PhyOnto: An Ontology based Framework for Educational Physics Units and Measurements

Catherine Hii Seng Jing
University of Malaysia Sarawak (UNIMAS)
Jln Datuk Mohammad Musa,
94300 Kota Samarahan, Sarawak

Bong Chih How
University of Malaysia Sarawak (UNIMAS)
Jln Datuk Mohammad Musa,
94300 Kota Samarahan, Sarawak

ABSTRACT
The study of physics plays a fundamental role in understanding the natural world and its complex phenomena. To support accurate representation and computation of physics knowledge, digital ontologies have been developed. This paper presents a comprehensive physics ontology, PhyOnto, which captures domain knowledge related to units and measurement tools – critical elements in physics education and calculation. The ontology is constructed using the Web Ontology Language (OWL) within Protégé, following the “101 method” for ontology development. A series of rigorous evaluations, including taxonomy assessment, competency question validation, and content review, were conducted to establish its reliability and completeness. PhyOnto demonstrates strong potential in supporting physics education and question-answering systems by enabling structured knowledge representation for calculation-based reasoning.

General Terms
Ontology, Physics

Keywords
Ontology, physics, education, calculation

1. INTRODUCTION
STEM, which stands for Science, Technology, Engineering, and Mathematics, promotes interdisciplinary learning in science-related disciplines across all education levels.

Among the core sciences, physics holds a central position in fostering critical thinking and problem-solving skills, particularly for students pursuing careers in scientific and technical domains.

In the context of the ongoing industrial revolution, physics continues to offer numerous career pathways, while also enhancing one’s understanding of the structure and behavior of matter and natural phenomena.

Ontology refers to a structured conceptualization that defines relationships within a domain and has been widely used in fields such as medicine [1], herbal plants [2], history [3], and music [4].

Ontologies also serve as foundational knowledge bases for intelligent systems, including question-answering systems (QAS). In educational contexts, ontologies support curriculum design and content delivery by enabling structured, knowledge-guided learning.

Multiple approaches have been explored for capturing knowledge in physics, one of which involves developing ontologies to represent semantic structures within the domain.

This paper introduces PhyOnto, a domain-specific ontology that models physics knowledge centered around units and measurement tools.

The ontology was developed using the “101 method” [5], implemented in the Web Ontology Language (OWL) [6], and constructed with the Protégé platform [7].

PhyOnto was evaluated through competency question analysis, ontology content review, and taxonomy verification to confirm its validity and applicability.

The evaluations indicated positive outcomes regarding its structural soundness and utility.

The remainder of the paper is organized as follows: Section 2 presents the related works; Section 3 outlines the motivation for PhyOnto; Section 4 describes the development methodology; Section 5 discusses the implementation; Section 6 details the evaluation process; Section 7 analyzes and discusses the results; and Section 8 concludes the paper and outlines directions for future work.

2. RELATED WORKS
A review of the existing literature on physics ontologies reveals a limited number of relevant works. To ensure novelty and avoid redundancy, it is necessary to identify whether ontologies for the same domain already exist before commencing ontology development.

Three significant studies were identified as being closely related to the present work: Collins and Clark [8], Lewis [9], and Cvjetkovic [10]. These ontologies cover subfields such as kinematics and dynamics, quantum theory, and physical quantities, respectively.

Collins and Clark [8] developed an ontology to support the Synthetic Environment Data Representation and Interchange Specification (SEDRIS), focusing on model dynamics and their progression over time. This ontology emphasized the relationship between statics representations and dynamic physical models, particularly through differential equations. However, it lacks coverage of a comprehensive set of physics equations.

Lewis [9] proposed a quantum physics ontology that explored foundational metaphysical issues, including supervenience, space, causation, and determinism. While offering a rich semantic framework for quantum mechanics, it remains limited to theoretical analysis without practical implementation and suffers from the problem of underdetermination by evidence.

Cvjetkovic [10] introduced an ontology to support web-based symbolic computation in physics. This work focuses on modeling the hierarchical relationships among physical quantities and supports the visualization and calculation of physics equations online. However, it does not incorporate unit-based relationships, limiting its utility in measurement-based reasoning.

A summary of these works is presented in Table 1.

Table 1. Summary of literature review

Authors	Objectives	Methodology	Key Findings	Limitations
Collins and Clark [9]	To address model dynamics in SEDRIS using ontology	Analysis of model dynamics and equations, ontology development	Successful representation of physical dynamics aids in selecting dynamical models	Limited coverage of physics equation
Lewis [10]	To describe different interpretations of quantum mechanics	Theoretical analysis, ontology development	Highlighted the problem of underdetermination in quantum ontologies	Limited to quantum physics, no practical implementation
Cvjetkovic [11]	To model relationship among physical quantities	Web application development, ontology design	Captured hierarchy of physical quantities and facilitated physics equations and calculations	No inclusion of units, limited scope to relationship modeling

Table 1 demonstrates that formalized knowledge representations in physics remain fragmented or incomplete. Existing ontologies tend to focus on specific subdomains and omit critical elements such as measurement units and comprehensive formula coverage. These limitations highlight the need for a unified and scalable ontology that integrates both physical quantities and their associated units and tools. PhyOnto aims to address these gaps by providing a domain-specific, semantically rich ontology tailored to physics education and computation.

