Does the Web Contain Pedagogically Informed Materials? The COSREW Outcomes

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Abstract: Web resources allow a learner to have more opportunities for study at any time and any place. It is still difficult, however, for learners to choose the right study materials to match their desired learning. A competence-based system for recommending study materials from the Web (COSREW) is proposed, based on the learner's competences. COSREW generates a list of learning paths, and extracts search terms from the competence statements on the chosen learning path. Three experiments were conducted to evaluate COSREW's recommendations. The first explored the differences between search engines and the qualities of the study material links in helping learners achieve their competences. The second experiment explored the differences between search keywords, and the third experiment compared COSREW with freely-browsing learning modes. The results showed that the Web is currently not a good resource for a pedagogically informed competence-based system, since Web pages predominantly comprise text-based subject matter content with little support for learning competence or capability.

Keywords: Competency Model; Competence Structure; Web-based Learning; Internet Supported Learning; Pedagogy; Self-learning

1 Introduction

The aim of this paper is to propose a competence-based system for recommending study materials from the Web (COSREW) which provides links as appropriate study materials. The main objective of COSREW is to help learners find study materials from the Web as supplementary resources outside the classroom. The Web can be an effective learning resource since it seems to offer diverse learning materials which could address learner needs. COSREW is based upon the COMBA competency model (Sitthisak et al. 2008), where a competence is conceptualised as consisting of three major components: subject matter, capability, and context. Within COSREW, the learner's existing and desired competences lead to a selection of different learning paths. Keywords are extracted from the competence statements on the chosen learning path, and the resulting links are presented to the learner as recommendations. COSREW deploys an XML-schema which provides a common framework for abstracting the information in a competence structure. It can be reused for any knowledge domains of subject matter content.

In the following sections, the major literature on competency models and competence structures is presented, followed by the COSREW design. Later, a method of implementing a competence structure and its XML-schema is proposed. Next, three experimental studies which evaluated COSREW's recommendations are presented and the results discussed. Finally, conclusions and further studies are addressed.

2 Competency Model and Competence Structure

This section introduces a competency model based on intended learning outcomes and discusses examples of existing competency models.

2.1 Definition of Competency

There are many definitions of competency in the literature. According to Smith (1996), 'competency' refers to the ability to do a particular activity to a prescribed standard. A definition of competency is given by the HR-XML consortium (HR-XML 2004):

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"specific, identifiable, definable, and measurable knowledge, skill, ability and/or other deployment-related characteristic (e.g. attitude, behaviour, physical ability) which a human resource may possess and which is necessary for, or material to, the performance of an activity within a specific business context."
Another definition is given by McClelland (1973), "competency can be the knowledge, skills, traits, attitudes, self-concepts, values, or motives related to job performance or important life outcomes." Friesen and Anderson (2004) define a competency as "the integrated application of knowledge, skills, values, experience, contacts, external knowledge resources and tools to solve a problem, to perform an activity or to handle a situation." Finally, Cheetham and Chivers (2005) suggest the following general definition of competence: "effective overall performance within an occupation, which may range from the basic level of proficiency through the highest levels of excellence."

2.2 Existing Competency Models and Structures

There are two existing international competency standards, IMS RDCEO (IMS RDCEO 2002) and HR-XML (HR-XML 2004). Their data models or schemas are minimalist but extensible.

IMS RDCEO provides five elements in its information model: identifier, title, description, definition and metadata. There are some disadvantages to this competency model, however, such as the oversimplification of the concept of competency, and the lack of provision for an adequate semantic level to support intelligent decisions. In particular, the model does not take into consideration explicitly important elements such as the knowledge and skills of learners (Baldiris et al. 2007), nor does it support a common language of competency.

HR-XML consortium's competency schema has nine components: name, description, required, competency Id, Taxonomy Id, Competency Evidence, Competency Weight, Competency, and user Area. HR-XML competency can refer to knowledge, skill, ability, attitude, behaviour, or a physical ability. In terms of its implementation, it aims to be used by different people within different disciplines such as human resources management, industrial psychology, and education

Sampson and Fytros (2008) identify some drawbacks to these competency standards, such as the titles and descriptor elements in these models not being directly machine understandable. Moreover, both standards adopt a competence description but do not take a proficiency level into consideration, although this is important to the competency concept (Sampson and Fytros 2008). Their proposed competency model is shown in Figure 1.

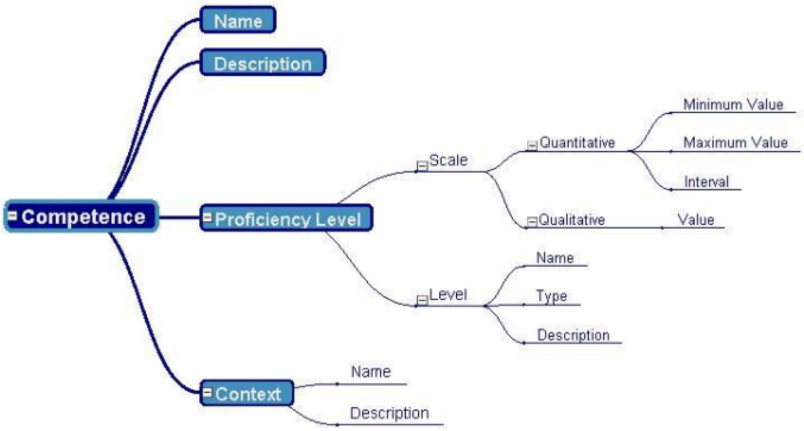

Figure 1: Competency Model Elements (Sampson and Fytros 2008)

The proficiency level in this competency model refers to skills, knowledge, and attitudes, but it remains inadequate. Proficiency can refer to either skills or knowledge in the model, but this is incompatible with considering an intended learning outcome as the combination of capability (skill) and subject matter (knowledge).

The competence structure specifies the range of competence elements/nodes for a particular knowledge domain and highlights the relationship between competence nodes. There are some existing competence structures which were designed from different aspects of competence. One competence structure was developed by Kickmeier-Rust et al. (2006) as shown in Figure 2. One node represents a competence state which is a set of all available competencies of a person. The prerequisite relationships are defined within this set of competencies. Each competency in a state represents a problem or subject matter which a learner is required to solve.

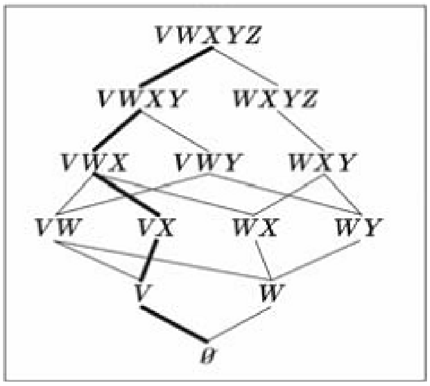

Figure 2: Competence Structure Established by the Prerequisite Function (Kickmeier-Rust et al. 2006)

Another competence structure was proposed by Heller et al. (2006). However, this structure represents a competence-based knowledge structure. It is extended from a knowledge structure as is shown in Figure 3. They introduced two other sets of learning objects (LOs) and related skills for solving problems corresponding to each node within the structure. Nonetheless, this structure is based on knowledge representation.

