OUTCOME BASED CURRICULUM ONTOLOGY (OBC-ONTO) DOCUMENTATION

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The Outcome Based Ontology (OBC-ONTO) is designed to model the curriculum planning process of a university study program, starting from the formulation of learning outcomes at the program level down to more detailed specifics. Based on these learning outcomes, instructional materials, learning activities, instructional media, as well as assessment instruments and achievement indicators are planned. This ontology can be utilized not only by lecturers, students, and other university stakeholders seeking to understand the program profile, but also by **curriculum reviewers**—an important yet often overlooked user group in previous research. These reviewers, who are external to the study program, are tasked with assessing whether the curriculum aligns with the principles of OBE. At universities implementing quality assurance processes, this review team evaluates the curriculum prior to implementation. Additionally, curriculum reviews are conducted by assessors when the study program undergoes national or international accreditation.

A. Ontology Specification

The purpose of developing the OBC ontology is to model curriculum design for higher education programs. The educational cycle in the OBE approach includes three interconnected stages:

- Outcome-Based Curriculum (OBC),
- Outcome-Based Teaching and Learning (OBTL), and
- Outcome-Based Assessment and Evaluation (OBAE).

This work limits the scope of the ontology to the **Outcome-Based Curriculum** (**OBC) stage**.

The primary users of this ontology are **curriculum reviewers** who responsible for verifying that a curriculum design meets general OBE criterias and it suitable for progressing to the next stages -- OBLT and OBAE. Additionally, program heads or curriculum designer teams can benefit from using this ontology structure when developing their curricula. This ontology may also provide students, faculty, and the general public with a comprehensive overview of a study program's curriculum.

B. OBE Terminology

Learning outcomes can be achieved in various levels and forms, even through multiple methods, and the results can also be measured in diverse ways, not solely through direct observation (Kemristekdikti, 2020). In OBE, learning outcomes are formulated at various levels, starting from the program level down to individual courses or even smaller units

within a course. The aggregation of learning outcomes achieved at the course level forms the basis for the achievement of program-level learning outcomes.

Table 1. Terminologies in OBE

Terminology	Meaning
Program Educational Objective (PEO)	Broad statements that describe what graduates are expected to attain **within a few years of graduation**.
Program Learning Outcome (PLO) Equivalent terminology: • Graduate Attribute (GA) • Student Learning Outcome (SLO) • Student Outcome (SO)	*Statements that describe what students are expected to know and be able to do **by the time of graduation***
Course Learning Outcome (CLO) Equivalent terminology: • Intended Learning Outcome (ILO) • Subject Learning Outcome	Statements that describe what students should be able to know, do, value **by the end of a course**.

Some study programs use Sub-PLOs to represent subsets of the PLO and Sub-CLOs to indicate subsets of the CLO. Additionally, at a level more detailed than the CLO or Sub-CLO, several study programs also formulate Unit Learning Outcomes or Topic Learning Outcomes.

C. OBE Principles

The principles of *clarity of focus*, *designing back*, *high expectations*, and *expanded opportunity* introduced by Spady (1994) serve as the main foundation in every step of developing an outcome-based curriculum

The principle of ***clarity of focus*** in OBE emphasizes the importance of clearly and specifically establishing the desired learning outcomes before designing the curriculum or teaching methods. According to Spady, this principle ensures that each element in teaching is directed towards achieving specific and measurable objectives. To provide students and teachers with clear guidance in the learning process, the desired learning outcomes must be defined in measurable success criteria.

The ***designing back*** or ***backward design*** principle involves structuring the curriculum and learning process by starting with the desired outcomes—what students are expected to achieve—and then designing backward steps to reach those outcomes. Spady emphasizes that through this backward design approach, each curriculum component is intentionally aligned with the learning objectives, creating a logical and directed structure within the educational process (Spady, 1994)

The principle of ***high expectations*** within OBE requires educators to set high standards for all students, encouraging them to achieve their best in learning. This standard not only boosts student motivation but also fosters a challenging and supportive learning

environment In the context of OBE, high expectations are crucial to building confidence that all students can achieve optimal results when provided with adequate support. According to Biggs & Tang (2011), effective teaching is defined as 'encouraging the majority of students to spontaneously employ the level of cognitive processes necessary to achieve the desired outcomes.' Traditional teaching methods such as lectures and tutorials do not inherently require students to engage in higher-level cognitive processes; therefore, OBE must incorporate active learning or student-centered learning approaches. Aligned with the principle of *high expectations*, assessments should also challenge students sufficiently to activate higher-order thinking skills, such as critical thinking, decision-making, and problem-solving.