3. MOTIVATION

The analysis of existing literature confirms a clear gap in the development of comprehensive physics ontology. The primary motivation behind PhyOnto is to establish a structured semantic model that captures physics knowledge based on its units and measurement instruments.

PhyOnto is intended to assist in solving calculation-based physics questions by enabling unit recognition and semantic reasoning. Additionally, PhyOnto contributes to the development of PhyQA, an ontology-based question-answering system designed to support inference-driven solutions for physics problems.

4. DESIGN AND DEVELOPMENT OF PHYONTO

There are many methods used to develop ontologies, such as Skeletal methodology [11], Tove process [12], and Methontology [13]. For this work, the “101 method” proposed by Noy and McGuinness [5] was selected due to its clarity, simplicity, and suitability for beginners. This method consists of seven well-defined steps, as illustrated in Fig 1. The process of explaining the seven steps is further detailed in the subsequent subsections

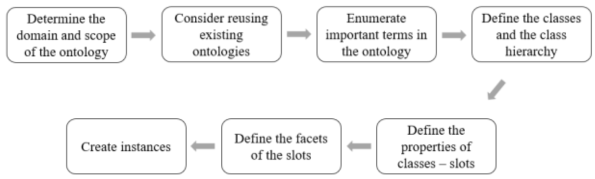

Fig 1: The processes of 101 method ontology development [5]

4.1 Determine the domain and the scope of the ontology

The ontology focuses on the domain defined by the Sijil Pelajaran Malaysia (SPM) syllabus, a national examination framework equivalent to the General Certificate of Secondary Education (GCSE) or O-Level qualifications. The subject of physics is emphasized within the Malaysian curriculum due to its relevance in science and engineering pathways.

In constructing the ontology, the scope was defined by referencing content from SPM Physics Form 4 and Form 5 textbooks [14, 15]. One effective method to establish the ontology’s scope is to outline competency questions as the initial step. These questions serve as a list of inquiries that can be resolved utilizing the ontology and are vital validating that every concept within the ontology is accounted for. Competency questions are sourced from textbooks without alternations, and only those solvable through calculation are considered. Within the appendices lies a set of competency questions covering the primary concepts within PhyOnto. These questions are reviewed to determine if the ontology contains sufficient information to answer them or if specific details are required.

4.2 Consider reusing existing ontologies

A comprehensive review of existing literature revealed that no available ontologies adequately fulfil the requirements of this study. The objective is to construct a domain-specific ontology that captures the semantic structure of physics through its units and measurement instruments. Such an ontology supports the resolution of calculation-based physics problems by enabling recognition and reasoning over relevant physical units.

4.3 Enumerate important terms in the ontology

Key terms were systematically extracted from the content of the selected physics textbooks. The process began with an analysis of the table of contents to identify core topics and subtopics. From this foundation, nouns were mapped to potential ontology classes, while verbs and related actions were evaluated as object properties. A summarized list of the extracted concepts – such as units, physical quantities, applications, and measurement tools – is presented in Table 2.

Table 2. Important terms in the ontology

Items	Basic terms
1	Unit
2	SI unit
3	Physical quantity

4	Base quantity
5	Derive quantity
6	Application
7	Measurement tool

4.4 Define the classes and the class hierarchy

The subsequent step in ontology construction involves defining and organizing the class hierarchy. For example, the concept of "Physical Quantity" is structured as a superclass, encompassing two subclasses: "Base Quantity" and "Derived Quantity". This hierarchical relationship allows the ontology to represent domain knowledge in a modular and extensible manner. The structure is visualized in Fig 2.

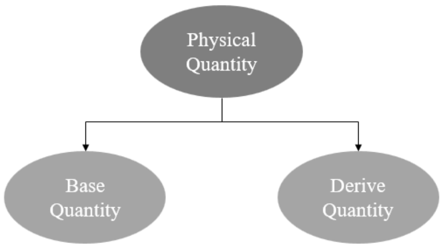

Fig 2: The class hierarchy of the "Physical Quantity" class

4.5 Define the properties of classes – slots

Table 3 outlines the core object properties defined in PhyOnto: "hasUnit", "hasSIUnit", "hasMeasurementTool", and "hasApplication". Each property enables the semantic representation of how physical quantities relate to their measurable aspects and real-world applications.

Table 3. Table captions should be placed above the table

Concepts	**Properties**	**Explanation**
Unit	*hasUnit*	To determine the units of a specific physical quantity, it is necessary to establish a standard unit of measurement. Using standard units of measurement is important for comparing and communicating physics quantities accurately. They provide consistency and uniformity, and meters are commonly used as a standard unit for length.
SI Unit	*hasSIUnit*	To define the SI unit of the physical quantity. The SI system employs seven fundamental units for quantifying diverse physical parameters, guaranteeing uniformity and conformity in scientific measurements.
Measurement Tool	*hasMeasurementTool*	To define the measurement tools which can measure physical quantities. Measurement tools are used to measure physical quantities accurately and reliably. Each tool must be precise, accurate, and have limitations. Calibration and quality control help keep accuracy and traceability.
Application	*hasApplication*	To define the application applied to the physical quantities. Physical quantities describe the behavior of objects or systems, such as velocity and time in motion studies. Units, formulas, and relationships are important for understanding them.

