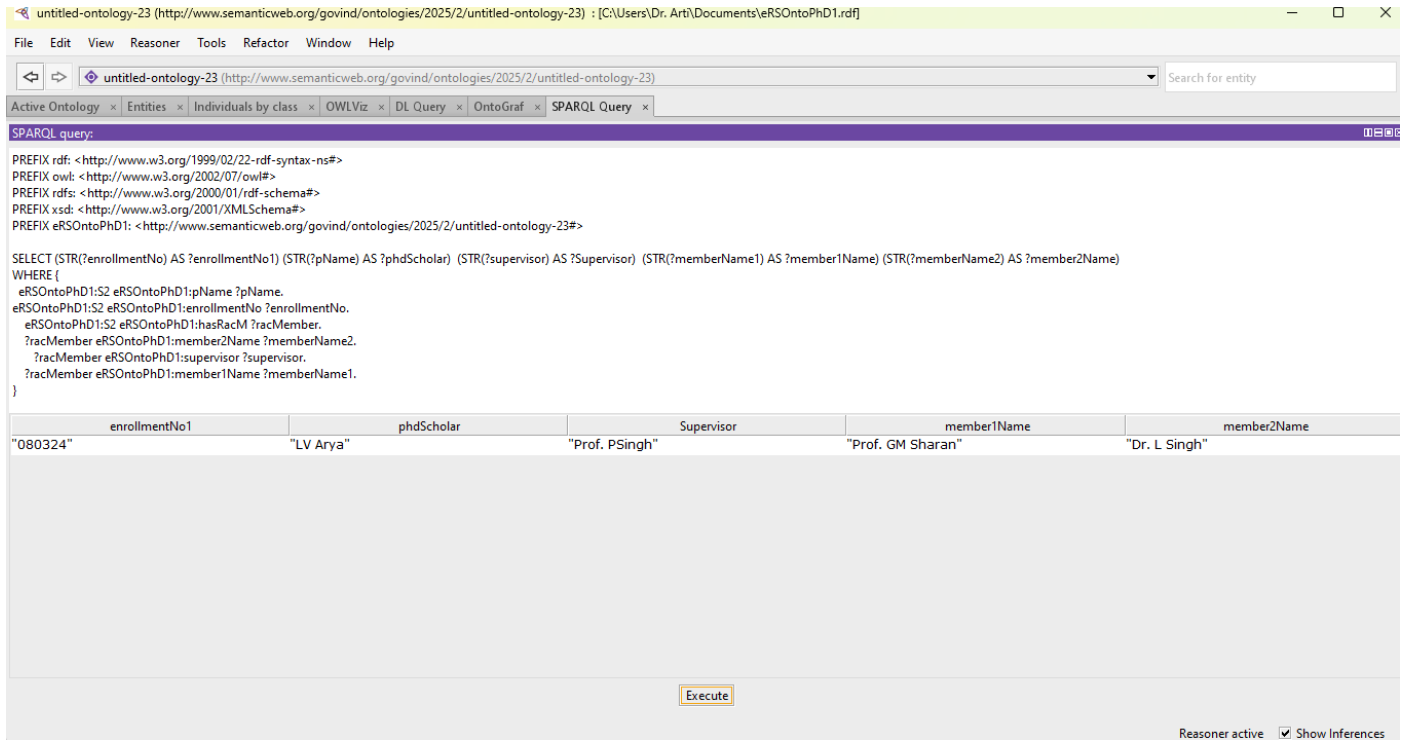


Fig. 8. RAC Committee of PH01

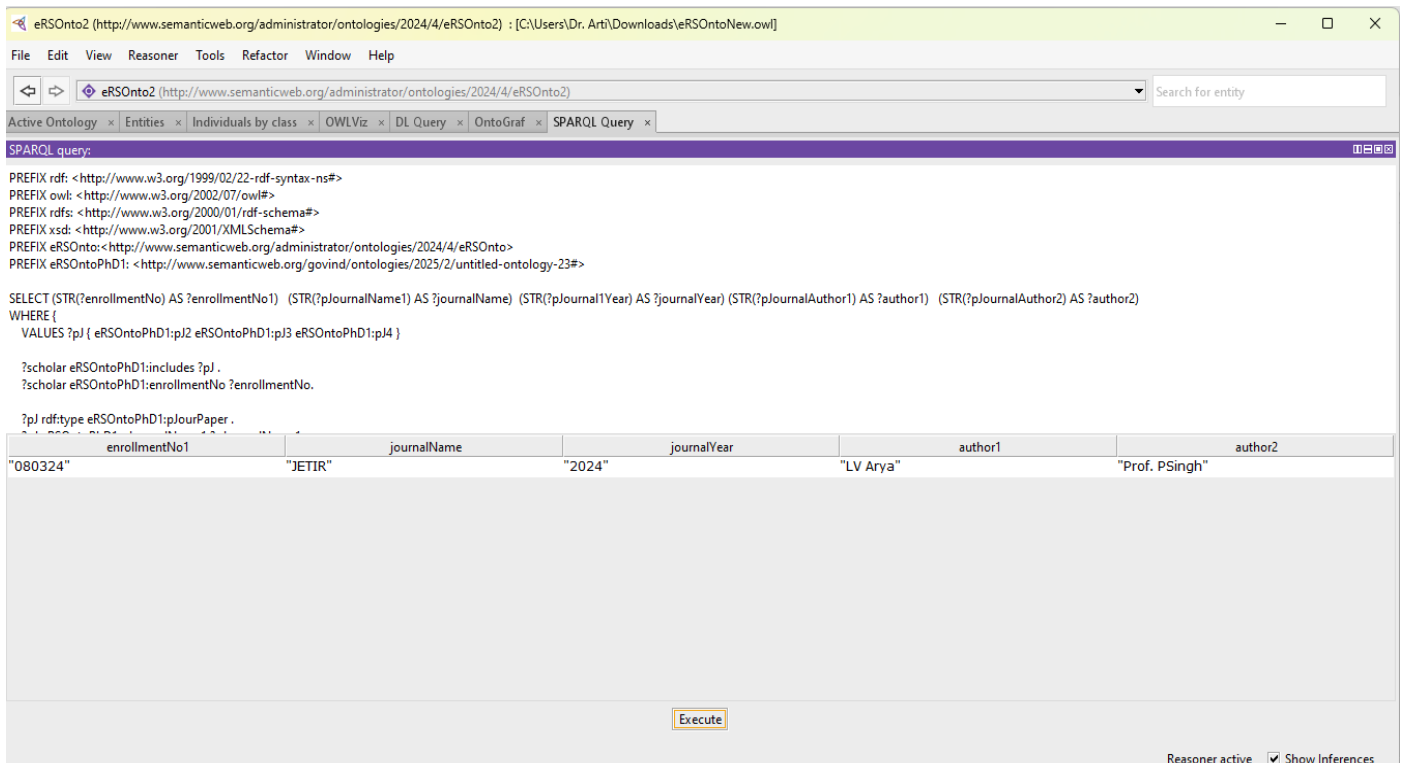


Fig. 9. Publication details of PH01

She was suggested to take training in research question development process to learn to break down broad topics into specific, researchable questions, teach to identify reliable sources. She was also suggested collaborating with peers and faculty to present a summary of recent research articles. She was also encouraged to collaborate with other researchers.

The progress of student PH04 was categorized as unsatisfactory. Thus, to improve the performance of student PH04 he is suggested to do research methodology courses, and should attend regular sessions on academic writing, and should be involved in hands-on training in Data Analysis. His supervisor was suggested to conduct periodic reviews of his research progress with constructive feedback, encourage him to analyze existing theories critically, assign senior PhD students as mentors to help him with structuring research, literature review techniques, and research planning, and provide opportunities to present research in conferences, symposiums, and seminars to build confidence in articulating research findings.

These recommendations were suggested by the members of the expert group and the members of the research advisory committee.

V. CONCLUSION

This paper focuses on developing PhD ontology and PhD Progress Evaluation Model to evaluate the progress of students in doctoral study. The model is developed by integrating the ontology with SWRL rules. The approach automates the performance classification process, ensuring fairness, consistency, and transparency in academic assessment. SWRL enhances OWL's reasoning capabilities by introducing rule-based decision-making, enabling a more sophisticated evaluation of PhD students based on research output, skills, and attendance. In future fuzzy logic could be applied to reduce the uncertainty in decision making and creating the system more accurate and optimized.

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