ONT-SLD: A DOMAIN ONTOLOGY FOR LEARNING DISABILITY

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Abstract - Knowledge-based technology with complete access to useful information is vital to support decision-making and solve complex problems in many areas such as management, medical, business, education and others. However, the domain of specific learning disabilities still suffers from the lack of explicit representation of knowledge and data modelling format through explicit format and standards such as RDF and OWL, which limits the effective sharing between experts and general users. Therefore, this article presents a novel domain ontology, called ONT-SLD, to formally conceptualize essential elements and rules, covering the characteristics of specific learning disabilities student and educational activities. During the ontology building, applicable standards and regulations have been extensively adopted. The proposed ontology model is evaluated in a real-world case to early identify a student with learning disabilities and recommend appropriate educational activities. Taxonomy evaluation is conducted using SPARQL to show the ontological model is able to detect any semantic conflicts. The future work includes the extension of ONT-SLD to other types of special education so that it can contribute to a broader range of applications in the special education environment.

Keywords**:** ontology; learning disability; dyslexia; dysgraphia; dyscalculia.

1 Introduction

The rapid growth of technological advancements demands a vital requirement to capture knowledge from multiple sources and store it under a single coherent interoperable resource that can be understood and read by computer programs especially for decision-making [1][2]. It gave heads-up to the development of the ontology model in multiple disciplines, including education. Ontology is the substance of cooperation and the semantic understanding between computers and humans that has been used in various domains. It is modelled to share and reuse information and knowledge in a specific domain. The ontology describes definitional information about concepts, properties, relationships and axioms among them in a particular domain along with the theories and principles governing the domain [3]. In the education domain, several dedicated ontologies have been proposed as the need to overcome the barriers of sharing educational resources [4][5], developing outcome-based curriculum [6][7][8], assessing teaching and learning skills [9], and personalizing student support [10][11]. In addition, ontology also has been introduced to identify types of special education [12] and suggest effective teaching and learning methods based on the particular needs of the special student [13][14][15]. Relevant learning disabilities such as dyslexia, dysgraphia and dyscalculia, nevertheless, have not been provided much consideration.

Identification children with specific learning disabilities is complicated as the definition of learning disabilities itself which is confusing and unclear [16][17], with implicit characteristics that have to be considered [18] and applying different methods and rules [19]. Currently, there are no comprehensive and universally accepted standards for the early identification of children with learning problems. Meanwhile, the identification involves a set of extensive screening and testing procedures that is highly dependent on human expertise such as medical practitioners, occupational therapists and special education teachers, contributing to increased workforce and time usage. By rights, any proper identification cannot be made without the availability group of experts. Besides that, there are limited numbers of experts who have sufficient experiences with a repertoire of knowledge in specific learning disabilities [20]. As experts are defined as someone who has uneven experiential knowledge, identification can be handled differently, and the result also tends to be different. According to Shifrer at al. [21], the disproportionate identification of a learning disability is due to the subjective definitions of a learning disability and the inconsistent criteria defined in differentiating types of learning disabilities. Thus, early identification of children who may at risk of having specific learning disabilities by general users such as parents and teachers is vital for the early intervention.

The importance of early intervention has led to a significant positive effect among children with specific learning disabilities [22][23]. Various educational approaches have been designed and applied to facilitate successful educational outcomes for children with learning problems such as neuropsychological rehabilitation [24], cognitive intervention [25], motor skill intervention [26][27], assistive technology intervention [28][29] and social intervention [30]. These current intervention approaches require the involvement of experts, especially medical practitioners, occupational therapists and trained teachers. Parents or untrained teachers rarely aware and knowledgeable on how to properly educate their special children on their own. According to Castro et al. [31], general education parental involvement significantly contributes to their children's academic achievement. However, parents of children with special disabilities encounter more significant barriers to involve in their child's educational planning process as they lack motivation and resources in terms of knowledge and practical skills on how to advocate their child [32]. Therefore, there are vital needs for the emergence of the ontology model to infer knowledge and provide the information (intervention and rehabilitation) about children with specific learning disabilities. So, the parents and teachers will be aware of their children's academic and social development, and they will at least, know what to do if they find that their child encounters any of the learning disabilities problems. In this article, ONT-SLD, an ontology model for specific learning disabilities environment is proposed.

The remaining article is structured as follows. Section 2 presents related works. Meanwhile, the proposed ONT-SLD model is discussed in Section 3. The taxonomy evaluation is explained in Section 4. Finally, the last section concludes the article with future research directions to improve the research in this field.

2 Related Works

The ontology used in special education aims to classify children with special abilities. A good ontology model could provide useful information about the disabilities child for the knowledge of teachers, practitioners, medical doctors and parents. Thus, the development of ontology model in this area is very demanding these days. A lot of studies on the application of ontology in the various scopes related to special education have been done.