In physics, all formulas must explicitly include units for clarity and consistency. The "hasUnit" property is used to identify the specific units involved in a physical formula. For example, the heat equation is $Q = mc\Delta T$, where Q stands for Heat in Joules (J), m represents mass in kilograms (kg), c represents specific heat capacity in Joules per Kelvin per kilogram (J kg-1 K-1), and ΔT represents the change in temperature in Kelvin (K). These units collectively enable accurate reasoning about heat transfer. The conceptual relationship among these quantities is illustrated in Fig 3.

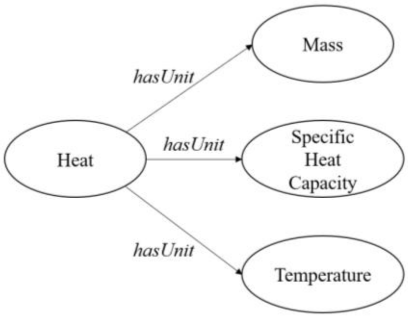

Fig 3: The relationship between heat, mass, specific heat capacity, and temperature

The "hasSIUnit" property is an object that determines the appropriate International System of Units (SI units) for a given physical quantity, namely length, mass, time, thermodynamic temperature, electric current, luminous intensity, and amount of substance, each with its own SI unit. For example, the SI unit for Heat is Joule (J). This is represented as "Heat hasSIUnit J" in Figure 4.

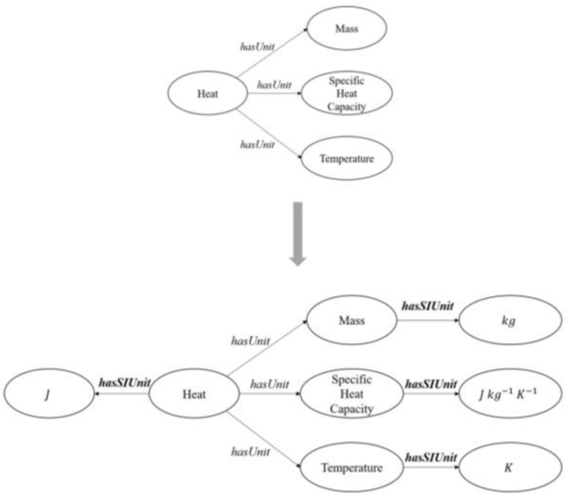

Fig 4: The "hasSIUnit" property

The "hasMeasurementTool" property accurately refers to a physical quantity that can be measured using one or more tools. For example, Choy et al.'s reference book explains that heat energy can be exchanged between two objects and measured using a thermometer [13]. This concept is depicted in Fig 5 of the ontology.

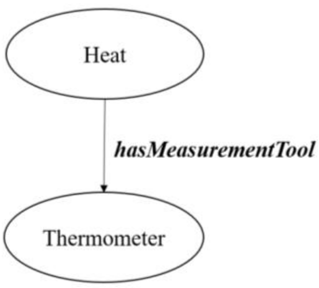

Fig 5: The heat with the property of "hasMeasurementTool"

The attribute "hasApplication", when utilized in the field of physics, plays a vital role in identifying the practical implementation of a given principle or law. One such example of this can be seen in utilizing heat capacity, defined as an object's ability to retain heat. The specific heat capacity, which measures the amount of heat energy required to raise the temperature of a unit mass of a substance by one degree Celsius, is used in various contexts including the design of cooking utensils, such as metal woks or clay pots, automotive radiator system, and the scientific phenomena of sea and land breezes [13]. With its widespread application in different fields, the concept of heat capacity is an essential aspect of studying physics.

Table 4 provides a comprehensive and detailed overview to show the interconnections between the different attributes and concepts associated with the "Heat" instance.

Table 4. Table captions should be placed above the table

Concept Name	Instance Name	Property	Value
Derived Quantity	Heat	hasUnit	Mass
			Specific Heat Capacity
			Temperature
		hasSIUnit	Joules (J)
		hasMeasurementTool	Thermometer
		hasApplication	Cooking utensils
			Car radiator system
			Sea breeze and land breeze

4.6 Define the facets of the slots

In ontology modeling, a slot defines a property that characterizes the relationship between a class and its values. Each slot may include facets that specify constraints such as the value type, cardinality, and permitted classes.

For example, the "hasUnit" property can accept multiple values, each corresponding to an instance of the "Unit" class. This facet ensures that only appropriate unit instances are associated with physical quantities. By formally defining these slot characteristics, the ontology maintains semantic precision and supports consistent data reasoning.

4.7 Create instances

The final step in ontology development involves instantiating classes with individual entities. For each class in the hierarchy, specific instances are created, and their associated slots are assigned values according to the ontology structure. For example, the "Derived Quantity" class includes an instance labeled "Heat", which is assigned properties such as "hasUnit", "hasSIUnit", and "hasMeasurementTool". These assignments establish semantic relationships between quantities and their corresponding attributes.

Table 3 (previously presented) outlines the critical concepts and associated properties during this stage.

These steps complete the seven-phase methodology described by Noy and McGuinness [5]. Following instance creation, the ontology was implemented using Protégé [7]. The next section provides details on this implementation process.

