

Visualization of Learning Outcome Structure for Self-Learning

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Abstract. The success and quality of an educational or training system is assessed by its match to the competences it claims to develop. In this research, we propose a conceptual model of contextualized competence (or learning outcome), being a learner's capability with respect to some subject matter. We also suggest a controlled vocabulary of capability verbs, based upon Merrill's theory insight that a particular capability should be associated with a particular type of subject matter. At this stage, the model is deployed as a subject matter graph without contextualization in the domain of programming fundamentals. The implemented tool associates learning resources (mainly html links) with the domain knowledge structures, offering graph creation and visualization, resource suggestions, and learning paths. Future work will include learning outcomes and related context, and will evaluate user satisfaction and accessibility.

1. Introduction

In the learning and teaching environment, knowledge refers to a value state of a person in cognitive contact with reality [1] and it has been used to in many ways such as: representing a content structure of learning documents [2]; supporting learners in their own knowledge acquisition [3]; and enabling suggestions to learners [4]. Knowledge relationships can be represented in many types: maps, trees, networks, and graphs. There are several methods of building knowledge structures [2] - [3] and an interesting question is how such structures can pedagogically support learning and teaching activities. In this research, we propose models of a learner's ability and of their contextualized competence, suggesting capability verbs associated with the cognitive domain [5] and suggesting subject matter types [6]. In the later section of this paper, we propose a knowledge structure based on a directed acyclic graph and illustrate its implementation in a prototype tool called MyTeLeMap (www.mytelemap.com). Currently, this tool offers support for: building and representing knowledge structures; identifying prerequisites; suggesting relevant study links; and attaching materials to knowledge nodes. Future work will allow the presentation of a knowledge structure as a learning outcomes structure. An experiment is planned to explore user satisfaction, usability, and accessibility of the tool.



2. Knowledge, Competence and Learning Outcome

A well-designed course, module, or unit of learning addresses one or more carefully delineated competences in the learner. The purposes of an educational or training activity is often expressed by its educational objectives or its intended learning outcomes, and these concepts are entirely consistent with the present discussion, which includes these structures in the concept of competence. We suggest that the success and quality of an educational or training system is gauged by its match to the competences it claims to develop. Figure 1 illustrates a conceptual model of competence, being a learner's capability with respect to some subject matter. In a teaching and learning situation, we want to ensure that our educational activity (a lesson or module, for example) is consistent with the competence we seek in the learner, and this is the theme of constructive alignment associated with the work of Biggs [7].

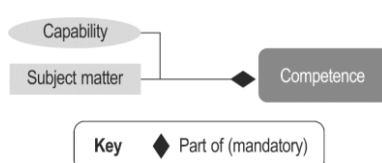


Figure 1. A Conceptual Model of “Competence” as a Learner’s Capability with Respect to Some Subject Matter.

The problem with this simple model of competence is that it lacks the contextual factors which are inherent in practical educational and training applications. Teachers and learners engage in activities which suit their individual and particular interests in teaching and learning, and the resulting competences are highly contextualised. For example, consider the competence of a student and their ability to draw a circle. They could do this using pencil with paper, or using a software tool. With the consideration of different tools used, the competence is different. Hence, we propose a model where knowledge is a contextualised competence, as illustrated in Figure 2.