Expanded opportunity focuses on providing diverse pathways and opportunities for students to achieve learning outcomes. Spady highlights that the curriculum should be flexible, offering various approaches and sufficient time for students to meet the defined standards of success (Rao, 2020). This principle acknowledges individual differences in learning speed and style, ensuring that all students have equal opportunities for success. This approach includes offering learning experiences outside the classroom and contextual learning, helping students develop practical skills relevant to real-world contexts. Additionally, this principle emphasizes the importance of lifelong learning and ongoing education.

D. Ontology Development Method

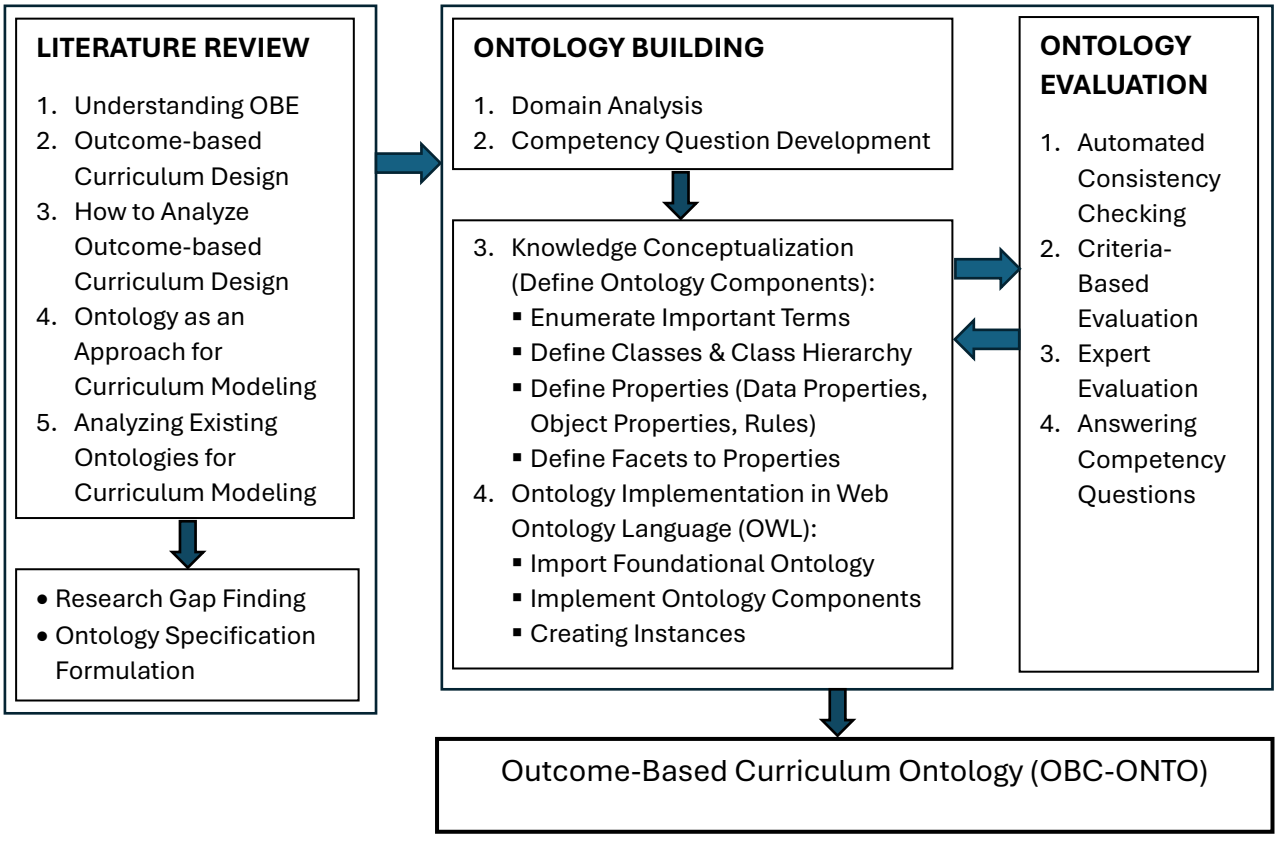

Figure 1. Ontology development method

E. Competency Question Development

After studying Outcome-Based Education (OBE) and analyzing relevant ontologies for curriculum modeling, the authors conducted a detailed domain analysis. This involved reviewing curriculum documents and examining OBE curriculum templates from various study programs across diploma, undergraduate, and master's levels, primarily from Universitas Indonesia and several other universities. Based on this analysis, competency questions were formulated as spesific questions tailored to the ontology's usage scenario. Curriculum review templates from Universitas Indonesia, along with discussions with curriculum reviewers (who have reviewed curricula over the past decade) played an essential role in developing these competency questions.