5. IMPLEMENTATION OF PHYONTO

PhyOnto was implemented using the Web Ontology Language (OWL) and the Protégé ontology editor. OWL provides a formal framework for encoding ontological structures and supporting reasoning tasks, while Protégé offers a user-friendly interface for constructing, visualizing, and managing ontology components.

The seven-step development methodology proposed by Noy and McGuinness [5] was effectively supported through Protégé toolset. The implementation process began with the definition of classes and their hierarchical structure, followed by the specification of object properties and instances.

Protégé supports exporting ontologies in OWL and Resource Description Framework Schema (RDFS) formats, facilitating interoperability with other semantic tools. Additionally, built-in validation tools and reasoners allow for real-time ontology verification and consistency checking [15].

A visual representation of the constructed ontology in Protégé is shown in Fig 6.

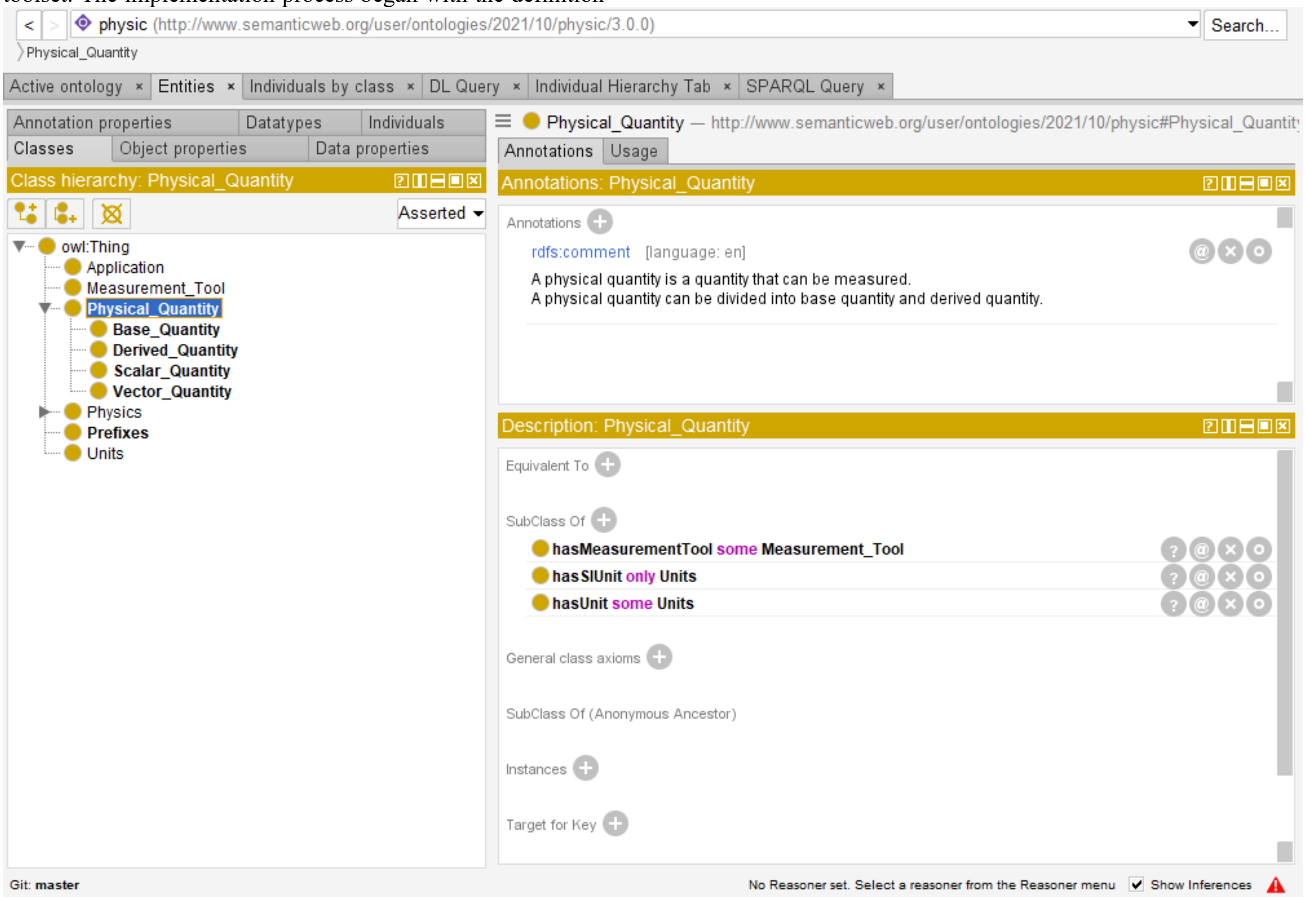

Fig 6: The snapshot of PhyOnto from Protégé

There are 9 classes, 4 object properties, 153 individuals, and 704 axioms included in PhyOnto. It is available for sharing on GitHub (https://github.com/CatherineHsj/PhyOnto.git). SPARQL can be used to retrieve knowledge from PhyOnto, which is the standard language for querying RDFS data. With Protégé, users can easily construct and execute SPARQL queries through its user interface.