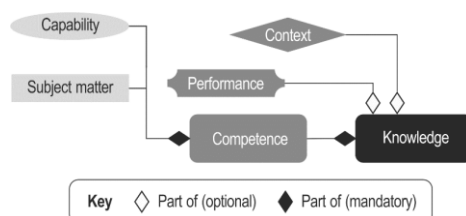


Figure 2. Conceptual Model of “Knowledge” as a Contextualised Competence

3. Structures of Learning Outcome and Their Uses

There are some methods of structuring subject matter and learning outcome in literature. However most of the structures used are subject matter based. Lee, Lee, and Leu [8] proposed a way of defining concepts and the mapping of concepts to support a learning focus. Another way of representing the structure of subject matter in a ‘concept map’ is proposed by Kent, Laslo, & Rafael [9], where relations between nodes are semantically tagged by teachers. Liu & Lee [9] also used a ‘concept map’ to represent subject matter as the content of learner knowledge. For learning outcomes, Albert, Hockemeyer, Mayer, and Steiner [10] designed structures as the combination of concepts and actions. Nitchot, Gilbert, and Wills proposed a method of analyzing subject matter content and tagging it with capability and context in order to yield what we now call a structure of knowledge. From section 2, each of the major components of the conceptual model of knowledge as a contextualised competence in Figure 2 – knowledge, competence, subject matter – may be found in a wide variety of depictions, ranging from concept maps, job descriptions, syllabus and curriculum lists, diagnostic and trouble-shooting decision trees, and so on. Formally, almost all of these depictions may be modelled as a directed acyclic graph

(DAG), and these aspects of the conceptual model are illustrated in Figure 3. The “pigs ear” notation means that a component – a node in a DAG -- can recursively reference or include itself, permitting network and tree structures. Within a DAG, nodes at a lower level support or are related to nodes at a higher level. In a subject matter DAG we term a lower-level node a “component” of a higher-level node; in a competence DAG the term is “enabling”; and in a knowledge DAG “prerequisite” as shown in Figure 3.

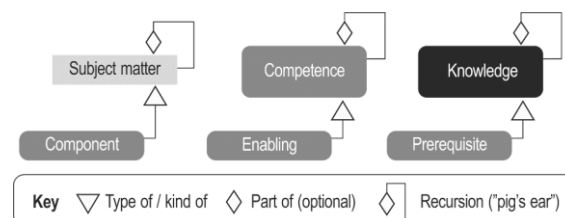


Figure 3. Subject Matter Characteristics According to Subject Matter Type (CER: cause-effect relationship)

4. Implementing Competence Structure Within MyTeLeMap

In our research, we identify 2 types of graphs: a subject matter graph, and a learning outcome graph. An example of a subject matter graph is illustrated in Figure 4 from a course on “programming”. There are 10 subject matter nodes, grouped into shaded areas belonging to similar intended learning outcomes (ILOs). For example, the lowest subject matter “primitive types” belongs to two ILOs, “Demonstrate the knowledge of terminology in primitive types” and, “Declare the primitive types using specific programming language” as identified by the shaded area metadata.

