



Outcome-based approach, the key linkage between different ontologies is the “Objectives/Goals”. Based on the objectives in different stages and different ontologies, the PEA team will discover user’s needs and act on behalf of user’s requests.

### 3. THE PERSONALIZED INSTRUCTION PLANNER

In order to provide a test-bed for developing and validating PEOnto, an ontology-driven Personalized Instruction Planner (PIP) has been implemented on top of the agent framework of PES [2]. The overall architecture of PIP consists of three layers (Figure 3): i) the Ontology Layer contains ontology schema and knowledge; ii) the Ontology Adaptor (DAOs) extracts logical rule sets from knowledge metadata and ontology schema using RDF Data Query Language (RDQL) in Jena 2.1; and iii) the PE Agent layer where the PE agents act (semi-)automatically to retrieve targeted educational resources.

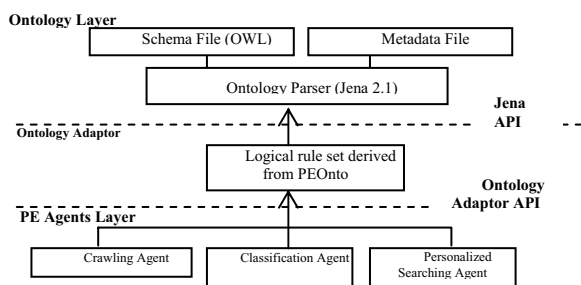


Figure 3 The Architecture of PE Search in PIP

The implementation of PIP is based on a number of Personalized Education Agents (PEAs) that commit to PEOnto ontologies and communicate with the defined subject domain vocabulary items and share knowledge with ontological commitments that assure the consistency with respect to queries and assertions exchanged among PEAs. PEOnto is designed to (a) assist in Web searches, (b) interpret retrieved information, (c) organize information in a semantic/meaningful way (i.e. resources are represented in OWL), and (d) facilitate communications among the PEAs. Figure 4 illustrates the search flow in relation to the ontologies within PEOnto.



Figure 4: Overview of the ontology-driven PEAs for Personalized Search

Through PIP, teachers can create instruction plans based on form filling that was driven by the pedagogy-ontology. The corresponding collection of instances could be queried using a form-based interface that generated RDF Data Query Language (RDQL) queries.

### 4. PERSONALIZED EDUCATION SEARCH

Using intelligent PE agents guided by PEOnto to perform personalized education search PE search agent team will collaborate to perform many tasks including: i) Monitor and manage individual user profile (i.e. teachers and students); ii) Provide a common structure for educational content annotation & indexing; iii) Search and recommend materials relevant to individual learning needs; and iv) Intelligently sequence learning materials to meet individual learning objectives. We will briefly describe some of these tasks below.

#### 4.1 Profile Construction

To understand user’s needs, personal profiles are essential. The PEOnto provides the underlying semantic for the Profile Agent to construct different types of learner’s profiles to reflect different desires and tasks in different stages as learning accomplishments. To maintain a personal profile that can clearly present personal needs and learning status, the Profiling Agent abstracts relevant information from the People Ontology and maintains explicit feedback history as well as history of the documents that have been suggested to the user and the user’s reaction to them. Stereotype profile template will be used as starting point and modified to fit the actual user. Profiles are used to identify user’s current stage needs. Set the goal stage from the Curriculum Ontology. A learning path is then generated according to the pedagogy ontology and the historical profile. An active profile file is also used for recording all current actions and results of individual user. All records will be transformed as a historical profile that maintains previous behaviors as consolidated information for further analyze. A comparative measure technique [3] between different profiles is used to adapt individual user profile to new interests and to forget the old ones. Figure 5 shows the profile information that used to filter the retrieved results.