The following is a SPARQL query that retrieve the units embedded in the formula Q = mcΔT used in heat calculations. The query includes two variables, ?physicalQuantity and ?Unit, and two properties: "hasUnit" and "hasSIUnit". The query results in the identification of three physical quantities, along with their respective SI units.

$$SELECT\ ?physicalQuantity\ ?Unit\ WHERE\{ \\ physics: hasUnit\ ?Unit?. \\ physicalQuantity\ physics: hasSIUnit\ ?Unit\}$$

[SPARQL Query 1]

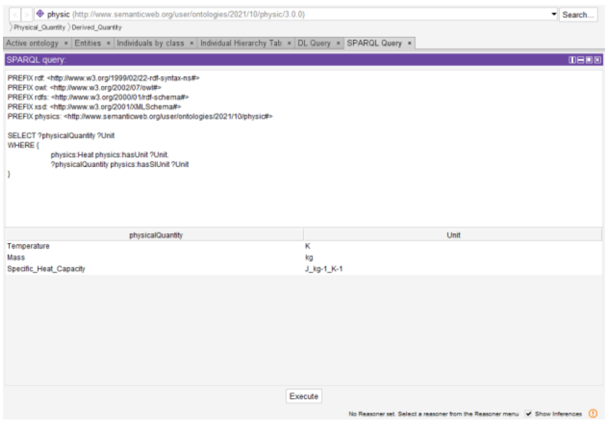

Fig 7: The result of the SPARQL query

The values for "mass", "temperature", and "specific heat capacity" are included in the query output, along with their units. Mass measures the amount of matter and is in kilograms. Temperature measures particle energy and is in Kelvin.

Specific heat capacity measures heat energy needed to raise the temperature and is in J/(kg·K). It is crucial to use the correct units for accurate calculations and discussions.

6. SECTIONS

Ontology evaluation is a critical phase in ontology engineering, ensuring the accuracy, consistency, and usability of the model prior to public release. As described by Fernández-López et al. [16], this process involves the technical assessment of the ontology, its software environment, and accompanying documentation across various stages of its lifecycle.

Evaluation consists of two primary components: ontology validation and ontology verification [17, 18]. Validation determines whether the ontology has been constructed correctly, while verification assesses whether the ontology effectively captures the intended domain knowledge.

For PhyOnto, validation was conducted using two methods: content evaluation and competency question analysis. Verification was performed through taxonomy evaluation, focusing on three key aspects – inconsistency, incompleteness, and redundancy – which are discussed in the following section.

6.1 PhyOnto validation

According to Gómez-Pérez [17], ontology validation ensures that the ontology accurately represents the intended domain context. For PhyOnto, validation was conducted through two main approaches: (i) ontology content evaluation, and (ii) competency question testing.

Table 5 presents the criteria used to assess the quality of PhyOnto, including consistency, completeness, conciseness, expandability, and sensitivity. These criteria were evaluated using the Protégé reasoner HermiT [19].

For instance, during the validation process, it was determined that the “Thermometer” instance was incorrectly categorized under the “Unit” class. This misclassification was corrected to ensure semantic accuracy. Reflecting the ontology’s sensitivity to structural refinements.

By addressing these five criteria, ontology maintains its integrity and scalability while remaining adaptable to future domain changes.

Table 5. Table captions should be placed above the table

Criteria	Satisfaction
Consistency	PhyOnto meets the consistency standard, as it ensures that no inconsistent information can be derived from its definitions and axioms. By utilizing the powerful Protégé reasoner, specifically the HermiT reasoner, any errors or inconsistencies in the ontology can be detected and addressed, thereby ensuring its coherence.
Completeness	Based on the specification determined by using the prepared resources, the ontology has a complete set of units and measurement tools. This guarantees that all instances are fully defined, and no mission definitions are in the ontology, meeting the completeness criterion.
Conciseness	PhyOnto is highly efficient in answering SPARQL queries as it only includes necessary concepts and avoids redundant definitions. This ensures that the retrieval of answers is quick and concise. Additionally, ontology satisfies the conciseness criterion by eliminating unnecessary concepts, allowing for a streamlined and effective approach to answering competency questions.
Expandability	The established properties in the ontology remain intact even as new units or measurement tools are added, making it easy to expand the ontology without altering its well-defined structure. This feature enables ontology to keep up with new information and discoveries, ensuring its growth and relevance over time.
Sensitiveness	One of the key benefits of PhyOnto is its ability to maintain consistency even when small changes are made to the definitions of concepts. This is due to its robustness, which allows for minor modifications without compromising the overall structure and coherence of the ontology.

6.1.1 Competency Question Evaluation

The scope and design objectives of PhyOnto were evaluated using a set of competent questions. These questions derived from the ontology’s core components were used to generate formal queries and validate the ontology’s capacity to support physic problem-solving. The answers produced through ontology reasoning were cross-referenced with those found in standard physics textbooks, and full justifications are provided in the Appendix.

Competency questions serve as a means of verifying that the ontology aligns with its intended purpose – namely to address calculation-based physics problems using structured semantic knowledge.