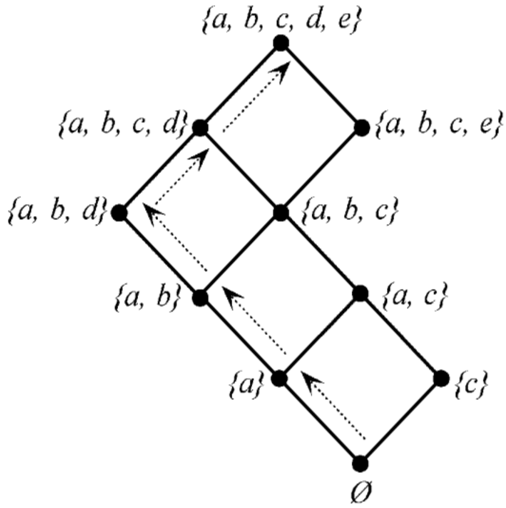

Figure 3: Overview of Knowledge Structure of Domain Q = 'a, b, c, d, e' (Heller et al. 2006)

2.3 COMBA model

The proposed model for this research draws on the multidimensional competency model (called COMBA) proposed by Sitthisak et al. (2008). This considers the learners' learnt capability instead of their knowledge level and views competences and learnt capabilities as a multidimensional space (Sitthisak et al. 2008). The COMBA model (Figure 4) consists of three major components: subject matter, capability, and context.

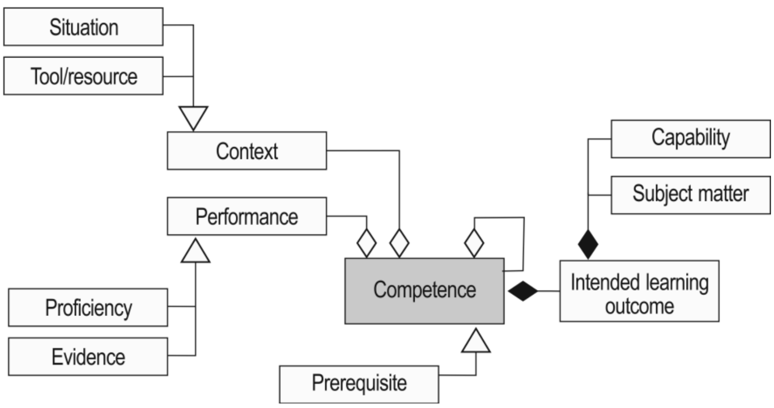

Figure 4: Competency Model Derived from COMBA Model Proposed By Sitthisak et al (2008)

The competence structure, which is designed based on the COMBA model, contains nodes comprising capability, subject matter, and context (optional).There are some existing competence structures based on COMBA model. One sample is a tree of nursing competencies from the UK Royal College of Nursing introduced by Sitthisak et al (2009). The general form of this competence structure is shown in Figure 5. The relationship between nodes is parent-child with no ordering on the same level. A parent-child relationship identifies what the learner must be able to do (child) before something else (parent) can be learned.

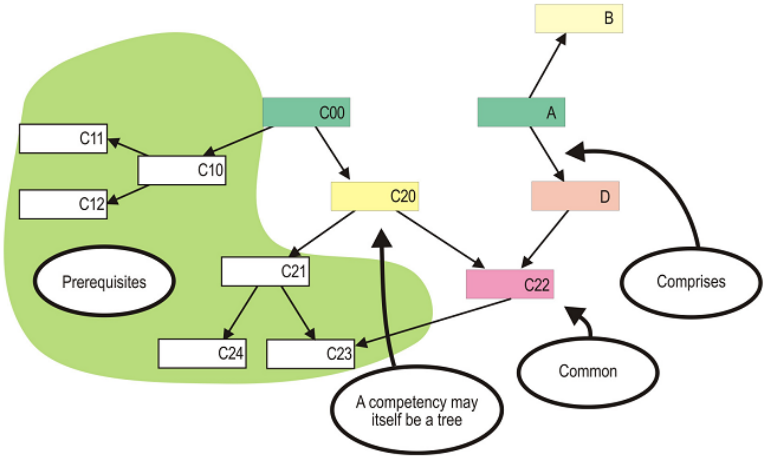

Figure 5: Nursing Competency Tree from the UK Royal College of Nursing (Sitthisak et al. 2009)

Another competence structure was developed by Iskandar et al. (2010). This competence structure is shown in Figure 6. The competence nodes in this structure are all intended learning outcomes independent of context. This structure is based on the sport of rowing in the motor skill domain. The relationship between the competence nodes is parent-child (as in the previous competence structure example).

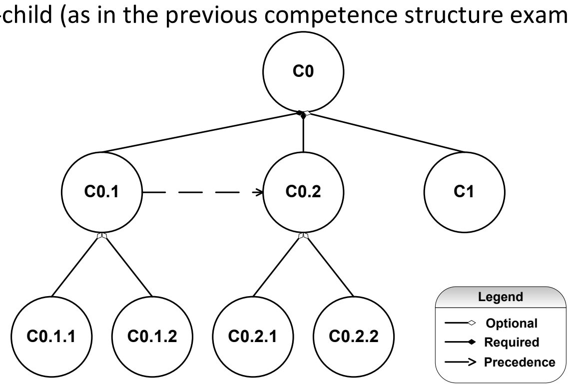

Figure 6: Conceptual Model of Learning Outcomes in the Motor Skill Domain (P Iskandar et al. 2010)

3 COSREW design

This section describes the application of the COMBA model to the COSREW design, and presents the system process of suggesting study materials from the Web.

3.1 Apply the COMBA Competency Model

There are some reasons why a COMBA competency model should be considered in this study.

First is the issue of a machine-processable, sharable, and modifiable representation of learner competence. Each individual learner's competences are clearly defined with a competency model. A learner's competences are connected to prerequisite or enabling competences and are formed as a network structure.

Second is the navigation of a competence structure or network. Navigating the structure offers various routes for providing learners with study material links to enable them to achieve a learning outcome.

The third issue is identifying the context of a learner's competence. Learners may have differing levels of proficiency in relation to a given intended learning outcome, depending upon the context. The defined context of a competence distinguishes a competence from an intended learning outcome.

The fourth issue is that the COMBA model formally defines the combination of 'capability' and 'subject matter' as 'intended learning outcome'. Intended learning outcomes describe what learners need to be able to do to complete a course satisfactorily (Macdonald 1999). An intended learning outcome (previously also known as an educational objective) has long been a central component in the design and structure of educational and training systems, particularly in schools and in industrial training (Reigeluth 1999, Gagne et al. 2004).In addition, an intended learning outcome provides a clear expectation on the part of the student which is a crucial part of their effective learning (Ramsden 1992).

3.2 COSREW Processes

The overview of the process within COSREW, illustrated at Figure 7, shows how COSREW deals with learners' competences and how it recommends appropriate study material links from the Web to learners so that learners can achieve their intended learning outcomes.