Kassahun et al., [12] used ontology to classify the epilepsy types. They used two methods which were ontology-based classification and genetics-based data mining algorithm. Another study carried out by Peleg et al. [33], which they combined ontological methods and clustering analysis to identify a group of comorbidities for developmental disorders. These researches, however, do not have a recommended method to help students improve their quality of life. Ontology was used to interpret and improve clustering results. They develop two (2) methods that were literature-based ontology and clustering. They used Protégé 2000 to create ontology and three steps to develop ontology. First of the process is to create a concept hierarchy, second is to create detailed concept definitions, and the last one is to define Super Diagnosis group. The researcher used 1175 data of patients to evaluate their methodology.

In 2015, Alsobhi et al. [10] used OWL-based ontology to personalize learning materials based on dyslexia types. Their study targeted to identify the appropriate learning style for the patients, which is in accordance with their types of dyslexia. Apart from children at primary levels, ontology also helps disabled students at a higher level of academics. This is proved by the works done by Nganji & Nggada [34], who proposed a personalization approach using disability ontology. It helped disable students to choose suitable learning resources based on their specific needs. The personalized system contained alternative formats of learning materials which have been modified to suit the needs and accessible to the disabled students. Besides disability classification, ontology also has been used to assist learning. Venkatesan et al. [15] used hybrid ontology (combination between domain knowledge and standard Dublin core onology) to teach children with autism. This e-learning expert system analyzed the children needs in their learning, and the content is suggested based on the disability of the users. When the users used the system, their performances were tracked, and the lessons were suggested based on the performances data.

Research by Cramerotti & Ianes[13], recommended a web-based decision support system (e-Planning) that support the construction of an Individualized Education Plan (IEP) that encoded in an OWL 2 ontology. This system called "SOFIA" as a commercial tool that can guide the users to define more suitable academic or life for the students with special education needs and can be used in all country. It also can give optional activities and educational materials suitable for the student. Summary of the review on the ontology model in special education domain is presented in the Table 1.

Table 1. Ontology model in special education

Ontological Applications	Purpose
Ontology-based classification [12]	Classification of special education and learning materials
Literature-based ontology [33]	
Learning style and assistive technology for dyslexia (Alsobhi et al., 2015)	
Personalized system [34]	Recommendation of suitable activity in learning
Hybrid ontology (domain knowledge and standard Dublin core ontology) [15]	
ONTODAPS (Ontology-Driven-Disability-Aware Personalized E-Learning System) [35]	
SOFIA [13]	

3 The Proposed Ontology Model: ONT-SLD

The main aim of ontological development is to capture knowledge related to a specific domain. This section presents the construction of special education ontology. The process includes a specialization, conceptualization, formalization and implementation. In summary, the followings are the outputs of each process, which are discussed further in here.

- Specialization – produces set of competency questions to determine purposes and scopes of the special education domain,
- Conceptualization – identifies the glossary of terms, the conceptual taxonomies, ad hoc binary relations between concepts, concepts dictionary table, ad hoc binary relations table, formal axioms table and rule table.
- Formalization and implementation – concepts, relations between concepts and axioms encoded in OWL.

3.1 Specification

The target scope of special education domain is three types of specific learning disabilities; dyslexia, dyscalculia and dysgraphia. In the specific learning disabilities field, children that may have the potential for specific learning disabilities should be identified in the early stage in order to assist their social and academic's development. The identification process is very complicated, and currently, it is manually done by experts. Children suspected with specific learning disabilities have to undergo a thorough checking before specifically categorizing them into dyslexia, dysgraphia or dyscalculia. Therefore, the purposes of developing special education ontology model are to support decisions in early identification and intervention's recommendation.

There are several required lists to be used as the references for identification and recommendation purposes. The lists are characteristics of dyslexia, dysgraphia and dyscalculia, and several related intervention and rehabilitation activities for each type. The output of this process is a set of natural language questions, called competency questions. Competency questions were used to represent the ontology requirements. The list of competency questions for developing the proposed ontology model is depicted in Table 2.

Table 2. An excerpt of competency questions for specific learning disabilities ontology model

List of competency questions	
Are difficulties in calculation resembles a learning problem?	Are difficulties in calculation indicate the child possess dyscalculia characteristics?
Are calculation problem, writing problem and read problem categorize in dyslexia problem?	Are difficulties in comprehension categorize in dyslexia characteristic or dyscalculia characteristics?
What are suitable suggested activities for the calculation problem?	If the children have a reading problem, are they have dyslexia?
Are difficulties in reading resembles a learning problem?	What are suitable suggested activities for the calculation problem?
Are there any existing related ontologies that can be reused and expand?	What are the benefits of using ontology?

The main target users for this developed specific learning disabilities ontology model are the medical practitioners, teachers, occupational therapist and parents. However, they may need to personally observe their children first if they think their children possess any unusual attributes before directly jump into the conclusion that their child is a specific learning disabilities child.

Up to this time, there are no existing reusable ontologies in special education and specific learning disabilities domains. So, most of the knowledge can only be attained from interviews with experts and conceptualization process. The utmost challenging matters for this work are the deficiencies of specific learning disabilities expertise in Malaysia, and most of the data are private and confidential.

*3.2 **Conceptualization***

There are seven tasks in conceptualization phase which are building a glossary of terms, building a concept of taxonomies, building ad hoc binary relation diagrams, describing ad hoc binary relations, and describing the formal axioms. The outputs for these activities are discussed in detail.