For example, in Competency Question 2 (CQ 2), the problem involves determining the pressure of compressed air, given the initial and final volume (60 cm³ and 48 cm³) and an initial pressure of 108 kPa. Using PhyOnto, a SPARQL query is dynamically generated to retrieve physical quantities associated with the provided units. Based on the matched units (volume in cm³ and pressure in kPa), the system correctly identifies Boyle’s Law as the applicable equation. This demonstrates PhyOnto’s ability to infer the correct physics formula based on unit-driven reasoning. The following shows the SPARQL query used to the CQ2.

$$SELECT\ ?physicalQuantity\ ?Unit\ WHERE\ \{$$
$$?physicalQuantity\ physics{:}hasUnit\ ?Unit.$$
$$?Unit\ rdfs{:}seeAlso\ ?z\ FILTER\ (?z\ = \textbf{ITEM})$$
$$\}\ ORDER\ BY\ ?physicalQuantity$$

[SPARQL Query 2]

In this query, “ITEM” represents the units extracted from the question. For CQ2, the provided values include 60 cm³,48 cm³, and 108 kPa. Based on these units, the ontology returns all physical quantities that are associated with volume and pressure. The system identifies Boyle’s Law as the applicable equation for this scenario.

Boyle’s Law is expressed as:

$$P_1V_1 = P_2V_2$$

Where P denotes pressure (SI unit: pascal, Pa) and V denotes volume (SI unit: cubic meter, m³).

Through unit-based reasoning, the ontology correctly derives the appropriate physical relationship, demonstrating its effectiveness in formula selection for calculation-based physics problems.

6.2 PhyOnto verification: ontology taxonomy evaluation

Verification of PhyOnto was performed using taxonomy evaluation approach, guided by the framework proposed by Gómez-Pérez [17]. This process assessed the structural soundness of the ontology using Protégé built-in reasoning tools. The three primary criteria for verification are: inconsistency, incompleteness, and redundancy. The results are summarized in Table 6.

Inconsistency is identified through circularity errors, partitioning issues, and semantic contradictions. The Protégé reasoner was used to detect and correct incorrect subsumption relationships, ensuring logical coherence within the ontology.

Incompleteness refers to the absence of essential concepts or improper classification within the ontology. The issue was mitigated by fully defining the class hierarchy in accordance with domain requirements, as detailed in Section 4.

Redundancy involves the presence of duplicate or semantically overlapping definitions. Each class and instance in PhyOnto were reviewed to confirm uniqueness, eliminating redundancy and ensuring clarity.

The evaluation confirmed that PhyOnto is consistent and non-redundant thereby meeting the structural quality standards required for ontology deployment.

6.2.1 Competency Question Evaluation

The heading for subsubsections should be in Times New Roman 11-point italic with initial letters capitalized and 6-points of white space above the subsubsection head.

Table 6. Table captions should be placed above the table

Criteria	Satisfactory
Inconsistency	PhyOnto is highly reliable as it remains consistent even with minor alterations in the definition. This robustness ensures that the overall structure and coherence of the ontology remain unaffected.
Incompleteness	The ontology’s knowledge outlined in Section 4.2 has been fully defined within PhyOnto. Each class and corresponding subclass have been properly defined, ensuring that there are no incomplete concept classifications. Moreover, all base classes have been accurately categorized, without any imprecise or over-specified classes present within the ontology.
Redundancy	PhyOnto ensures that each class has only one definition, eliminating any grammatical redundancies. Additionally, there are no instances or classes with identical formal definitions, meaning that there are no duplicate definitions within the ontology.

7. DISCUSSION

PhyOnto has demonstrated high reliability and trustworthiness, successfully fulfilling all criteria outlined by [17] for verifying the taxonomy of an ontology. By utilizing the HermiT reasoner in Protégé, PhyOnto achieved logical consistency, completeness, and the removal of redundancies, thereby ensuring its quality and effectiveness for its intended applications.

A comprehensive testing process was conducted using a variety of validation and verification techniques to ensure adherence to the required standards. Competency questions were instrumental in evaluating the ontology’s performance, serving as benchmarks to assess its accuracy and relevance. For instance, when posed with a question concerning a specific measurement—such as the acceleration of a car—PhyOnto accurately identified the corresponding unit (m/s^2) and provided a valid response supported by a reasoned explanation.

The ontology taxonomy assessment further confirmed the ontology’s consistency, completeness, and conciseness. No violations or inconsistencies were identified during the verification process, indicating that PhyOnto satisfies all specified requirements.

These evaluation techniques provide assurance regarding the accuracy and reliability of PhyOnto as a source of physics-related information. Moreover, the implementation of SPARQL (SPARQL Protocol and RDF Query Language) enables efficient querying and retrieval of relevant information, thereby enhancing the ontology's usability and applicability across diverse physics-related domains.

In conclusion, PhyOnto serves as a robust and dependable ontology, suitable for various applications in the field of physics. Its structured development, rigorous validation, and successful performance evaluation affirm its value as a comprehensive knowledge base for researchers, educators, and professionals seeking accurate physics-related information.

8. CONCLUSION AND FUTURE WORKS

PhyOnto is an ontology for physics that has been developed and evaluated to capture the semantic knowledge of the domain, specifically focusing on units and measurement tools. Its primary objective is to facilitate the resolution of calculation-based questions. The limited availability of physics-specific ontologies and the potential contributions of PhyOnto to the discipline provided strong motivation for the creation of this specialized resource.

The development of PhyOnto followed the seven-step methodology outlined in the 101 Ontology Development Process. It was implemented using Protégé and is represented in the Web Ontology Language (OWL). Knowledge retrieval is facilitated through the use of SPARQL queries. For evaluation purposes, two validation methods and one verification method were applied, collectively demonstrating the successful construction and assessment of the ontology.