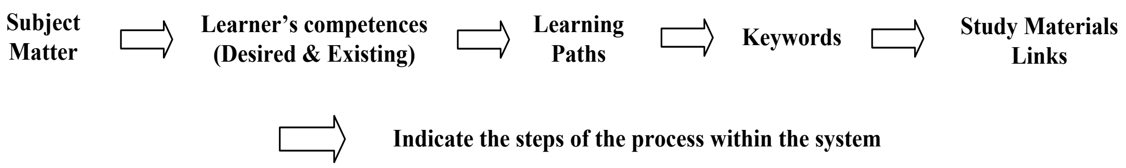

Figure 7: Process within COSREW

First, a sub-process constructs a learner's competence structure so that COSREW can generate lists of targeted subject matter and competences for learners to choose from. After the chosen subject matter and competences (desired and existing) are obtained, COSREW then generates a list of learning paths. COSREW constructs a search based on the chosen learning paths, and then suggests the resulting links to learners.
The reason for considering competence statements as the source of keywords for a search engine is explained as follows. Designing a system that will enable a learner to find appropriate study materials from the Web without any interaction from a teacher requires a method of obtaining information on the Web. Gordon and Pathak (1999) discussed four different methods for locating information on the Web:

- *Go directly to a webpage location.*
- *Hypertext links emanating from a webpage provide built-in associations to other pages.*
- *Narrowcast services can push pages that meet particular user profiles.*
- *Use search engines to find and then furnish information on the Web that hopefully relates to that description.*

As the learner's competences are the information (input) that the system obtains from the learners, so the system should recommend study materials based on these competences. The appropriate method is to use queries to a search engine based on the desired competences. There are many search engines, for example, Google, Bing, Yahoo, Alta Vista and Microsoft. The type of search engine is not considered as an important point in this research: the search engine is used merely as the intermediate tool to get relevant study materials, using the learners' competences.

4 Design of Competence Structure

This section begins with a procedure for designing a competence structure from an existing course syllabus. The XML-schema of the resulting competence structure is then presented which may be useful for construction, implementation, and evaluation, especially for those approaches which require the advantages of usability, semantics, and modifiability.

4.1 Method of designing a Competence Structure

In order to design a structure of competence information on the intended learning outcomes for the specific subject matter content of a course, the topic, syllabus, or curriculum is required. The subject matter content is categorised and tagged with relevant learner capabilities and contexts in order to derive the structure of competences.

4.1.1 Step 1: Choose the topic

Intended learning outcomes in UK education are published by, for example, AQA, OCR, and Edexcel. In this research, the intended learning outcomes from the course specification for photosynthesis at a Key Stage 4 (GCSE, UK) from AQA (revised version), (The Assessment and Qualifications Alliance 2010) were chosen for constructing the competence structure. Examples of intended learning outcomes from this specification are as follows:

- recall photosynthesis equation
- recall photosynthesis definition
- define chlorophyll
- interpret data showing how factors affect the rate of photosynthesis
- demonstrate a photosynthesis procedure
- predict the rate of photosynthesis in different conditions using computer simulations

4.1.2 Step 2: Task Analysis of Subject Matter

Next, the subject matter is extracted from all the intended learning outcomes and categorized into the four types of content following Merrill's CDT (Component Display Theory) analysis (Merrill 1994). They are: fact, concept, procedure and principles. A specific technical definition of each category is provided in (Gilbert and Gale 2008).

Table 1: Definition of CDT Categories of Subject Matter (Gilbert and Gale 2008)

CDT Categories	**Definition**
Fact	Fact pair
Concept	Name of concept Superordinate concept class Attribute–value pairs that classify objects
Procedure	Name of procedure used in situation to achieve a goal via a set of steps using tools
Principle	Name of principle applied in situation involves cause-effect relationships between objects or events.

For photosynthesis at Key Stage 4, the list of subject matter and their CDT categorizations are provided in Table 2.

Table 2: Subject Matter Content and Categorization of Photosynthesis for Key Stage 4 Learners

CDT Subject Matter Category	Subject Matter
Fact	Photosynthesis equation, photosynthesis definition, substance, energy, sun, bulb, gas, CO_2, H_2O, O_2, plant cell, location, mesophyll cell, etc.
Concept	Chlorophyll, light, carbon dioxide, water, oxygen, chloroplast, etc.
Procedure	Photosynthesis procedure
Principle	Photosynthesis rate

Task analysis in instructional design is a process of analyzing and expressing the nature of learning content so that a learner knows how to perform (knows what to do) (Jonassen et al. 1998). The intention is to represent the subject matter content in the form of a diagram which is based on CDT categories. The CDT category "fact" comprises two elements, making a 'fact pair'. Notationally, each element can be represented by a circle. For example, the fact, 'Chemical formula of Carbon Dioxide is CO_2' is represented by a fact pair, 'chemical formula' and 'CO_2' as shown in Figure 8.

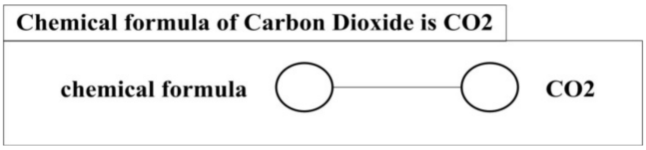

Figure 8: Task Analysis of Fact 'Chemical formula of Carbon Dioxide is CO_2'

The CDT category "concept" involves the concept name and its super ordinate class, which is normally a fact pair. The relationship between class and super ordinate class is 'is a kind of'. Notationally, a concept may be represented by a triangle. A concept comprises a number of attribute-value pairs which distinguish the concept from other similar concepts. For example, the concept of carbon dioxide is shown in Figure 9.

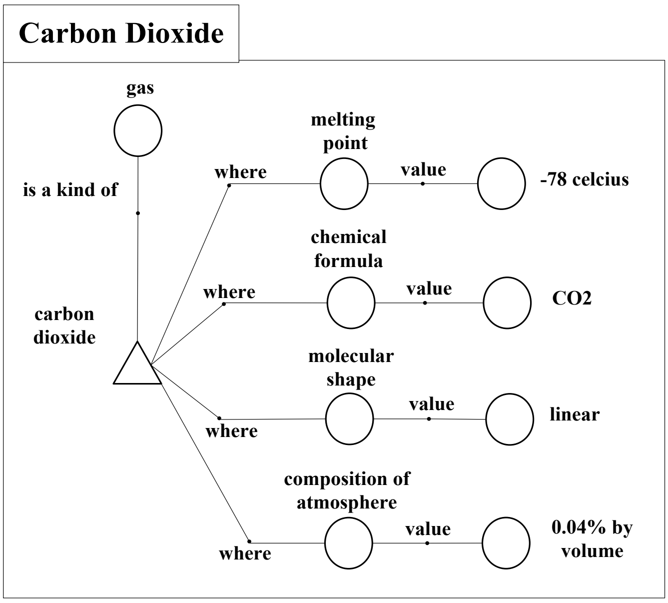

Figure 9: Task Analysis of the Concept of Carbon Dioxide

The CDT category "procedure" consists of a set of steps. Notationally, each step may be represented by a square. For example, the photosynthesis procedure is shown inFigure10.

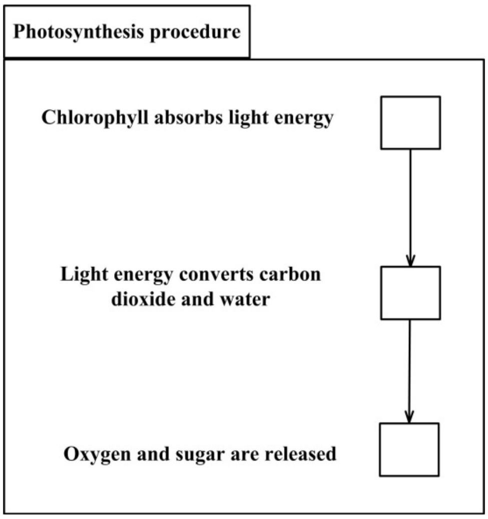

Figure 10: Task Analysis of the Photosynthesis Procedure

The CDT category "principle" involves causes and their effects. Notationally, the principle itself may be represented by a pentagon. For example, the principle of photosynthesis rate is shown in Figure11. Causes are shown on the left side of pentagon and the right side shows the effects or results.