Table 2. describe the competency questions, presented alongside the OBE principles associated with each question (CoF for Clarity of Focus, BD for Backward Design, EO for Extended Opportunity, HE for High Expectation).

Tabel 2. Competency Questions

No	Question	Principle
1	What is the name of the study program? What is the program's vision and mission?	-
2	Describe the curriculum owned by the study program	-
3	Describe the Program Educational Objectives (PEO) of the study program.	CoF
4	Describe the Program Learning Outcomes (PLO) of the study program.	CoF
5	Describe references used in curriculum development, including: • International/regional/national accreditation bodies (if applicable) • Reference documents, such as international standard curriculum, national standard curriculum, document consist of stakeholders' input, alumni survey report, relevant document from benchmark institution.	CoF
6	Outline the mapping of the national quality framework within the PEO or PLO (including framework level, knowledge element, working skill element, authority and responsibility element).	CoF
7	Describe the domain (cognitive, affective, psychomotor) associated with each PLO.	CoF
8	Describe the mapping between PEO and PLO.	CoF
9	Describe the mapping between PLOs and courses within the curriculum.	BD
10	Describe the Course Learning Outcomes (CLO) within the curriculum	CoF, BD

11	Describe the components of each CLO (Condition, Action, Content, Criteria).	CoF
12	Describe the domain (cognitive, affective, psychomotor) associated with each CLO.	CoF
13	Describe the knowledge category of each CLO (e.g., Factual, Conceptual, Procedural, Metacognitive).	CoF
14	Describe alignment between PLO and CLO mappings.	BD
15	Describe the mapping between PLO, learning activities, performance indicators, and appropriate assessment types for each PLO.	BD, HE, EO

F. OBC – ONTO Description

Based on the domain analysis and the need to address competency questions, the classes are developed as shown in Table 3. These classes represent the concepts embedded within the design of a curriculum, specifically within the OBC stage, as defined by the scope of this ontology. Operational elements, such as course delivery, instructors, and students, fall under OBLT and OBAE stages and are thus excluded from this scope. However, elements that are rarely included in traditional curriculum documents but hold importance in the OBE context —such as curriculum references, the national quality framework (NQF), learning outcomes— are incorporated within the scope of this ontology.

Table 3. The Class and Subclass

Class (without subclass)	StudyProgram, Curriculum, CurriculumReference, ProgramEducationalObjective, KnowledgeCategory, SubjectMatter, Course, LearningActivity, Assessment, PerformanceIndicator, ProgramMapping	
Class with Subclass	**Class**	**Subclass**
	NationalQualificationFramework	NQFKnowledge, NQFWorkingSkill, NQFAuthorityResponsibility
	LearningOutcome	ProgramLearningOutcome, SubProgramLearningOutcome, CourseLearningOutcome
	LearningDomain	AffectiveDomain, CognitiveDomain, PsychomotoricDomain

The Class Definition

1. **StudyProgram**
   - **Definition**: An academic program that offers a curriculum aimed at achieving specific educational objectives

- **Example Instances**: Undergraguate program of Computer Science at the Universitas Indonesia

2. **Curriculum**
   - **Definition**: The structured plan of learning organized by a study program to achieve targeted learning outcomes.
   - **Example Instances**: Curriculum of Undergraguate program of Computer Science at the Universitas Indonesia Year 2020

3. **CurriculumReference**:
   - **Definition**: References used in curriculum development, including:
     - International/regional/national accreditation bodies (if applicable)
     - Reference document, such as international standard curriculum, national standard curriculum, minutes of meeting from FGD with stakeholders, alumni survey document, curriculum document from benchmark institution.
   - **Example Instances**: ABET (Accreditation Board of Engineering and Technology) as accreditation body, ACM computing curricula 2020 as reference document.