3.2.1 Glossary of terms

Glossary of terms is the documentation of all the relevant concepts and relations between concepts of specific learning disability domain, their descriptions, synonyms and acronyms. All these terms were identified from the obtained answers of competency questions. Fig. 1 shows the main concepts in the hierarchy, starting from the top class `Thing` to the main classes and subclasses. The proposed ontology comprised of two basic concepts; `characteristics` and `activity`, meanwhile three subconcepts; `lexiaCharac, graphiaCharac` and `calculiaCharac`, which inherits from the concept of `characteristics.` Each of these concepts incorporates a set of properties and conditions in order to be conceptualized. An instance that satisfies those properties is considered a member of that concept.

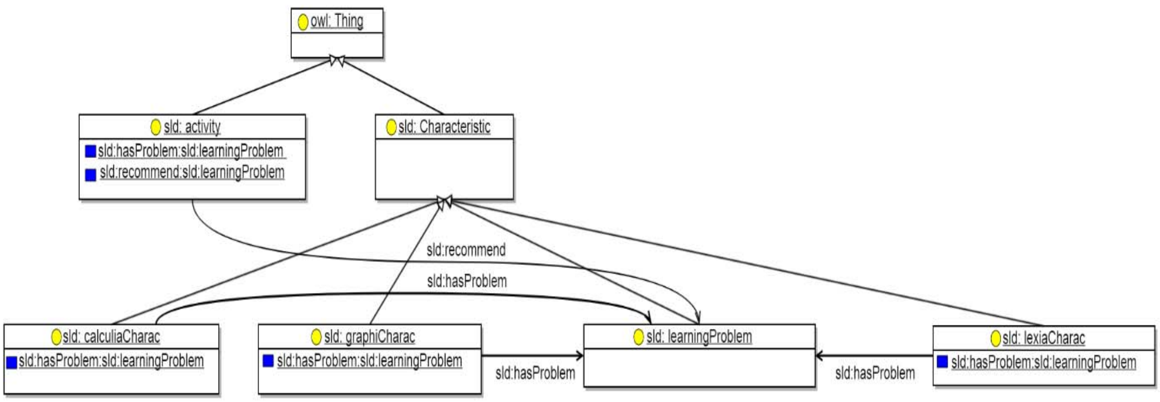


Fig. 1. The main classes of ONT-SLD

- Concept of `characteristics`

This concept is about characteristics of special education in term of learning problem. The characteristic is a feature belonging typically to a person that might have a learning problem that serves to identify them. Based on the feature, they can be identified.

- Concept of `activity`

This concept is about an activity that specific learning disability children can commit. It is a specific activity that helps those children to learn and practice to make a good life in the future. Each type of activity is linked to each type of problem in learning.

- Concept of `lexiaCharac`

This concept is about the characteristic of dyslexia that mainly has a problem in reading. Among the characteristics of dyslexia is comprehension, listening, motor control, reading, spelling, writing, and spatial-temporal.

- Concept `graphiaCharac`

This concept is about the characteristic of dysgraphia that mainly has a problem in writing. There are many characteristics of the dysgraphia children such as classroom management, concentration, handwriting difference, manipulation difference, organization, problem-solving, spelling, memory, motor control, fatigue, paper position, posture and composition.

- Concept of `calculiaCharac`

This concept is about the characteristic of dyslexia that mainly has a problem in mathematics. There are many characteristics of the dyscalculia, including calculation, counting, measures, memorize numbers, and calendar.

3.2.2 Conceptual of taxonomies

The relationships between the main concepts are defined using three different taxonomic relations using subclass-of, partition and exhaustive-decomposition. Fig. 2 shows the subclass-of relations between `Thing` and `characteristics`, in which the concept of `characteristics` is derived from the concept of `Thing`.

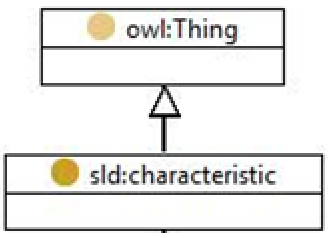


Fig. 2. Subclass-of relation

Fig. 3 shows that the concept of `activity` and `characteristic` make up the partition in relation to the concept of `Thing` because `activity` and `characteristic` are a set of mutually disjointed classes and do not share common instances. Every instance of `characteristic` is an instance of exactly one of the subclasses in the partition.