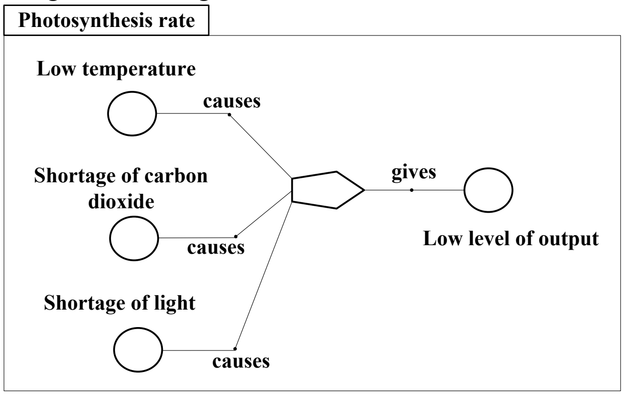

Figure 11: Task Analysis of the Principle of Photosynthesis Rate

4.1.3 Step 3: Decompose Levels of Task Analyses

Step 3 composes of 3 sub steps as follows:

- **Sub-Step 1 (Construct Level 0):** Identify the topic of the whole subject or syllabus. For example, level 0 contains one subject matter as 'photosynthesis'.
- **Sub-Step 2 (Construct Level 1):** From the course specification structure and its top level statements, identify the subject matter which comprises the level 0 topic. For example, from the AQA Key Stage 4 course specification, level 1 comprises four subjects as 'photosynthesis definition', 'photosynthesis equation', 'photosynthesis procedure', and 'photosynthesis rate'.
- **Sub-Step 3 (Construct Level i+1):** Consider each of the subject matters identified in level i. For any concepts, procedures, or principles, place their constituent elements (which may be facts or further concepts, procedures, and principles) at this level i+1. These constituent elements are those as found in sub-step 2. If there are no such subject matters, then END. Otherwise, repeat this sub-step 3 for level i+2.

4.1.4 Step 4: Structure Subject Matter Relationships

Assign a parent-child relationship between subject matter nodes as follows:

- **Sub-Step 1:** The level 0 subject matter is the parent of level 1 subject matter.
- **Sub-Step 2:** Each level i+1 subject matter is the parent of its level i+2 constituent elements.

For example, the resulting structure of the Key Stage 4 photosynthesis subject matter is illustrated in Figure12.

4.1.5 Step 5: Tag Each Node with Capability and Context

In order to develop a competence structure, each node of subject matter requires tagging with a corresponding capability and a context. These tags are taken from the course specification. For example, the resulting competence structure of photosynthesis for Key Stage 4 learners is shown in Figure13.

The competence structure is represented as a tree structure and the relationships between nodes are represented as parent-child relationships. This method of designing a competence structure allows developers to design the competence structures they may need from existing course specifications, curricula, and syllabi.