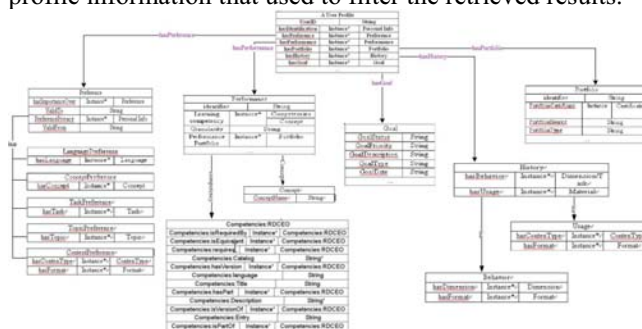


Figure 5: The Profile Information

## 4.2 Automatic Query Formulation and Construction

For personalization search, PIP will respond to users' learning progress automatically according to information provided by the profile agent. On the other hand, the customization engines allow the user inputs a query, check interest from a checklist or select from an electronic catalog. The Filtering Agent will handle the results from three different approaches for making recommendations: demographic filtering, content-based filtering and collaborative filtering. [4] Since education resources are defined in various descriptions that affect the efficiency of the search engine, a standardized description form is needed. An ontological representation of learning objects is one way to deal with the interoperability and reusability of learning objects. Data instances in our ontologies are richly structured datasets which can be represented as a graph where the nodes are objects and the edges are links or relations between objects. Figure 7 is the structure of the materials and its related profile information.



**Figure 7.** The material structure based on the Curriculum Ontology

To give a flavor of the kind of expressivity that was used, in this example the relevant part of the ontology is extracted in the following table:

<pre>&lt;owl:Class rdf:ID="LearningActivity"&gt;   &lt;owl:oneOf rdf:parseType="Collection"&gt;     &lt;owl:Thing rdf:about="#RolePlay"/&gt;     &lt;owl:Thing rdf:about="#Discussion"/&gt;     &lt;owl:Thing rdf:about="#WordActivities"/&gt;     &lt;owl:Thing rdf:about="#StoryTelling"/&gt;     &lt;owl:Thing rdf:about="#Brainstorming"/&gt;     &lt;owl:Thing rdf:about="#Presentation"/&gt;   &lt;/owl:oneOf&gt; &lt;/owl:Class&gt;</pre>	<pre>&lt;owl:Class rdf:ID="WritingTask"&gt;   &lt;owl:oneOf rdf:parseType="Collection"&gt;     &lt;owl:Thing rdf:about="#Exchanges"/&gt;     &lt;owl:Thing rdf:about="#InformationText"/&gt;     &lt;owl:Thing rdf:about="#Explanatory"/&gt;     &lt;owl:Thing rdf:about="#Narrative"/&gt;     &lt;owl:Thing rdf:about="#Persuasive"/&gt;     &lt;owl:Thing rdf:about="#Procedural"/&gt;   &lt;/owl:oneOf&gt; &lt;/owl:Class&gt;</pre>
<pre>&lt;owl:Class rdf:ID="InformationText"&gt;   &lt;owl:oneOf rdf:parseType="Collection"&gt;     &lt;owl:Thing rdf:about="#Charts"/&gt;     &lt;owl:Thing rdf:about="#Leaflets"/&gt;     &lt;owl:Thing rdf:about="#Lists"/&gt;     &lt;owl:Thing rdf:about="#Rules"/&gt;     &lt;owl:Thing rdf:about="#Tables"/&gt;     &lt;owl:Thing rdf:about="#Timetables"/&gt;   &lt;/owl:oneOf&gt; &lt;/owl:Class&gt;</pre>	<pre>&lt;owl:Class rdf:ID="NarrativeText"&gt;   &lt;owl:oneOf rdf:parseType="Collection"&gt;     &lt;owl:Thing rdf:about="#Diaries"/&gt;     &lt;owl:Thing rdf:about="#Accounts"/&gt;     &lt;owl:Thing rdf:about="#Songs"/&gt;     &lt;owl:Thing rdf:about="#Stories"/&gt;     &lt;owl:Thing rdf:about="#Rhymes"/&gt;   &lt;/owl:oneOf&gt; &lt;/owl:Class&gt;</pre>

Based on the classes or vocabulary items defined in PEonto, the search agent can automatically construct queries by combining them as query search parameters, such as:

- Q\_1: {Subject, GradeLevel, Objective}
- Q\_2: {TargetVocab, SentenceStructure, TextType}
- Q\_3: {LearningActivity, LearningTask, ResourceType}

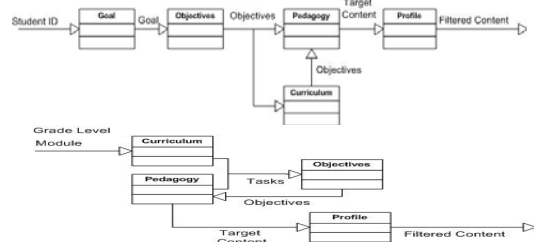
And Figure 6 shows the query request defined in RDQL in relation to the ontologies in PEONto.

```
Select ?material_url, ?material_type
Where (?material_url, Pedagogy: Material_Type, ?material_type),
(<#ReadingActivity>, Pedagogy: hasMaterial, ?material_url),
(?material_url, Pedagogy: hasTargetVocab, "Car"),
(?material_url, Pedagogy: hasTargetAudience, <#GradeLevel4>)
```