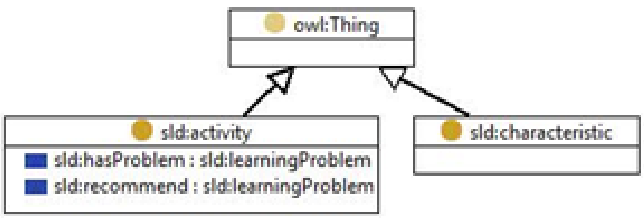
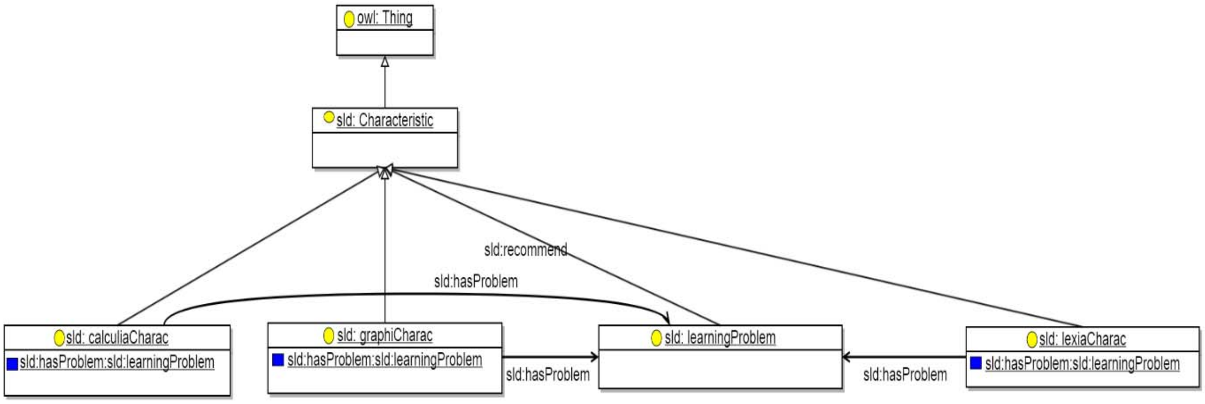


Fig. 3. Partition relation

Meanwhile, the concepts of `lexiaCharac, graphiaCharac`, and `calculiaCharac,` as depicted in Fig. 4 make up an exhaustive decomposition of the concept `characteristic` because the instance of `characteristic` must belong to at least one of the concepts in the decomposition.



3.2.3 *Ad hoc relation*

Ontology establishes ad hoc relationships between concepts of the same (or different) concept taxonomy. The domain and ranges of each argument of each relation delimit exactly and precisely the classes that are appropriate for the relation.

3.2.4 *Conceptual of dictionary*

Concept dictionary includes domain concept and their relations.

3.2.5 *Ad hoc binary relation*

The relation of `hasProblem` means that the children who are having `calculiaCharac` (dyscalculia characteristic), `graphiaCharac` (dysgraphia characteristic) and `lexiaCharac` (dyslexia characteristic), are considered to have a problem in learning that is in `learningProblem`. It can be a reverse relation; when the children have a problem in learning (`learningProblem`), it is a problem of `calculiaCharac` (dyscalculia characteristic) or `graphiaCharac` (dysgraphia characteristic) or `lexiaCharac` (dyslexia characteristic). Each of the characteristics in `learningProblem` will point it to `activity` via relation `recommend`.

The relation of `hasProblem` means that the learning problem can be treated by doing activities recommended by an expert. Example, if the children have a problem in `counting`, the model recommends doing counting exercises activity using some tools based on the class `raCounting`. The ad hoc binary relations defined in the ontology is shown in Table 3.

Table 3. The ad hoc Binary Relation table of specific learning disabilities ontology

Relation name	Source concept	Source card (Max)	Target concept	Inverse relation
hasProblem	calculiaCharac graphiaCharac lexiaCharac	1	learningProblem	is a problem of
recommend	learningProblem	1	activity	-

3.2.6 *Class axioms*

The class axioms are identified, and the expressions are shown as Fig. 5, Fig. 6 and Fig. 7. Children with dyscalculia usually have problems related to mathematics such as recognition of numbers, calculations and measurements, whereas dysgraphia characteristics are resembled by writing difficulties. Children with dysgraphia have problems in handwriting; infrequent and non-uniform sizes and types of fonts. Dyslexia, on the other hands, are children having problems in readings, such as tend to read sentences in backward, writing numbers/letters/words in wrong position etc. There are some similarities in characteristics of these three types of specific learning disabilities, so knowledge from experts are really needed to for a precise diagnosing.

Axiom name	Dyscalculia characteristic
Description	Every characteristics that is dyscalculia characteristics that has problem in learning

Expression	…
	`If`
	`there is some problem with calculation`
	`Then`
	`it is a dyscalculia characteristics`
	`End if`
	`If`
	`there is some problem with calendar`
	`Then`
	`it is a dyscalculia characteristics`
	`End if`
	…

Concept	characteristic, calculiaCharac, calculation, calendar, comprehension, counting, measures, memory_numbers, numbers, spatialTemporal and word
Ad hoc binary relations	hasProblem

Fig. 5. An excerpt of formal axioms expression for class dyscalculia characteristics.

Axiom name	Dysgraphia characteristic
Description	Every characteristics that is dysgraphia characteristics that has problem in learning

Expression	…
	`If`
	`there is some problem with posture`
	`Then`
	`it is a dysgraphia characteristics`
	`End if`
	`If`
	`there is some problem with spacing`
	`Then`
	`it is a dysgraphia characteristics`
	`End if`
	…

Concept	characteristic, graphiaCharac, classroomManagement, concentration, letter_formation, spacing, size_of_letters, joins, speed, left_to_right, grip, using_equipment, hand_dominance,write3, essay, solve, spelling, posture, paperPosition, slow, fatigued, motorControl, mc2, form_letters, reversal_of_the letters
Ad hoc binary relations	hasProblem

Fig. 6. An excerpt of formal axioms expression for class dysgraphia characteristics.