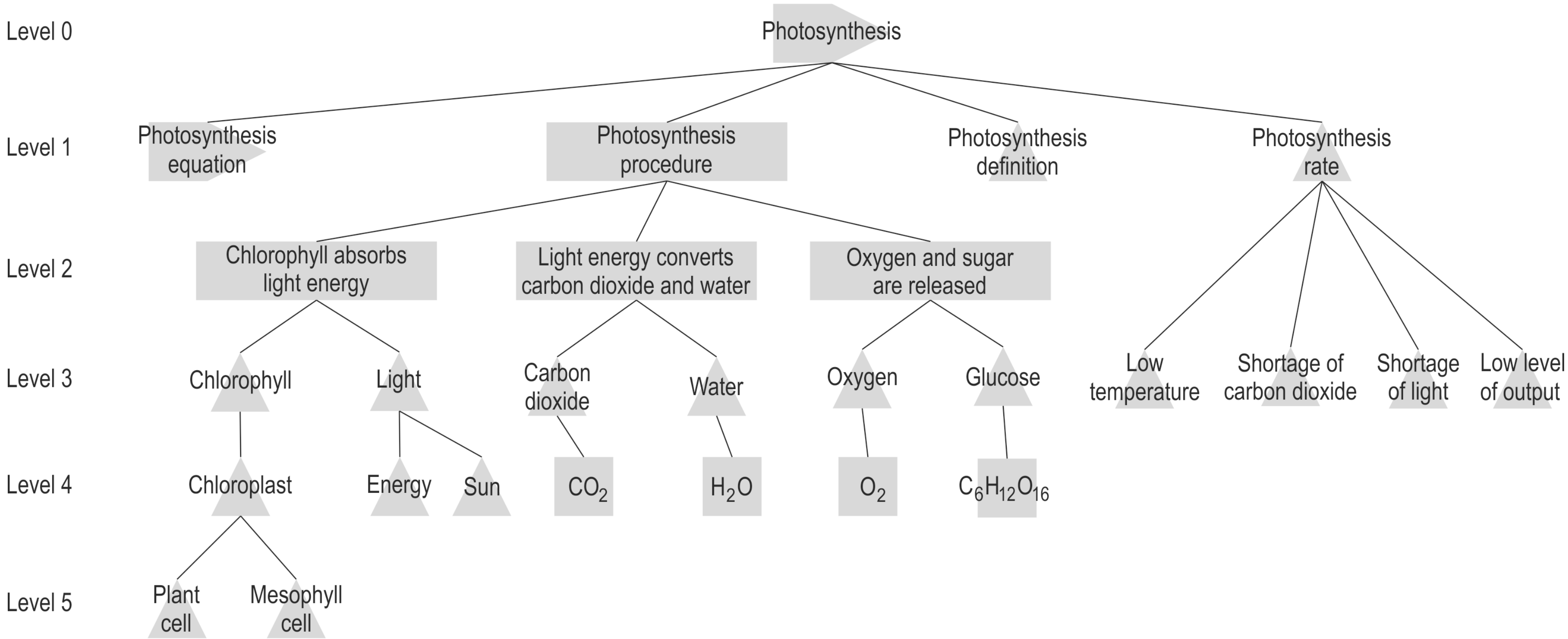

Figure 12: Knowledge Structure of Photosynthesis for Key Stage 4 Learners

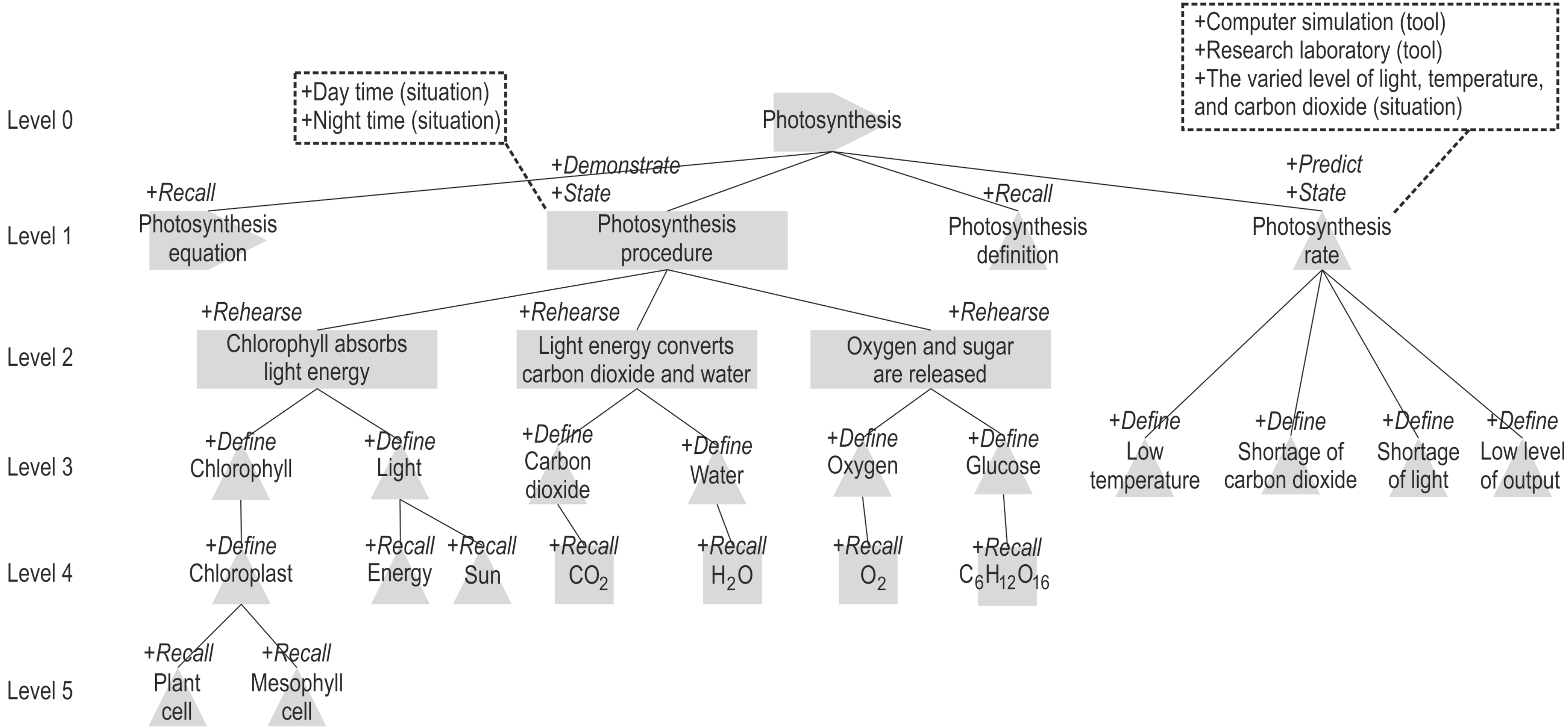

Figure 13: Competence Structure of Photosynthesis for Key Stage 4 Learners Domain Mapped XML-Schema

The XML format for representing a competence structure is now illustrated. XML enables a focus upon the definition of shared vocabularies for exchanging information, supporting the reuse of the content in other applications (St.Laurent 1998). In this section, the derivation of the XML schema is described, based upon an entity relationship diagram.

4.1.6 Entity Relationship Diagram Representing Competence Structure

The entity relationship diagram (ERD) of Figure 14 generally represents all the data entities and attributes in any competence structure, including intended learning outcomes, different types of subject matter content (including their task analyses), and contexts.

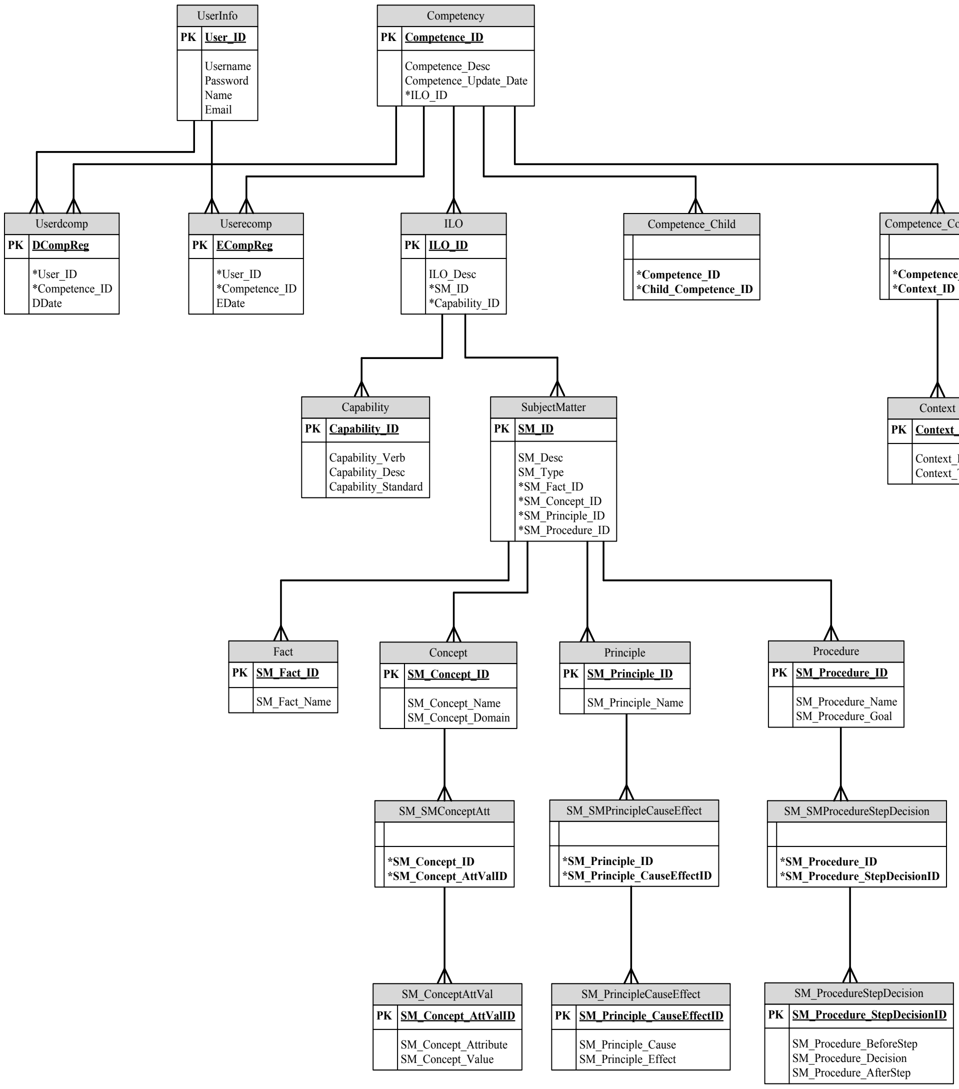

Figure 14: ER Diagram of Competence Structure

4.1.7 Mapping XML-Schema

An XML-Schema defines the terms, relationships, and constraints required to support communication in a particular application domain (Carlson 2001). All schemas provide some degree of definition and documentation for an XML vocabulary. For a competence-based system, an XML-schema represents a common framework for abstracting the required information. Figure 15 illustrates an XML-schema for a competence structure. This schema is the ER diagram of section 4.2.2 represented in XML.

```
<!-- declare all types of table-->
  <xsd:complexType name="UserInfoType">
    <xsd:sequence>
      <xsd:element name="User_ID" type="xsd:string"/>
      ……
    </xsd:sequence>
  </xsd:complexType>

<!-- Content of all elements / all tables -->
  <xsd:element name="Competence_Data">
    <xsd:complexType>
      <xsd:sequence>
        <xsd:element name="UserInfo" type="UserInfoType" minOccurs="0" maxOccurs="unbounded"/>
        ………..
      </xsd:sequence>
    </xsd:complexType>

<!-- Declare Primary keys  and other keys-->
    <xsd:key name="PK_UserInfo_User_ID">
      <xsd:selector xpath=".//UserInfo"/>
      <xsd:field xpath="User_ID"/>
    </xsd:key>
    ………...

<!-- declare foreign keys -->
    <xsd:keyref name="FK_UserInfoUserDComp" refer="PK_UserInfo_User_ID">
      <xsd:selector xpath=".//UserDComp"/>
      <xsd:field xpath="User_ID"/>
    </xsd:keyref>
    ……………..
```