**Figure 6:** PEonto RDQL Formulation/Construction

## 4.3 Using Multiple Ontologies for Query Construction and Content Search: A scenario walkthrough

For a grade 4 learner who wants to find and retrieve relevant materials to meet his learning objective, the profile agent will assist the search agent by providing the profile information that tells the current state, goal state, and previous records of the learner through the PEonto. Based on the curriculum and pedagogy ontology, the system will generate the expected learning paths. For a grade 4 English teacher who wants to prepare a lesson plan to accomplish the objectives of a class of grade 4 students, the teacher can explicitly specify the search query into the input box of the curriculum vocabulary items such as subject, gradelevel, objective, module, activity, and/or task. Or, the teacher can intuitively specify his/her needs based on the curriculum such as English/Chinese in *subject*, KS / Grade / Age in *gradelevel*, and/or knowledge, skills, or valueAttitudes in *the learning objective*. Based on this high level specification of the needs, the search agent can use the curriculum and pedagogy ontology to analyze the relations between different learning objectives, learning tasks, learning activities, and expected outcomes through the curriculum ontology. Figure 8 illustrates the search flow of the search agent.



**Figure 8.** Personalized Search Flow

Given the basic information that the user is a Grade 4 English teacher, the Agent will automatically search for instruction plan or relevant queries for resources using the following steps and code segments that reference to the Curriculum and Pedagogy ontologies:

Step 1. Retrieve available instruction plan of the English subject from Pedagogy Ontology

```
SELECT ?subject_name, ?subject_id WHERE (?subject_id,
Peda:Subject_Name, ?subject_name),
(<http://peonto.cityu.edu.hk/CurriculumData.owl#MyInstructionPlan>
```

Peda:consistOf, ?subject\_id) USING Peda For  
<http://peonto.cityu.edu.hk/Pedagogy.owl#>

## Step 2. Filter out the retrieved list to the expected GradeLevel

```
SELECT ?grade_level_name, ?grade_level_id WHERE (?grade_level_id,
Curr:GradeLevel_Name, ?grade_level_name), (?module_id,
Peda:hasTargetAudience, ?grade_level_id),
(<http://peonto.cityu.edu.hk/CurriculumData.owl#English>,
Peda:hasModule, ?module_id) USING Curr FOR
<http://peonto.cityu.edu.hk/Curriculum.owl#>,
Peda For <http://peonto.cityu.edu.hk/Pedagogy.owl#>
```

## Step 3. Retrieve related subject objectives for Primary 4 English Learning.

```
SELECT ?subject_objective_name, ?subject_objective_id WHERE
(?subject_objective_id, Peda:Subject_Objective_Name,
subject_objective_name), (?subject_objective_id,
Peda:hasTargetAudience, <http://peonto.cityu.edu.hk/CurriculumData.owl#P\_4>), (<http://peonto.cityu.edu.hk/CurriculumData.owl#English>,
Peda:hasObjective, ?subject_objective_id) USING Curr FOR
<http://peonto.cityu.edu.hk/Curriculum.owl#>, Peda For
<http://peonto.cityu.edu.hk/Pedagogy.owl#>
```

Step 4. Further narrow down the search results, teacher can select from the particular set of “Writing” objective. Then corresponding “Writing Task|Writing Activities” with correlated materials will be extracted

```
SELECT ?material_URL, ?material_desc, ?material_id WHERE
(?material_id, Peda:Material_Description, ?material_desc), (?material_id,
Peda:Material_URL, ?material_URL), (?learningtask_id,
Peda:hasMaterial, ?material_id), (?learningactivity_id,
Peda:hasLearningTask, ?learningtask_id), (?lesson_id,
Peda:hasLearningActivity, ?learningactivity_id), (?lesson_id,
Peda:hasLessonObjective, ?lesson_objective_id), (?lesson_objective_id,
Peda:fullfill, ?topic_objective_id), (?topic_objective_id, Peda:fullfill,
<http://peonto.cityu.edu.hk/CurriculumData.owl#English\_Writing\_Task>) USING
Peda For <http://peonto.cityu.edu.hk/Pedagogy.owl#>
```