Axiom name	Dyslexia characteristic
Description	Every characteristic that is dyslexia characteristics that has a problem in learning

Expression	…
	`If`
	`there is some problem with read1`
	`Then`
	`it is a dyslexia characteristic`
	`End if`
	`If`
	`there is some problem with listen1`
	`Then`
	`it is a dyslexia characteristic`
	`End if`
	…

Concept	characteristic, lexiaCharac, listen1, listen2, dates, sequences, mc1, mc2, mc3, read1, read2, read3, read4, st1, st2, st3, spell1, spell2, spell3, write1, write2, write3, comprehension
Ad hoc binary relations	hasProblem

Fig. 7. An excerpt of formal axioms expression for class dyslexia characteristics.

All the characteristics are a subclass-of learning problem. The axiom as in Fig. 8 shows `calculation` is subclass-of `learningProblem`.

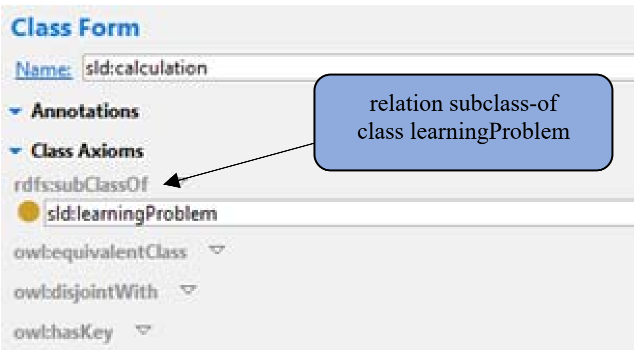


Fig. 8. Class form for the concept of `calculation`.

Every learning problem characteristic is linked via relation `recommend` to specific learning problems. An example is shown in Fig. 9, in which the class of `calculation` is linked via `recommend` to `raCalculation`. All of the activity details are stored in the specific learning disabilities database.

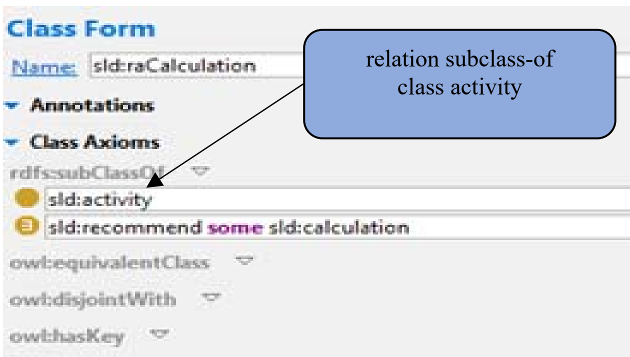


Fig. 9. Class Form for Dyscalculia characteristic (Class Axioms)

A set of intermediate representation (Concepts, attributes, relations, axioms and rules) are developed for specific learning disabilities ontology.

3.2.7 Rules

Rule names, natural language description, the expression of the rules, concepts involved, variables and relationships are defined. Fig. 10, and Fig. 11 show the rules constructed for screening and recommendation.

Rule name	Screening rule
Description	Every characteristic that is dyscalculia characteristics that has a problem in learning
Expression	If comprehension(?a) and counting(?b) and [hasProblem](?a)(?b) then [calculiaCharac]
Concept	Comprehension Counting calculiaCharac
Ad hoc binary relations	hasProblem
Variables	?a ?b

Fig. 10. The rule for screening children with dyscalculia

Rule name	Recommendation rule
Description	Every characteristic that is learning problem have recommended activity
Expression	If counting(?x) and [recommend](?x) then [raCounting]
Concept	counting raCounting
Ad hoc binary relations	recommend
Variables	?x

Fig. 11. The rule for recommending particular educational activities

3.2.8 Formalization and implementation

The class hierarchies of ONT-SLD includes `activity`, `characteristic`, `calculiaCharac`, `graphiaCharac`, `lexiaCharac` and `learningProblem` as presented Fig. 1 are formalized and implemented using TopBraid Composer tool. This tool supports graphical representations of a class hierarchy that can be easily understood by the ontologists and users. Through the use of property characteristics which include functional property, inverse functional property, transitive property, symmetric property, and etc., the meanings of each property can be enriched using OWL.

The relationships between each entity were used to create rules that will enable the model to produce end results for the users. Based on combining all entities (model, class axioms, and rules) the problems of a child can be diagnosed. For example, if a child has at least one characteristics of dyslexia, they might be dyslexic. The same assumptions occur for dyscalculia and dysgraphia. Each of these problems comes with linked (using `recommend` relation) activities which are outlined under activity class.

The `Thing` is a class which includes everything. Both `activity` and `characteristic` have relationships with `Thing`. Required characteristics and suggested activities for each learning problems (dyslexia, dysgraphia and dyscalculia) were specified. Properties connect class to class. After the definition of properties (by interpreting each class characteristic), the domain and ranges were specified. Class characteristic includes types of learning problems (dyslexia, dysgraphia and dyscalculia) and their characteristics. Based on Fig. 1, children who possess any characteristics of these types of specific learning disabilities are all linked to learning problems. Before a child is concluded to have dysgraphia, dyscalculia or dyslexia, all rules have to be fulfilled.