Figure 15: Mapped XML-Schema of Competence Structure

5 Experiment One

In this experiment, the search results given by the Google browser (www.google.com) were compared to those given by the API to Google, in terms of user ratings of achievement. The Google API is the mechanism by which COSREW carries out a search.

In general, the Google browser tends to weight the search results based upon the user's browsing activities, but this information is not employed by the Google API (Kilgarriff 2007). Hence, the results from their searches can be different.

5.1 Experimental Methodology

The research question of experiment one concerned the users' reactions (Kirkpatrick 2007) and required expert review. The topic was photosynthesis for Key Stage 4 learners. Four competence nodes were used, representing a range of competence types on Bloom's taxonomy from 'recall' to 'predict', as follows:

- Recall a photosynthesis equation
- Demonstrate a day time photosynthesis procedure
- Predict a photosynthesis rate
- Define chlorophyll

Keywords (combination of capability, subject matter, and context) were generated for each of the nodes. For example, the node "Predict a photosynthesis rate" yielded the keywords "predict", "photosynthesis", and "rate". These keywords were submitted to Google (www.google.com) on the one hand, and to the Google API on the other. The first three resulting links were presented to the participant, who rated them.

The estimated number of participants required was obtained using G*Power software (Buchner et al. 2010) which was designed as a general stand-alone power analysis program for statistical tests commonly used in social and behavioural research (Faul et al. 2007). The number of participants required in each experiment differed according to the nature of the experiment. The required sample size (ie the required number of links) of this experiment was 24 according to G*power, using an effect size f = 1, an alpha error probability = 0.05, power = 0.8, the test family as F-test, the number of groups = 2, and the statistical test as ANOVA fixed effects.

5.2 Questionnaire Analysis

The participant gave a rating of 'helpfulness to achieve learning outcome' to each link on a scale of six (1, 2, 3, 4, 5, and 6). The 6-point Likert scale was adopted in order to avoid a neutral or mid-point, resulting in a 'forced choice'. Eliminating the mid-point category from the Likert scale reduces social desirability bias (Garland 1991). Chen, Lee, & Stevenson (1995) and Stening & Everett (1984) found that Asian participants were more likely to choose the midpoint of Likert scale item than Americans. The use of forced choice in the Likert scale, as is common in opinion research, was considered appropriate given the Thai participants in the experiment.

In this experiment, the participant was obliged to rate the links as either non-useful (1-3) or useful (4-6). The scales were:

- This website is not related to any materials required in order to learn how to achieve a competence
- This website gives little information required in order to learn how to achieve a competence
- This website gives some information required in order to learn how to achieve a competence
- This website gives useful information required in order to learn how to achieve a competence
- This website gives very useful information required in order to learn how to achieve a competence
- This website gives, not only the very useful information required in order to learn how to achieve a competence, but also with systematic feedback

5.3 Experimental Results

A two-way ANOVA was used to analyse the obtained data in order to find any significant differences between mean ratings of the search engine types and competence node types.
'Search Engine_Type' comprised two levels: Google and Google API. 'Competence_Node' type comprised four levels: 'Recall a photosynthesis equation', 'Demonstrate a day time photosynthesis procedure', 'Predict a photosynthesis rate', and 'Define chlorophyll'.
Table 3 and Table 4 show the descriptive statistics, and tests of between-subjects effects respectively.

Table 3: Means and Standard Deviations of Ratings of Links (Google VS. GoogleAPI)

SearchEngine_Type	Competence_Node	Mean	Std. Dev	N
Google	Recall a photosynthesis equation	4.0	2.00	3
	Demonstrate a day time photosynthesis procedure	2.3	0.58	3
	Predict a photosynthesis rate	1.0	0.00	3
	Define chlorophyll	1.3	0.58	3
	Total	2.2	1.39	12
GoogleAPI	Recall a photosynthesis equation	4.3	1.53	3
	Demonstrate a day time photosynthesis procedure	2.3	0.58	3
	Predict a photosynthesis rate	1.0	0.00	3
	Define chlorophyll	1.3	0.58	3
	Total	2.3	1.55	12
Total	Recall a photosynthesis equation	4.2	1.60	6
	Demonstrate a day time photosynthesis procedure	2.3	0.52	6
	Predict a photosynthesis rate	1.0	0.00	6
	Define chlorophyll	1.3	0.52	6
	Total	2.2	1.50	24

Table 4: Tests of Between-Subjects Effects (Google vs GoogleAPI)

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
SearchEngine_Type	0.04	1	0.04	0.04	0.837
Competence_Node	36.46	3	12.15	12.68	0.000
SearchEngine_Type * Competence_Node	0.13	3	0.04	0.04	0.987
Error	15.33	16	0.96		
Total	169.00	24			

The data obtained (as shown in Table 3) gave the statistical results (Table 4) as follows.

1. There was no significant interaction effect between type of search engine and type of competence node (0.05< p = 0.987).
2. There was no significant main effect for type of search engine. This indicates that there was no significant difference between the means of ratings of links generated from Google and GoogleAPI (0.05< p = 0.837)
3. There was a significant main effect for type of competence node. This indicates that there were significant differences among mean ratings of links based on different types of competence node (p <0.05).

6 Experiment Two

Experiment two was conducted to explore whether the search results for competence keywords were better than those for subject keywords in terms of learner achievement of the competence concerned. The research question was whether the Web links from competence keywords were likely to be more helpful for a learner than those from subject keywords.

6.1 Experimental Methodology

The methodology was similar to experiment one. While experiment one considered 'types of search engine', experiment two considered 'types of keywords'. There were two types of keywords: subject (only subject matter) and competence (combination of capability, subject matter, and context).

6.2 Questionnaire Analysis

The questionnaire was similar to experiment one (see section6.2), where the participant gave a rating of 'helpfulness to achieve learning outcome' to each link.

6.3 Experimental Results

A two-way ANOVA was used to analyse the obtained data in order to find any significant differences between mean ratings of the keywords types and competence node types.

'Keyword_Type' comprised two levels: subject and competence. 'Competence_Node' comprised four levels: 'Recall a photosynthesis equation', 'Demonstrate a daytime photosynthesis procedure', 'Predict a photosynthesis rate' and 'Define chlorophyll'. Table 5 and Table 6 show descriptive statistics and the tests of between-subjects effects respectively.