Step 4.1. Filter/Categorized the learning task corresponds to different module|topic|chapter|lesson.

```
SELECT ?learningtask_desc, ?learningtask_id WHERE
(?learningtask_id, Peda:LearningTask_Description, ?learningtask_desc),
(?learningactivity_id, Peda:hasLearningTask, ?learningtask_id),
(?lesson_id, Peda:hasLearningActivity, ?learningactivity_id),
(?chapter_id, Peda:hasLesson, ?lesson_id), (?topic_id,
Peda:hasChapter, ?chapter_id), (?module_id, Peda:hasTopic, ?topic_id),
(?module_id, Peda:hasTargetAudience,
<http://peonto.cityu.edu.hk/CurriculumData.owl#P\_4>),
(<http://peonto.cityu.edu.hk/CurriculumData.owl#English>,
Peda:hasModule, ?module_id) USING Peda FOR
<http://peonto.cityu.edu.hk/Pedagogy.owl#>
```

Step 4.2. Get the list of related materials in respect to the writing tasks

```
SELECT ?material_URL, ?material_desc, ?material_id WHERE (?material_id,
Peda:Material_Description, ?material_desc), (?material_id,
Peda:Material_URL, ?material_URL),
(<http://peonto.cityu.edu.hk/CurriculumData.owl#Writing\_Task>,
Peda:hasMaterial, ?material_id) USING Peda FOR
<http://peonto.cityu.edu.hk/Pedagogy.owl#>
```

The above automatically constructed RDQL result in a set of appropriate query terms for finding the relevant materials to support this user needs. These query terms are then submitted to the Search agent to retrieve a list of educational materials. An example of the retrieved list of relevant learning tasks and the specifications for the associated learning materials is shown as follow:

```
<WritingTask rdf:ID="WritingTask_5">
  <hasGradeLevel rdf:resource="#KS2_9"/>
  <TaskTitle rdf:datatype="http://www.w3.org/2001/XMLSchema#string">
    >Letter Writing</TaskTitle>
  <TaskDescription rdf:datatype="http://www.w3.org/2001/XMLSchema#string">
    >Write a personal letter</TaskDescription>
  <hasObjective>
```

```
<Skills_domain_objective rdf:ID="Skills_domain_objective_12">
  <Obj_Description rdf:datatype="http://www.w3.org/2001/XMLSchema#string">
    >Gather and share information, ideas and language by using strategies such as
    brainstorming, listing, questioning and interviewing</Obj_Description>
  <Obj_related_term rdf:datatype="http://www.w3.org/2001/XMLSchema#string">
    >gather and share information, ideas and language</Obj_related_term>
  <Skills_domain_objective>
</hasObjective>
</WritingTask>
```

```
<WritingTask rdf:ID="WritingTask_13">
  <TaskTitle rdf:datatype="http://www.w3.org/2001/XMLSchema#string">
    >About my family</TaskTitle>
  <TaskDescription rdf:datatype="http://www.w3.org/2001/XMLSchema#string">
    >Write about their family</TaskDescription>
  <hasGradeLevel rdf:resource="#KS2_9"/>
  <hasObjective>
  <Skills_domain_objective rdf:ID="Skills_domain_objective_14">
    <Obj_related_term rdf:datatype="http://www.w3.org/2001/XMLSchema#string">
      >writing non-narrative texts</Obj_related_term>
    <Obj_Description rdf:datatype="http://www.w3.org/2001/XMLSchema#string">
      >Develop written texts by expressing own ideas and feelings when writing non-
      narrative texts</Obj_Description>
  </Skills_domain_objective>
  </hasObjective>
</WritingTask>
```

To further control the volume of the retrieved result (i.e. if a huge amount of materials is returned), the materials will be grouped into different categories according to the modules/topics, or objective domain/types. The above process successively narrows down the specific queries and relevant learning tasks for Grade 4 English and the relevant educational resources based on an analysis of the user needs and the user profile with the support of the relevant ontologies.

## 4. CONCLUSION

This paper presents an ontology-driven personalization search for educational resources within the instructional design process and focused on automatic query generations for relevant educational resources from a high level specification of the user teaching/learning needs. The procedure that makes use of a group of inter-related ontologies (PEOnto) is demonstrated for English language learning.

## 5. REFERNCIES

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- [4] Cristea, V., & Trausan-matu, S., *Authoring and Delivering adaptable learning objects in SINTEC*, retrieved November 2005 from [http://www.wis.win.tue.nl/~acristea/AAAEH05/papers/8-vcristea\\_formatted.pdf](http://www.wis.win.tue.nl/~acristea/AAAEH05/papers/8-vcristea_formatted.pdf).