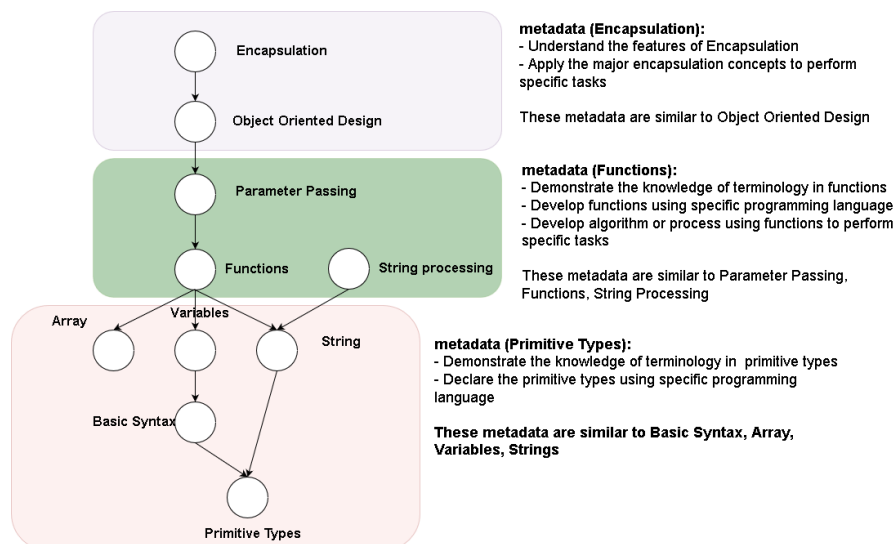


Figure 4. Subject Matter Graph for a Programming Course

In practice, the subject matter graph of Figure 4 would be split into three subgraphs and displayed independently, giving three subject matter graphs: “Encapsulation”, “Parameter passing”, and “Functions”. In our research, a tool for suggesting learning resources’ links based on knowledge structures has been implemented as a prototype. We use the “Functions” subject matter subgraph, illustrated in Figure 5, to demonstrate the input to the “MyTeLeMap” prototype tool.

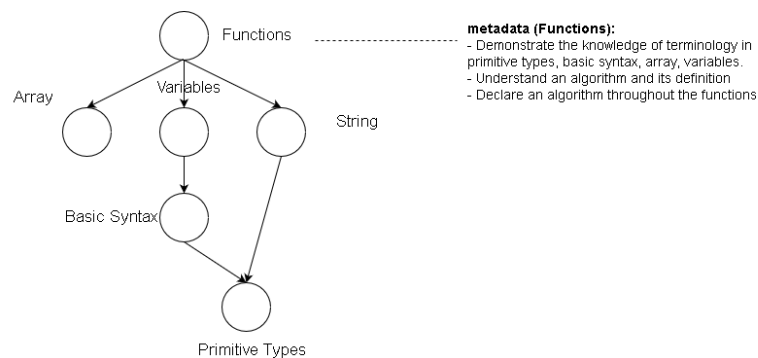


Figure 5. Subject Matter Graph for a 'Functions' Lesson Tagged with Corresponding Metadata

The current tool incorporates the designed knowledge structures and their associated learning resources (mainly html links). Graph visualization libraries (such as Graphviz [11]), and Microsoft Automatic Graph Layout, (Nachmanson [12]) are used to display the graph nodes and edges from the knowledge database. The Google API is used to gather links from the web, and authors provide links to materials embedded in a learning management system. The tool infrastructure is illustrated in Figure 6.

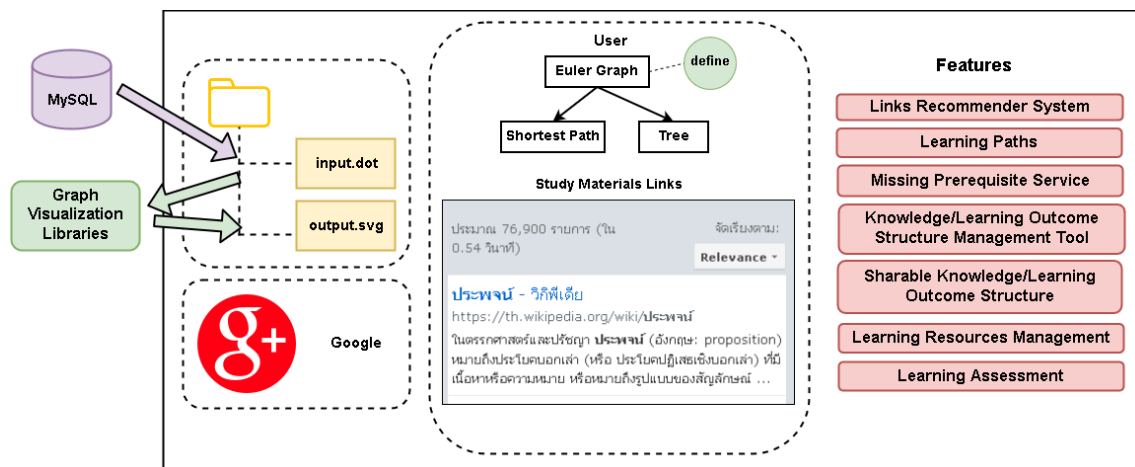


Figure 6. 'MyTeLeMap' Prototype Tool Infrastructure in This Research

Currently, the tool has the following features.