Table 5: Means and Standard Deviations of Ratings of Links (Subject vs Competence)

Keyword_Type	Competence_Node	Mean	Std. Deviation	N
Subject	Recall a photosynthesis equation	5.0	0.00	3
	Demonstrate a day time photosynthesis procedure	2.3	0.58	3
	Predict a photosynthesis rate	4.7	0.58	3
	Define chlorophyll	4.7	0.58	3
	Total	4.2	1.19	12
Competence	Recall a photosynthesis equation	4.7	0.58	3
	Demonstrate a day time photosynthesis procedure	1.7	0.58	3
	Predict a photosynthesis rate	5.0	0.00	3
	Define chlorophyll	5.0	0.00	3
	Total	4.1	1.50	12
Total	Recall a photosynthesis equation	4.8	0.41	6
	Demonstrate a day time photosynthesis procedure	2.0	0.63	6
	Predict a photosynthesis rate	4.8	0.41	6
	Define chlorophyll	4.8	0.41	6
	Total	4.1	1.33	24

Table 6: Tests of Between-Subjects Effects (Subject vs Competence)

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Keyword_Type	0.42	1	0.42	0.20	0.661
Competence_Node	36.13	3	12.04	57.80	0.000
Keyword_Type * Competence_Node	1.13	3	0.38	1.80	0.188
Error	3.33	16	0.21		
Total	449.00	24			

The data obtained (as shown in Table 5) gave the statistical results (Table 6) as follows.

1. There was no significant interaction effect between types of keywords and types of competence node (0.05< p = 0.188).
2. There was no significant main effect for types of keywords. This indicates that there was no significant difference between the means of ratings of links generated from subject and competence keywords (0.05< p = 0.661)
3. There was a significant main effect for types of competence node. This indicates that there were significant differences among mean ratings of links based on different types of competence node (p <0.05).

7 Experiment Three

Experiment three was conducted to compare whether learning using COSREW was better than learning by freely browsing.

7.1 Experimental Methodology

The pictorial representations of both learning modes are shown in Figure 16 and Figure 17.

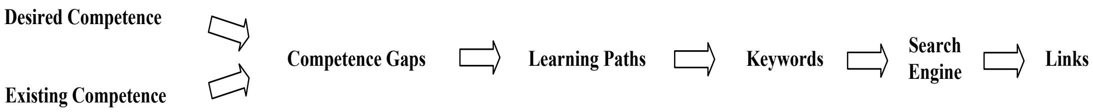

Figure 16: COSREW Learning Mode

Figure 17: Freely-browsing Learning Mode

In the COSREW learning mode, learners were given a set of subject matter to study, and they decided their own choice of competences. COSREW generated the keywords from the chosen competences and suggested links to learners. In the freely-browsing learning mode, learners were given the same set of subject matter to study, and were required to decide the keywords to be given to the Google search engine on their own.

The experiment was concerned with the second, 'learning', level of Kirkpatrick's four levels of evaluation (Kirkpatrick 2007). The participants were assigned to one of two groups: one group experienced the COSREW learning mode and the other group experienced the freely-browsing learning mode. All participants were required to take a pre-test and a post-test, before and after experiencing the respective learning modes. The pre-test and post-test were the same for all participants, being a multiple choice test consisting of 10 questions. The scores obtained from the pre-test and post-test were compared for each learning mode.

The required sample size of this experiment was 6 according to G*power, using an effect size f = 1, an alpha error probability = 0.05, power = 0.8, the test family as F-test, the number of groups = 2, and the statistical test as ANOVA repeated measures, within-between interaction.

7.2 Questionnaire Analysis

The questions in the pre-test/post-test were based on selected subject matter of the Key Stage 4 photosynthesis competence structure (see Figure13). The chosen subject matter was as follows:

- Photosynthesis rate
- Photosynthesis procedure
- Chlorophyll
- Carbon dioxide, Oxygen, Water, Glucose
- Chloroplast

Table 7 shows some of the pre-test/post-test questions.

Table 7: Examples of Questions in Pre-test and Post-test (Experiment III)

Subject Matter Content	Questions in Pre-Test/Post-Test
Photosynthesis rate	Which factor does not affect the rate of photosynthesis?
Photosynthesis procedure	What are the products of photosynthesis?
Chlorophyll	Which cells in leaf contain chlorophyll?
Carbon dioxide, Oxygen, Water, Glucose	Which chemical formulas represent carbon dioxide, oxygen, water and glucose respectively?
Chloroplast	A key molecule NOT found in a chloroplast is …

7.3 Experimental Results

Two-way repeated measures ANOVA was used to analyze the obtained test scores, in order to determine the better learning mode. 'Learning mode' comprised two levels, freely-browsing and COSREW. 'Test type' comprised two levels, pre-test and post-test.

Table 8, Table 9, and Table 10 show the descriptive statistics, the tests of within-subjects effects and the tests of between-subjects effects. Figure 18 displays the profile graphs.

Table 8: Mean and Standard Deviation of Test Scores

Test_Type	Learning_Mode	Mean	Std. Deviation	N
Pre_Test	Freely_Browsing	7.0	1.41	4
	COSREW	4.5	1.29	4
	Total	5.8	1.83	8
Post_Test	Freely_Browsing	7.8	1.89	4
	COSREW	6.3	1.26	4
	Total	7.0	1.69	8
Total	Freely_Browsing	7.4	1.50	8
	COSREW	5.4	1.41	8
	Total	6.4	1.76	16

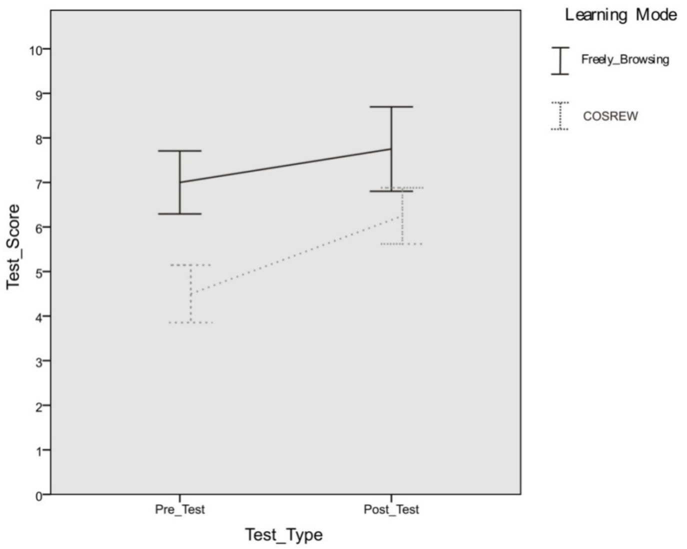

Figure 18: Profile Graph of Mean Ratings of Test Scores of Pre-Test and Post-Test for Two Learning Modes (Error Bars Show +- 1SE)

Table 9: Tests of Within-Subjects Effects

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Test_Type	6.25	1	6.25	4.84	0.07
Test_Type * Learning_Mode	1.00	1	1.00	0.77	0.41
Error	7.75	6	1.29		

Table 10: Tests of Between-Subjects Effects

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Learning_Mode	16.00	1	16.00	5.12	0.06
Error	18.75	6	3.13		

The data obtained (as shown in Table 8) gave the statistical results (Table 9 and Table 10) as follows.