As a specialized addition to ontology repositories, PhyOnto offers a dedicated resource tailored to the physics domain. It enables more efficient problem-solving and serves as a foundational component for the development of physics-oriented question-answering systems. Given the scarcity of ontologies specifically designed for physics, the significance of this contribution is evident and may encourage further efforts in the development of domain-specific ontologies.

Future directions for research and development include expanding the ontology’s coverage of physics equations, incorporating additional subdomains, enhancing the integration of units and measurement tools, promoting interoperability with other ontologies, and refining the system’s question-answering capabilities. By pursuing these avenues, physics ontologies such as PhyOnto can remain adaptable, current, and instrumental in advancing knowledge and applications within the field.

9. ACKNOWLEDGMENTS

The main author would like to express sincere appreciation to Associate Professor Dr Bong Chih How for his exceptional mentorship, insightful guidance, and unwavering support throughout the development of this research. His contribution has been instrumental in shaping the direction and quality of this work. Gratitude is also extended to the Centre for Graduate Studies and the Faculty of Computer Science and Information Technology, University of Malaysia Sarawak, for their administrative and academic support.

10. REFERENCES

[1] Thukral, A., Dhiman, S., Meher, R., & Bedi, P. (2023). Knowledge graph enrichment from clinical narratives using NLP, NER, and biomedical ontologies for healthcare applications. International Journal of Information Technology, 15(1), 53–65. https://doi.org/10.1007/s41870-022-01145-y

[2] Tran, A. C., Tran, T. K., Nhut, N. M., & Long, N. H. V. (2023). Building a deep ontology-based herbal medicinal plant search system. International Journal of Information Technology, 15(4), 2209–2223. https://doi.org/10.1007/s41870-023-01250-6

[3] Bahadorani, B., & Zaeri, A. (2020). A method for using temporal reasoners to answer the history of science questions. International Journal of Information Technology, 12(1), 181–188. https://doi.org/10.1007/s41870-019-00373-z

[4] Kaur, N., & Aggarwal, H. (2021). Query reformulation approach using domain specific ontology for semantic information retrieval. International Journal of Information Technology, 13(5), 1745–1753. https://doi.org/10.1007/s41870-020-00464-2

[5] Noy, N. F., & McGuinness, D. L. (2001). Ontology development 101: A guide to creating your first ontology.

[6] McGuinness DL and Van Harmelen F. OWL web ontology language overview. W3C recommendation 2004; 10(10): 2004.

[7] Musen MA. The protégé project: a look back and a look forward. AI matters 2015; 1(4): 4–12.

[8] Collins JB and Clark D. Towards an ontology of physics. Naval Research Lab Washington DC, 2014.

[9] Lewis PJ. Quantum ontology: A guide to the metaphysics of quantum mechanics. Oxford University Press, 2016.

[10] Cvjetkovic V. Web physics ontology: online interactive symbolic computation in physics. In: 2017 4th Experiment@ International Conference (exp. at'17), June 2017, pp. 52-57, IEEE.

[11] Uschold M and King M. Towards a methodology for building ontologies. University of Edinburgh, 1995.

[12] Grüninger M and Fox MS. Methodology for the design and evaluation of ontologies, https://citeseerx.ist.psu.edu/viewdoc/summary?doi=10.1.1.44.8723 (1995, accessed 21 August 2022).

[13] Choy CS, Chuan KK, Beng OH, Mustafa MKAM and Ragavan R. Physics Form 4. Sasbadi Sdn Bhd, 2019.

[14] Chuan KK, Choy CS, Bongkek NR, Kasron J, Mustafa MKAM and Chakrabarty PK. Physics Form 5. Penerbit Bestari Sdn Bhd, 2020.

[15] Knublauch H, Horridge M, Musen MA, Rector AL, Stevens R, Drummond N, Lord PW, Noy NF, Seidenberg J, Wang H. The Protege OWL Experience. In Proceedings of the OWLED*05 Workshop on OWL: Experiences and Directions, 11-12 November 2005, Galway, Ireland.

[16] Fernández-López M, Gómez-Pérez A and Juristo N. Methontology: from ontological art towards ontological engineering. In: Proceedings of the Ontological Engineering AAAI-97 Spring Symposium Series, 24-26 March 1997, Stanford University, EEUU.

[17] Gómez-Pérez A. Ontology evaluation. In Handbook on ontologies. Springer, Berlin, Heidelberg., 2004, pp. 251-273.

[18] Vrandečić D. Ontology evaluation. In Handbook on ontologies. Springer, Berlin, Heidelberg., 2009, pp. 293-313.

[19] Glimm B, Horrocks I, Motik B and Stoilos G. Optimising ontology classification. In: International Semantic Web Conference, November 2010, pp. 225-240. Springer, Berlin, Heidelberg.

11. APPENDIX

A set of competency question answers and justification.