Relationships can be represented by using OWL properties such as object property and datatype property. Object property is the relationship between two individuals and is used to define the relations between classes. Properties are the characteristics of a class that have certain types of values and data type property. Datatype properties are used to link instances to data values. The properties are `hasProblem` and `recommend`. Under `hasProblem`, an analysis of determining whether a child has learning problems are conducted. If the result is positive, the process proceeds to `recommend` for the decision of the specific type of specific learning disabilities the child might have.

Meanwhile, each subclass of `learningProblem` is connected to the subclass of `activity`. This means that every learning problem is linked to their suggested learning activities. However, for each activity, only short terms/acronyms are used, since a long description is not suitable to be placed in the class. The elaborations of the activities were added into the database and will be retrieved when the model is running.

4 Taxonomic Evaluation

The effectiveness and accuracy of information (taxonomies) were verified before being applied in the model to prevent any inconsistencies, incompleteness and redundancies in the produced outputs. Taxonomy evaluation was used to measure consistencies, completeness and conciseness of the ONT-SLD model.

Inconsistencies of errors can be classified to circularity errors, semantic inconsistency errors and partition errors. There are three types of circularity errors which are circularity error at distance zero, circularity error at distance 1 and circularity error at distance *n* that contain classes. Circularity errors at distance zero include only one class that be Subclass-Of its own class. An example is shown in Fig. 12.

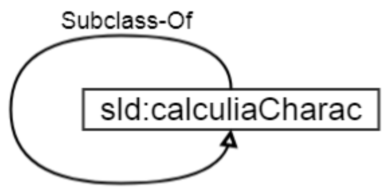


Fig. 12. Circularity error at distance zero.

Circularity errors at distance 1 include two classes that circulate. Example as in Fig. 13 that have `lexiaCharac` is subclass-of `characteristic` and vice versa.

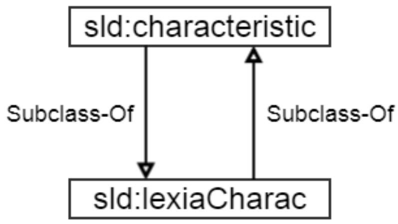


Fig. 13. Circularity error at distance 1

In the hierarchies of SLD ontology model, all of the classes that subclass-of such as the concepts of `Thing`, `characteristic`, `learningProblem`, and `lexiaCharac` show their subclass-of another class that upper than them as in Fig. 14 that prove no circularity errors at distance *n*. But, Fig. 15 shows that there is circularity error at distance *n*.

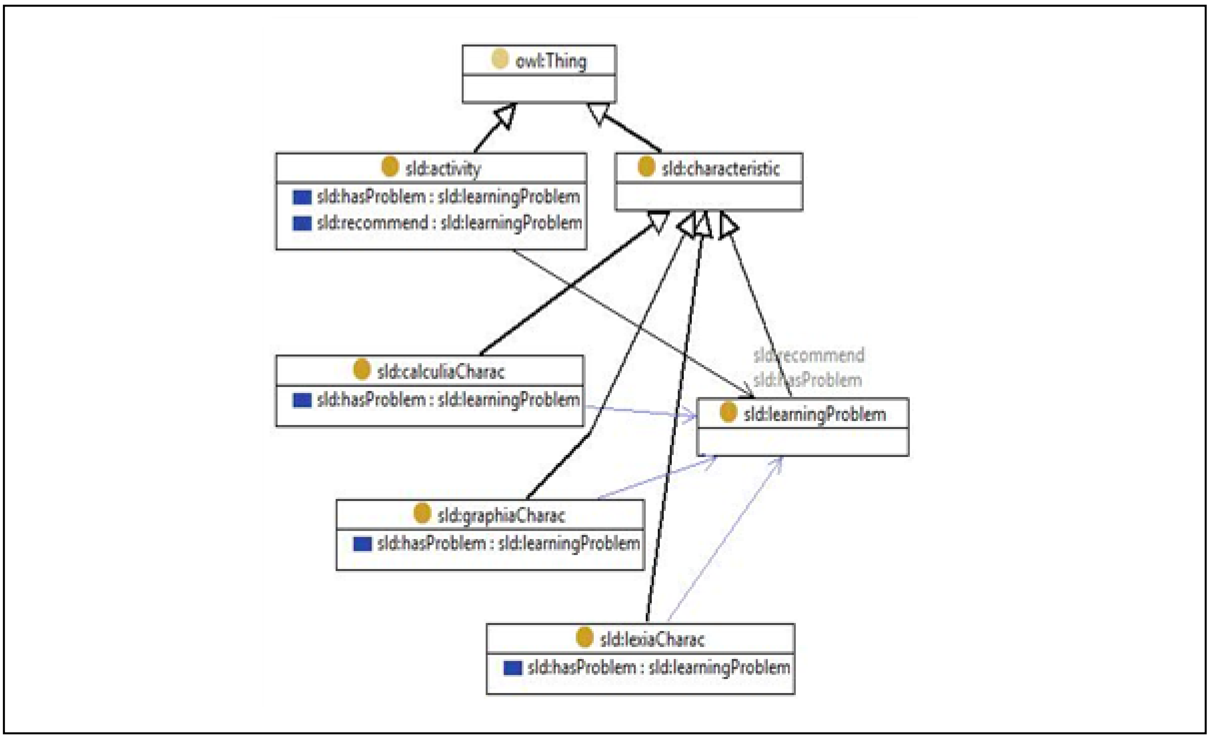


Fig. 14. Class model of ONT-SLD with no circularity error.