4. **ProgramEducationalObjective**:
   - **Definition**: Broad statements that describe what graduates are expected to attain **within a few years of graduation**.
   - **Example Instances**: "Students understand economics concept"

5. **LearningOutcome**
   - **Definition**: educational goals and represent a statement of what students are expected to know, understand, and be able to do after completing a learning period
   - **Subclass**: ProgramLearningOutcome, SubProgramLearningOutcome, CourseLearningOutcome

6. **ProgramLearningOutcome**
   - **Definition:** Statements that describe what students are expected to know and be able to do by the time of graduation.
   - **Example Instances: "**Students are able to apply basic theories of Finance & Financial Management"

7. **SubProgramLearningOutcome**
   - **Definition**: Subclass of ProgramLearningOutcome and Superclass of CourseLearningOutcome. This type of outcome is only created when needed or desired. The study program does not have to define this outcome.

8. **CourseLearningOutcome**
   - **Definition**: Statements that describe what students are expected to know, do and value **by the end of a course**.
   - **Example Instance**: "*When presented with a real-world, moderately complex problem that requires artificial intelligence and data science solutions, students are able to select the appropriate Artificial Intelligence and data science models for the problem and implement them as high-performance solutions*".

9. **NationalQualificationFramework**
   - **Definition**: Framework which serves as a human resource qualification system in a country. This framework links, equates, and integrates education with training and work experience within a recognized skill structure tailored to various occupational sectors. In this study, the Indonesian National Qualification Framework (KKNI) is applied, defining nine levels of qualifications—Level 1 being the lowest and Level 9 the highest. Diploma 3 graduates are are generally expected to achieve at least level 5; Bachelor's degree graduates at least level 6, specialists at least level 7, and master's degree graduates at least level 8.
   - **Example Instances**:

NQF Level	NQF Element	Description
6	Knowledge	Master the theoretical concepts of a particular field of knowledge in general and the theoretical concepts of a special section in that field of expertise in depth and formulate procedural problems
6	Working Skill	Able to apply their fields of expertise and take advantage of science, technology, or art to solve problems and adapt to situations at hand.
6	Authority & Responsibility	Able to make correct decisions based on analysis of information and data and provide guidance in choosing various alternative solutions independently and in groups.
6	Authority & Responsibility	Responsible for his work and can be given responsibility for the achievement of the work of the organization.
8	Knowledge	Able to develop knowledge, technology, or art in their scientific field or practice professionally through research to produce innovative and tested works.
8	Working Skill	Able to solve science, technology, or art problems in their scientific fields through an interdisciplinary or multidisciplinary approach.
8	Authority & Responsibility	Able to manage research and development beneficial to society and science and can get national and international recognition.

10. **KnowledgeCategory**
   - **Definition**: Categories of knowledge encompassing various domains or areas of learning.
   - **Instances**: Anderson and Krathwohl (2001) divide knowledge category into factual, conceptual, procedural, metacognitive

11. SubjectMatter
   - **Definition**: Specific topics or content areas covered within the curriculum.
   - **Example Instances**: "Descriptive Statistics", "Regression".

12. **Course**
    - **Definition**: A unit of study within the curriculum that includes a set of topics and learning activities.
    - **Example Instances**: Microeconomics, Foundations of Programming.

13. LearningActivity
    - **Definition**: Activities designed to support the learning process of students.
    - **Example Instances**: project-based learning, internship.

14. **Assessment**
    - **Definition**: Procedures or tools used to measure achievement of learning outcomes.
    - **Example Instances**: Project presentation, written test.

15. PerformanceIndicator
    - **Definition**: Specific criteria used to evaluate skills or knowledge achievement.
    - **Example Instances**:

16. **LearningDomain**
    - **Definition**: Domains of learning that define the focus of learning outcomes, such as cognitive, affective, or psychomotor domains.
    - **Sublass**: CognitiveDomain, AffectiveDomain, PsychomotoricDomain

17. **AffectiveDomain**
    - **Definition**: The domain addresses emotions and feelings, often expressed as reactions to events, objects, or situations.
    - **Instances**: based on Pierce-Gray's taxonomy (2013), categorizes affective responses in six levels: *perceive, react, conform, validate, affective judge,* and *effective create*.

18. **CognitiveDomain**
    - **Definition**: The domain involving thinking skills and understanding of concepts.
    - **Example Instances**: Based on Revised Bloom's Taxonomy by Anderson and Krathwohl (2001) includes *remember, understand, apply, analyze, evaluate,* and *create* (abbreviated as C1 to C6 in this paper)

19. **PsychomotoricDomain**
    - **Definition**: The domain focused on physical skills and motor coordination.
    - **Example Instances**: Pierce-Gray's taxonomy (2013), structured in six levels: *psychomotor perceive, activate, execute, maneuver, psychomotor judge,* and *psychomotor create*.