- Teachers can create subject matter graphs (Figure 7)
- The tool gives the material links found by a Google search according to subject matter (Figure 8)

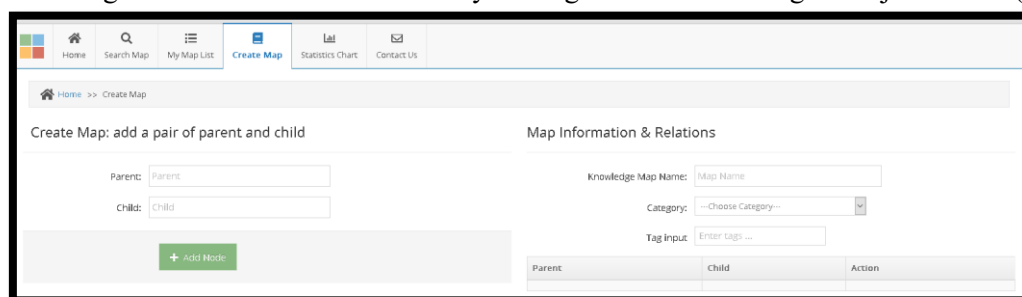


Figure 7. 'MyTeLeMap' Prototype Tool Infrastructure in This Research

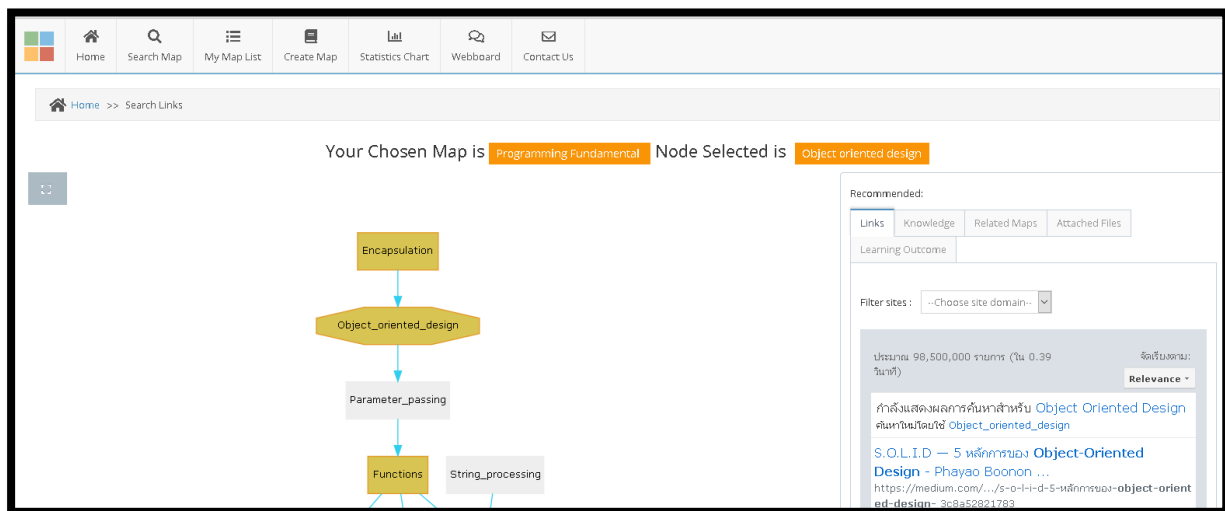


Figure 8. “MyTeLeMap” Prototype Tool Popup Page for for Teachers to Input the Study Material Links

We will add two more tabs: ‘Related ILO’ and ‘Related Context’. These tabs will be applied only to the highest-level nodes. In this example, it is the ‘Functions’ node with ILOs, “Demonstrate the knowledge of terminology in primitive types, basic syntax, array, variables”, “Understand an algorithm and its definition”, and, “Declare an algorithm throughout the functions”. When the user clicks on the ‘Functions’ node, the tab ‘Related ILO’ will show as in Figure 9.