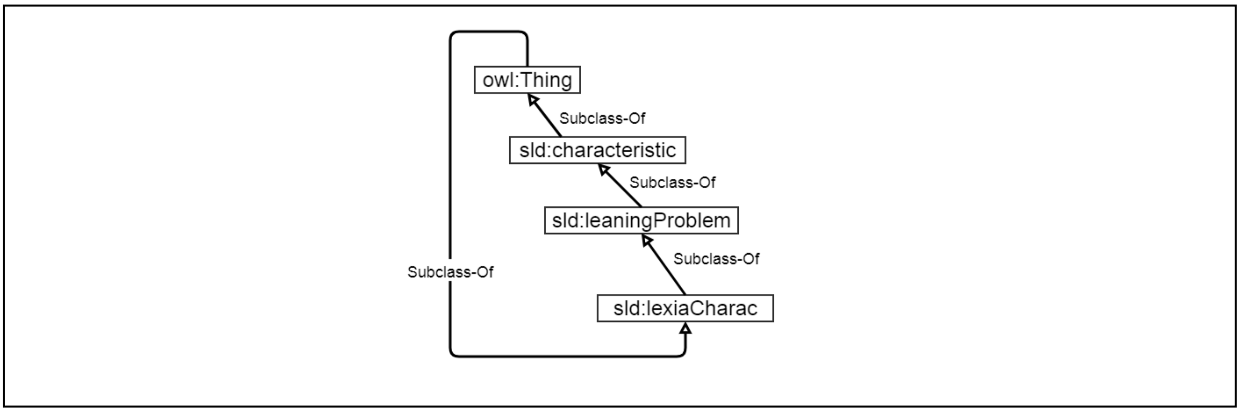


Fig. 15. Circularity error at distance n.

Semantic inconsistencies errors occurred when the concept or instance as a subclass classify a concept or instance which is wrong. SLD ontology model makes the correct semantic consistencies by applying the right concept in the correct way. Partition error can be identified as common classes in disjoint decomposition and partitions. There is no partition error in the classes of SLD ontology model. The concepts of `activity` and `characteristic` make up the partition in relation to the concept of `Thing` because `activity` and `characteristic` do not share common class or instances. However, the concepts of cannot be disjoint which are `calculiaCharac,` and `lexiaCharac` because both concepts share the same concept of `learningProblem` as shown in Fig. 16.

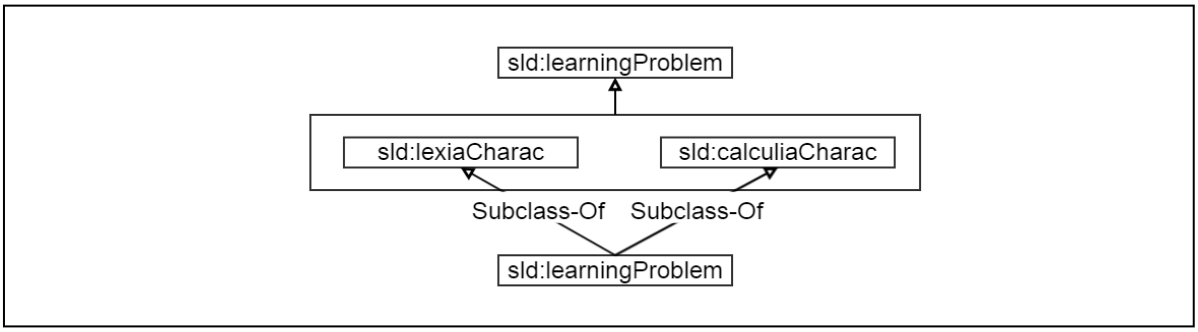


Fig. 16. Class model of ONT-SLD

Query used to test whether the ontology model gives the correct results. The test was conducted using SPARQL in TopBraid. SPARQL query language gets its values from structured and semi-structured data. SPARQL generalizes the path expressions, supports the search input on the graph, substitutes the variables in place of property and constrains the values using Boolean. SPARQL is used to retrieve data from the SLD ontology model. It is suitable for testing because the SPARQL is able to read-only, so it cannot modify the dataset. If the output is correct, it can be concluded that the SLD model has been successfully implemented. Fig. 17, Fig. 18, and Fig. 19 show the sample queries that the output from the SLD model uses in the SPARQL query.