Table 4. outlines the data properties associated with each class in the Outcome Based Curriculum ontology, specifying essential attributes for each entity within the curriculum structure. For instance, the StudyProgram class includes properties such as spName (the name of study program), degreeLevel, awardedDegree, vision, and mission, capturing fundamental program details. Similarly, the Curriculum class is characterized by properties like curriculumName, curriculumCode, currStartDate, and totalCredit, which define the identity and timeline of the curriculum. The Course class has data properties such as courseName, courseCode, credit, and courseType, providing critical details for each course offered within the program. Additionally, classes such as CurriculumReference, NationalQualityFramework, and LearningOutcome include attributes to capture accreditation, quality standards, and learning expectations, respectively. These data properties ensure that each class within the ontology can represent precise information, facilitating detailed analysis and alignment with the Outcome Based Education (OBE) framework's requirements.

This ontology consists of some enumerated classes. In the context of ontology, an **enumerated class** is a class that has a finite and explicitly defined set of instances or members. This means that all possible instances of the class are known and listed, rather than being defined by a set of properties or conditions. Enumerated classes are particularly useful for representing categorical or predefined values, such as specific learning outcomes or knowledge categories, as seen in the classes LearningOutcome and KnowledgeCategory in Table 5. By listing these instances directly, enumerated classes enable precise and controlled representations within the ontology, ensuring consistency and clarity when categorizing or analyzing specific concepts.

Table 4. The Class and Its Datatype Properties

Class	**Datatype properties**
StudyProgram	programName, degreeLevel, awardedDegree, programVision, programMission
Curriculum	curriculumName, curriculumStartDate, totalCredit
Course	courseName, courseCode, credit, courseType
ProgramEducationalObjective	label, description
AccreditationOrganization	accreditationName, fieldOfApplication, organizationWebsite, country, accreditationScope
ReferenceDocument	documentTitle, documentType, publishedYear, issuedBy, documentVersion, url
NationalQualityFramework	label, nqfLevel, nqfElement, description
LearningOutcome	label, description
CourseLearningOutcome	condition, action, content, criteria
TeachingLearningActivity	activityName, activityType, learningMethod

MediaOrTechnology	mediaName, mediaType, mediaFeature
Assesment	assesmentMethod, assesmentType
PerformanceIndicator	label, description

Table 5. Enumerated Class and Its Instance

Class	Instance
CognitiveDomain	C1_Remember, C2_Understand, C3_Apply, C4_Analyse, C5_Evaluate, C6_Create
AffectiveDomain	A1_Perceive, A2_React, A3_Conform, A4_Validate, A5_Affective_Judge, A6_Affective_Create
PsychomotoricDomain	P1_Psychomotor_Perceive, P2_Activate, P3_Execute, P4_Manoeuvre, P5_Psychomotor Judge, P6_Psychomotor_Create
KnowledgeCategory	Factual, Conceptual, Procedural, Metacognitive

Figure 2 represents the class and object properties, the big picture of OBC ONTO. Table 6 describes the object properties that define relationships among classes within the Outcome Based Curriculum (OBC) ontology. For example, a **StudyProgram** is linked to a **Curriculum** through the property hasCurriculum, indicating that each program includes one or more curricula, while the inverse relationship belongsToSP signifies the curriculum's association with its study program. Learning outcomes are organized hierarchically: **ProgramLearningOutcomes** encompass **SubProgramLearningOutcomes** and **CourseLearningOutcomes** through the hasPart and partOf relationships, illustrating a breakdown from program-level to course-specific goals. Furthermore, each **LearningOutcome** is associated with specific learning domains—cognitive, affective, or psychomotor—using properties such as hasCognitiveDomain, which categorizes competencies across different learning dimensions. These object properties ensure coherence and support the ontology's role in defining structured educational goals and requirements across various curriculum components.