CQ	CQ Text	Responses	Justification
CQ 1	A car travels from a stationary position and reaches a velocity of 36 m/s in 8 seconds. What is the acceleration of the car?	Acceleration: Acceleration (ms^{-2}) = (Final velocity (m/s) - Initial velocity (m/s) / Time for the velocity change (s)	The equation correctly shows acceleration by subtracting the initial velocity from the final velocity and dividing it by the time taken for the velocity change. The acceleration unit is correctly stated as meters per second squared (m/s^2).
CQ 2	Air in a closed syringe has a volume of 60 cm^3 and a pressure of 108k Pa. The piston of the syringe is pushed to compress the air to a volume of 48 cm^3. Calculate the pressure of the compressed air.	Boyle's Law: P1(Pa) * V1(m^3) = P2(Pa) * V2(m^3)	The equation represents Boyle's Law, which states that the product of initial pressure and volume equals the product of the final pressure and volume. The units are not explicitly mentioned, but since the equation follows Boyle's Law, the pressure should be in pascals (Pa), and the volume should be in cubic meters (m^3).
CQ 3	An electric current of 50m A flows through a fan for 10 seconds. Calculate the total electric charge that passes through the fan in this period.	Charge: Charge (C) = Current (A) * time (s)	The equation correctly shows the total electric charge by multiplying the current in amperes (A) by the time in seconds (s). The unit of charge is correctly stated as coulombs (C).
CQ 4	Gas in a closed steel cylinder has a pressure of 180k Pa at a temperature of 25 °C. What is the gas pressure when the cylinder is heated to a temperature of 52 °C?	Gay-Lussac's_Law: P1(Pa) / T1(K) = P2(Pa) / T2(K)	The equation represents Gay-Lussac's Law, which states that the ratio of initial pressure to initial absolute temperature equals the ratio of final pressure to final absolute temperature. The equation correctly shows the gas pressure when the cylinder is heated. The units are not explicitly mentioned, but the pressure should be in pascals (Pa) and the temperature should be in kelvin (K).
CQ 5	A trolley P of mass 2 kg moving with a velocity of 5 m/s collided with a trolley Q of mass 5 kg moving with a velocity of 2 m/s in the same direction. Find the momentum of the system after the collision.	Momentum: Momentum ($kg\ m/s$) = mass (kg) * velocity (m/s)	The equation correctly shows the momentum of the system by multiplying the mass in kilograms (kg) by the velocity in meters per second (m/s). The unit of momentum is correctly stated as kilogram meters per second (kg m/s).
CQ 6	A school bus moves from rest with an acceleration of 2 ms^2 for 5 s. Calculate its velocity after 5 s.	Third_Linear_Motion: Displacement (m) = (Initial velocity (m/s) * time (s)) + 1/2(Acceleration (m/s^2) * time (s)) First_Linear_Motion: Final velocity (m/s) = Initial velocity (m/s) + (Acceleration (m/s^2) * Time taken for change of velocity (s))	Two equations are provided. The first equation represents the third linear motion equation, which calculates displacement. The second equation represents the first equation of linear motion, which calculates the final velocity. But the correct equation to solve the question is first linear motion.
CQ 7	Chan released a stone from a cliff of 10 m height. Determine(a) the time taken for the stone to reach the bottom of the cliff and (b) the velocity of the stone just before it touches the ground Ignore air resistance. [g = 9.81 ms^{-2}]	Liquid_Pressure: P=hρg, where P = pressure, h = depth of the liquid, \\rhoρ = density, g = gravitational acceleration Fourth_Linear_Motion: (Final velocity (m/s))^2 = (Initial velocity (m/s))^2 + 2(Acceleration (m/s^2) * displacement (m))	Two equations are provided. The first equation represents the liquid pressure formula, which calculates pressure based on the depth of the liquid, density, and gravitational acceleration. The second equation represents the fourth equation of linear motion, which calculates the final velocity squared based on the initial velocity squared, twice the acceleration, and displacement. But the correct equation to solve the question is fourth linear motion.
CQ 8	Encik Nizam drives a car at a speed of 108 kmh^{-1}. Suddenly he sees a car	Centripetal_Acceleration: Centripetal Acceleration (m/s^2) =	The equation provided incorrectly mentions centripetal acceleration,

	in front moving very slowly. Therefore, Encik Nizam slows down his car to a speed of 72 kmh^{-1}. The displacement made by the car is 125 m. If the acceleration of the car is uniform, calculate the acceleration of Encik Nizam's car	(Linear speed of satellite (m/s))^2 / radius of the orbit of satellite (m)	which is not applicable in this context. The question is about the acceleration of Encik Nizam's car, which is not related to circular motion or satellite orbits.
CQ 9	45000 J of heat energy raises the temperature of a 2 kg block of metal from 30 °C to 45°C. What is the specific heat capacity of the metal?	Specific_Heat_Capacity: Specific heat capacity ($J\ kg^{-1}\ K^{-1}$) = Quantity of heat supplied (J) / (mass (kg) * change of temperature (K or ℃))	The equation correctly shows specific heat capacity by dividing the quantity of heat supplied by the product of mass and change in temperature. The units of heat, mass, and temperature are mentioned correctly.
CQ 10	An iron block that has a volume 0.3 m^3 is immersed in water. Find the upthrust exerted on the block by the water. [Density of water = 1000 kg/m^3]	Archimedes_Principle: Buoyant Force (N) = Density of fluid (kg/m^3) * Volume of the displaced fluid (m^3) * Acceleration due to gravity (m/s^2)	The equation provided correctly represents Archimedes' Principle, which shows the buoyant force by multiplying the density of the fluid, the volume of the displaced fluid, and the acceleration due to gravity. The thickness, volume, and acceleration units due to gravity are mentioned correctly.