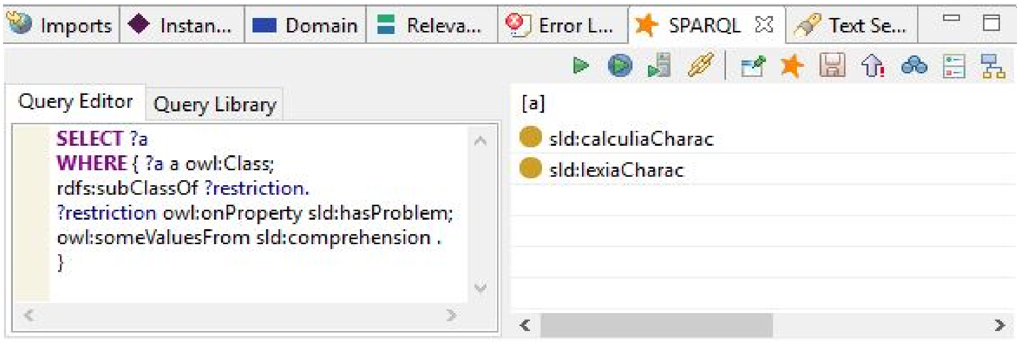


Fig. 17. List of SLD that has comprehension as characteristics

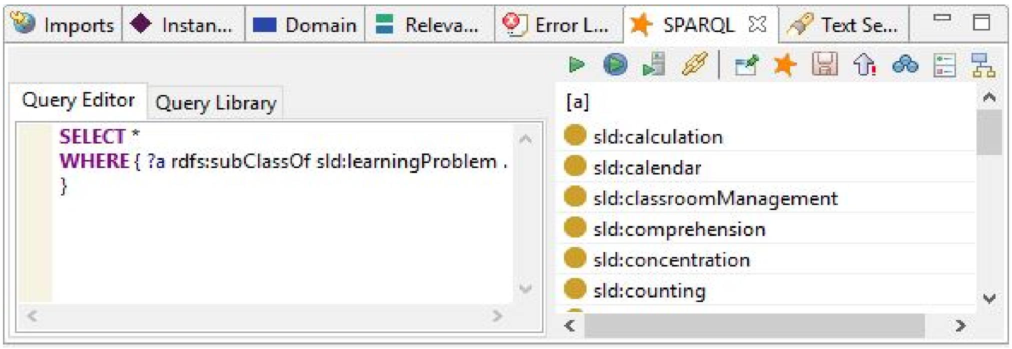


Fig. 18. A part of the list of learning problems queried from the model

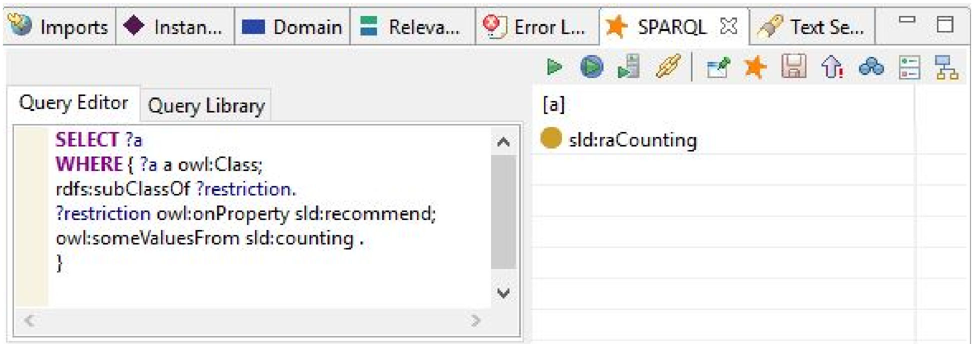


Fig. 19. Recommended activity of counting for the counting learning problem

The second type of taxonomies evaluation is to detect incompleteness based on concept classification and partition errors. Generally, an error of incomplete concept classification is made when the concepts are classified without the existing concept in the domain. Examples of partition errors are exhaustive knowledge omission define the decomposition of a class, omitting the completeness constraint between the subclasses and the base class.

The last process is the redundancy detection in Subclass-Of relation and formal definition of classes. There is only one explicit definition in hierarchy relation in SLD domain when two classes are with the same formal definition. All of the processes to evaluate taxonomies run in parallel with design and development of the model. The incorrect of the knowledge (class) and relationship (property) can be avoided to save time.

5 Conclusion

This article focuses on building a new ontology model for specific learning disability. This model is used to capture the semantics of information in order to early detect children with learning disability problems and to suggest effective educational activities according to the problems identified. The proposed ONT-SLD is purposely developed explicitly to classify three types of specific learning difficulties; dyslexia (reading problems), dyscalculia (mathematical problems), and dysgraphia (writing problems).

For future research directions, the development of ONT-SLD can be expanded to other special education categories such as autism, intellectual disabilities, syndrome down, deafness, etc. Besides, developing manually an ontology model is extremely complicated and cumbersome as it is highly dependent on the domain expert's knowledge. Even though the development of ONT-SLD is guided based on relevant standards and regulations, repeated interviews should be done with domain experts to obtain adequate knowledge in independently developing the ontology model. Therefore, research in ontology learning and ontology mapping can be exploited to automatically identify and develop concepts, relationships and individuals in the ontology model without the intervention from domain experts.

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