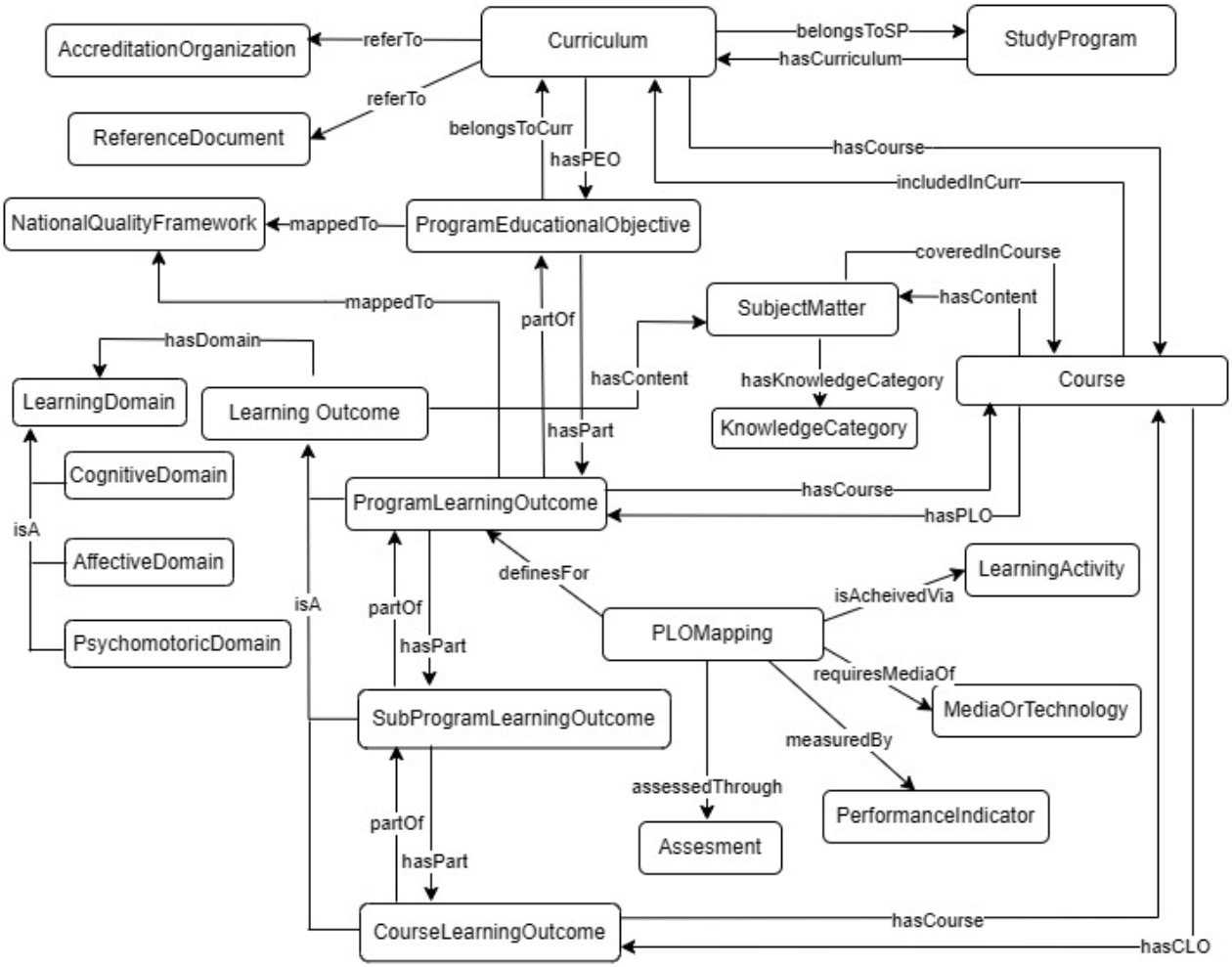

Figure 2. Class and Object Properties of OBC ONTO

Table 6. Object Properties

Object properties	**Domain**	**Range**
hasCurriculum	StudyProgram	Curriculum
belongsToSP	Curriculum	StudyProgram
referTo	Curriculum	ReferenceDocument
referTo	Curriculum	AccreditationOrganization
hasPEO	Curriculum	ProgramEducationalObjective
belongsToCurr	ProgramEducationalObjective	Curriculum
belongsToCurr	ProgramLearningOutcome	Curriculum

hasPLO	Curriculum	ProgramLearningOutcome
hasCourse	Curriculum	Course
includedInCurr	Course	Curriculum
hasPart	ProgramEducationalObjective	ProgramLearningOutcome
part of	ProgramLearningOutcome	ProgramEducationalObjective
hasPart	ProgramLearningOutcome	SubProgramLearningOutcome
part of	SubProgramLearningOutcome	ProgramLearningOutcome
hasPart	ProgramLearningOutcome	CourseLearningOutcome
part of	CourseLearningOutcome	ProgramLearningOutcome
hasPart	SubProgramLearningOutcome	CourseLearningOutcome
part of	CourseLearningOutcome	SubProgramLearningOutcome
ploHasCourse	ProgramLearningOutcome	Course
hasPLO	Course	SubProgramLearningOutcome
hasDomain	LearningOutcome	LearningDomain
hasContent	LearningOutcome	SubjectMatter
hasKnowledgeCategory	SubjectMatter	KnowledgeCategory
mappedTo	ProgramEducationalObjective	NationalQualityFramework
mappedTo	ProgramLearningOutcome	NationalQualityFramework
definesFor	PLOMapping	ProgramLearningOutcome
isAchievedVia	PLOMapping	LearningActivity
requiresMediaOf	PLOMapping	MediaOrTechnology
measuredBy	PLOMapping	PerformanceIndicator
assessedThrough	PLOMapping	Assesment
prerequisiteOf	Course	Course
hasContent	Course	SubjectMatter
SubjectMatter	coveredInCourse	Course