- There was no significant interaction effect between test type and learning mode ($0.05 < p = 0.41$).
- Accepting alpha = 0.10 as a "suggestive" level of significance, there was a significant test type effect. The result suggested that there was a significant difference between the mean test scores between pre-test and post-test at a significance level of 0.10 ($0.05 < p = 0.07 < 0.10$). Inspection of the means in Table 8 shows that the post-test mean was significantly higher than the pre-test mean.
- Accepting alpha = 0.10 as a "suggestive" level of significance, there was a significant learning mode effect. The result suggested that there was a significant difference between the mean test scores between a freely-browsing learning mode and a COSREW learning mode ($0.05 < p = 0.06 < 0.10$). Inspection of the means in Table 8 shows that the mean of the freely-browsing learning mode was significantly higher than the mean of the COSREW learning mode.

The profile plot illustrates the interaction (Figure 18). The profile lines are apparently not parallel, visually suggesting an interaction, but this was not a statistically significant effect.

8 Discussion

8.1 Experiment One

Experiment one sought to determine whether the search results given by the Google browser (www.google.com) were significantly better than those given by the Google API in terms of their rating of 'helpfulness to achieve learning outcome'. The means ratings of links between the two types of search engine did not differ according to type of competence node; the two types of search engine gave similar results. This suggests that future development of search-based learning materials does not need to be concerned about any differences in the resulting links between the search engine itself or the provided API.

8.2 Experiment Two

Experiment two sought to determine whether the search result ratings of 'helpfulness to achieve learning outcome' for competence keywords were significantly better than those for subject keywords. The mean ratings of links for the two types of keywords did not differ according to type of competence node; the two types of keywords gave similar results. While it is commonly thought that the Web is a sufficient resource for learning and learners, it was expected that the Web would support the competence keywords for better results. The obtained results, however, showed no significant differences between the two types of keyword. All the generated links from both subject and competence keywords were reviewed and it was confirmed that they mostly contained subject matter explanation, with little capability and context elements. It seems that the Web does not, in general, provide pedagogically-informed learning materials. It may be that future work should explore the value of video in sites such as YouTube[1], Yahoo! Video[2], and Flickr[3]since such video

[1]http:// www.youtube.com/
[2]http://screen.yahoo.com/
[3]http://www.flickr.com/explore/video/

resources are involved in many current learning systems, for example, MOOCs (Pappano 2012, Kay et al. 2013). Choi and Johnson (2005) concluded that context-based videos in online courses have the potential to enhance learners' retention and motivation better than traditional text-based instruction. Hence video resources can be another domain to explore.

8.3 Experiment Three

Experiment three explored whether a COSREW learning mode was better than a freely-browsing learning mode, where it was expected that learners would achieve higher test scores in the COSREW learning mode, as illustrated in Figure19. In such an experiment, ideally the pre-test scores for the two groups should be equal; in other words, the participants in the two groups should have equal initial knowledge.

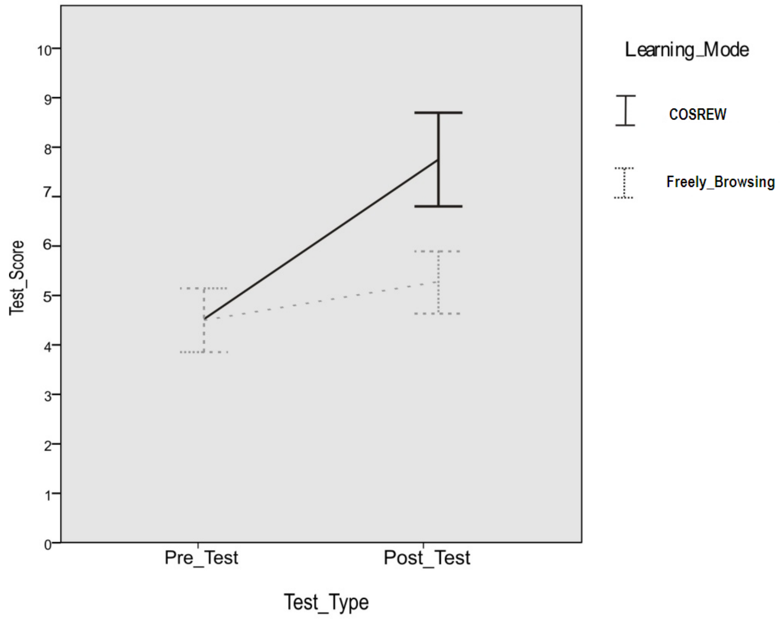

Figure 19: Expected Results of Profile Graph of Mean Ratings of Test Scores of Pre-Test and Post-Test for Two Learning Modes (Error Bars Show +- 1SE)

Significant improvements were shown in both modes of learning. Participants in the freely-browsing learning mode were initially more knowledgeable than those in the COSREW learning mode group. It could be that the learners' existing knowledge helped them to improve their learning, leading to the finding of no significant interaction between learning mode and pre-test/post-test change. This also supports the view that the Web may not currently be pedagogically informed.

8.4 Generalisation of results

While the experiments involved one subject and one stage of education, their focus was on whether and how enhancing content keywords with competence capabilities might improve learning. In such a context, it would not be expected that the specifics of the subject (photosynthesis) and level of education (GCSE) would particularly prevent appropriate generalisation of the findings to other subjects and other educational levels.

9 Conclusions and Future Work

COSREW was proposed for suggesting study materials from the Web, deriving Web links from learners' competences. A process for designing a competence structure and presenting its corresponding mapped XML-schema was also proposed. Three experiments were conducted. In experiment one, the search results generated by Google and by the Google API were equally good in terms of perceived ratings of learning outcome achievement. In experiment two, the search results generated from subject keywords and from competence keywords were equally good in terms of perceived ratings of learning outcome achievement. In experiment three, learners' improvements were equal in both modes of learning (freely-browsing and COSREW). From experiment two and three, it may be concluded that the Web may not currently be a good resource for learning or for a pedagogy-informed approach to learning, especially for COSREW. Most Web pages contain subject matter-based explanation and this may not be sufficient for learning where capability and context is important.

For future work, related video may better support the learning of certain competences and should be included in the COSREW system. Second, authors should be encouraged to provide competence metadata when constructing Web pages. Search engines may then find more pedagogically relevant Web pages when their capability and context metadata is identified. Third, Linked Data principles (Berners-Lee 2006) can be applied by setting the Linked Data set and related metadata as the required competence information. The resulting RDF links ensure all Web materials with the same data set and metadata are linked to each other, providing the desired pedagogically-informed support for competence-based Web resources. Fourth, context classification using the COMBA competency model can be explored further. The literature discusses various aspects of context yet this concept is still not well defined. De Jong (2007) specifies context as identity, location, time, environment, and relation. Sampson and Fytros (2008) define context as job, occupations, function, life outcome, situation, and task. Zimmermann, Lorenz and Oppermann (2007) classified context information into five categories: individuality, activity, location, time, and relations. A well-defined and standard definition of context is still needed. Fifth, a competence structure repository should be considered so that the structures can be stored, discovered, searched, and reused. Lastly, the outcomes of experiment three suggested that the learning improvement of learners in the freely-browsing mode was due to the higher initial knowledge of participants. In order to validate this suggestion, future work could include the study of the impact of knowledge on learners' learning when interacting with a freely-browsing learning mode. This is to explore the significant differences between the learning of knowledgeable learners and that of non-knowledgeable learners when interacting with a freely-browsing learning mode.

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