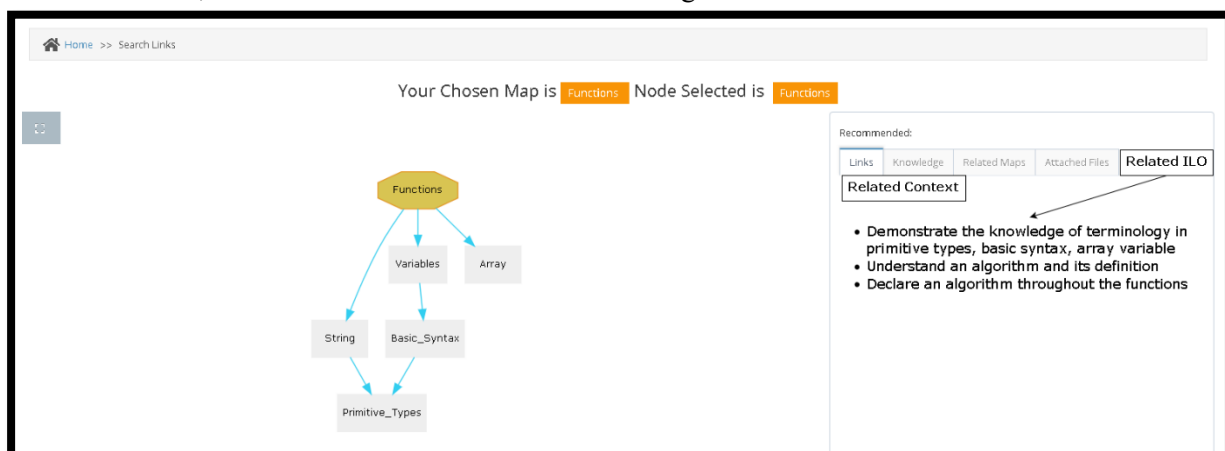


Figure 9. “MyTeLeMap” Prototype Tool Related ILO for Subject Matter ‘Functions’

5. Experimental Design

The experiment will assess teachers’ overall reaction [13] to the tool and its features. Using G*Power we estimate the required number of participants to be $N = 26$. A questionnaire asks users to review, and give a rating to, the knowledge structure and system’s features on a 5-point Likert scale. The designed questionnaire under experimental design is shown in Table 1. The ratings for each scale are 1, 2, 3, 4 and 5, respectively.

Table 1. Designed Questionnaire under Experimental Design

No	Variable	Question
1	Clarity of node appearance	Node appearance within the tool is well explained and clear.
2	Clarity of the tagging learning outcome	Tagged learning outcome within the tool is well explained and clear.
3	Usefulness of tagging learning outcome	Tagged learning outcome is useful for learners
4	Ease of use	This tool is easy to use
5	Usefulness of attachment feature	The attachment of learning materials according to each node is useful
6	Overall user's satisfaction on tool	I feel satisfied with the tool in general
7	Recommendation	I would like to suggest this tool to others in the future

A one-way repeated measures analysis of variance will show whether there are any differences between the mean user ratings, and Sidak-adjusted confidence intervals will be expected to show that the mean ratings are significantly higher than 3 (the middle, 'neutral', point).

6. Conclusion and Future Work

This research is expected to provide fruitful methods for instructional designers (teachers and experts) within many knowledge domains to express and share their subject matter, learning outcome, competence, and knowledge structures. We will develop the tool to help identify learners' missing competence or knowledge and to help such learners undertake focused self-study to obtain relevant study material links. Later, the capability verbs associated with subject matter types will be provided as a controlled vocabulary to support users in creating appropriate knowledge structures. In the final stage, we will explore and evaluate user satisfaction, including usability and accessibility.

Acknowledgement

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