G. Ontology Implementation in OWL (Web Ontology Language) using Protégé

The Web Ontology Language (OWL) is chosen for implementing ontologies because it is specifically designed to model complex relationships between concepts in a structured and machine-readable format. OWL supports defining classes, properties, and constraints that allow for precise representation of domain knowledge, making it highly suitable for applications that require semantic understanding rather than mere data presentation. Furthermore, OWL's compatibility with RDF and XML allows it to link data across diverse sources, thus supporting integration and interoperability across systems.

The OWL implementation was conducted using the Protégé, a free and open-source OWL editor and framework for building intelligent systems that has been widely adopted by academics and ontology engineers globally.

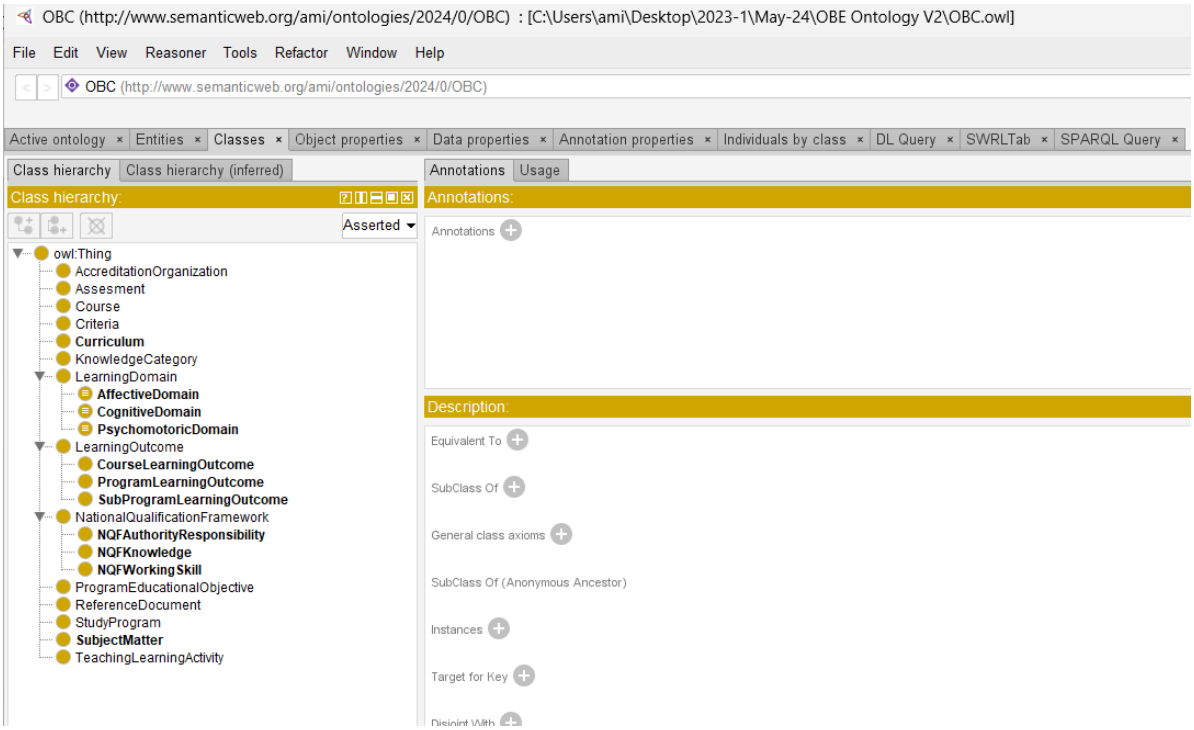

Figure 4. Example of Class Definition in Protégé

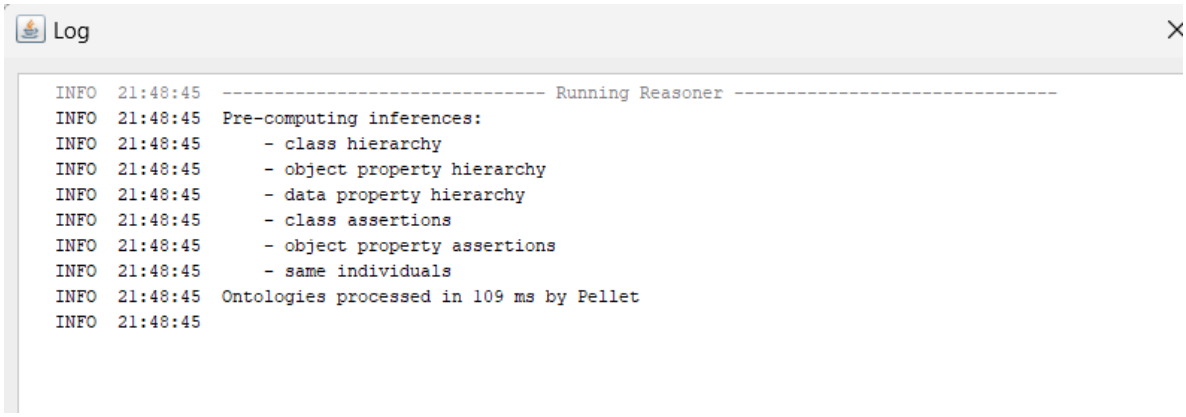

Figure 5. Reasoning with Pellet Reasoner in Protégé

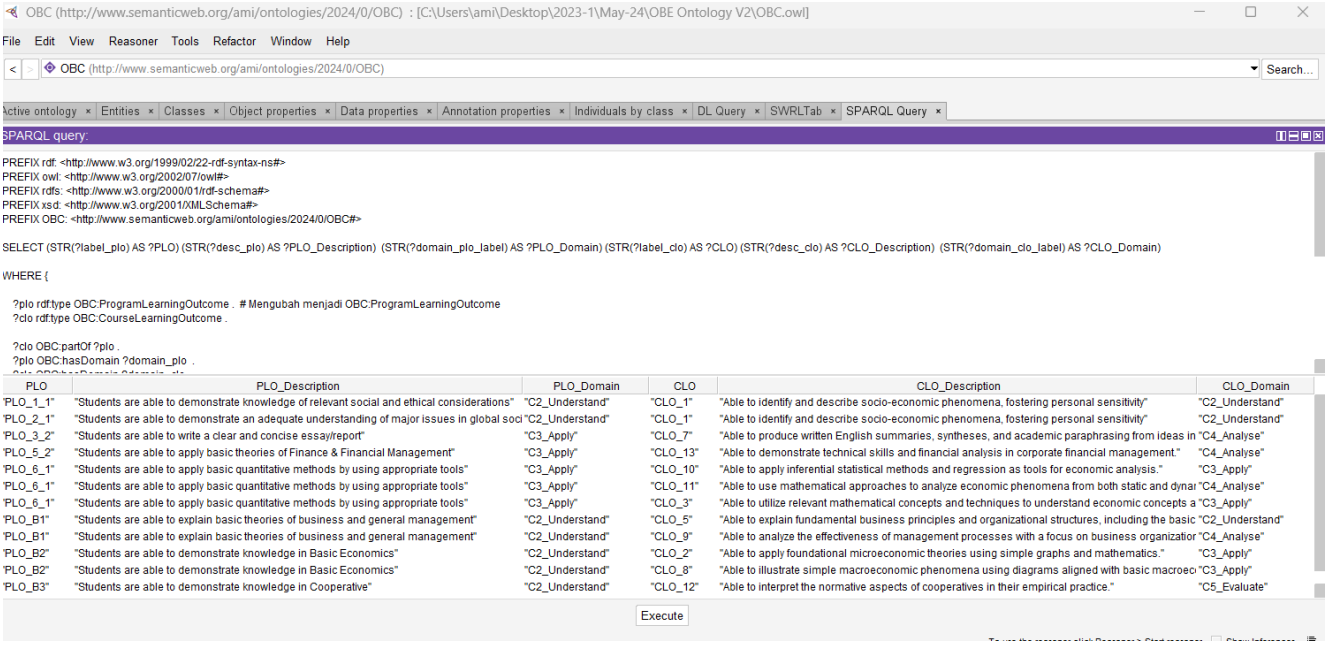

Figure 5. Example of SPARQL Query to Answer Competency Question in Protégé.