# Error-Based Simulation in Concept Mapping for Learning about Meaning of Class Structure

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**Abstract:** We describe development and evaluation of a learning support environment with error-based simulation functions using concept maps for class structure meaning. There are various relations between concepts in scientific domains, and understanding these relations is vital. Understanding class structure is particularly important. To that end, it is effective for learners to construct class structures by themselves. We develop a learning support environment using concept maps to aid the independent construction of structures by learners. The environment offers error-based simulation when learners make mistakes during construction. We report on implementation of the environment in a junior high school, and confirm that junior high school students can use the environment.

**Keywords:** Learning Support Environment, Concept Map, Error-based Simulation, Learning Science, Class Structure

## Introduction

It is important for learners to understand the meaning of class structure in scientific domains. In such domains, important concepts are arranged using class structures. For example, sparrows belong to a 'birds' class, and the 'birds' and 'mammals' classes belong to a higher-ranked 'vertebrates' class. The class structure is composed of instances, classes, and properties. Instances are concrete concepts such as 'sparrow.' Classes are abstract concepts, such as 'birds,' which are constructed from instances or lower classes having common properties. Properties are features such as 'wings' or 'egg-laying.' Classes are differentiated by properties, which are passed down from higher classes to lower classes or instances. Understanding the meaning of a class structure corresponds to understanding these characteristics and to the ability to systematically arrange the various concepts. In the classroom, however, learners often blindly memorize class labels and properties.

Practical use of concept maps is effective in understanding class structures. Various studies of concept mapping have been conducted [4]. When learning with concept maps, correction activities are important [3]. This is a complex task, however, making computer-based correction support appealing. We developed a learning support environment with error-based simulation (EBS) [2] for concept maps. The purpose of this environment is to visualize learner errors when made, helping learners notice errors. This paper reports the results of deploying the environment in a junior high school.

# 1. Support Learning Environments using Concept Maps with Error-Based Simulation

Our learning support environment gives learners feedback regarding property inheritance and discrimination of classes by properties. Figure 1 shows an interface for constructing skeleton concept maps. Learners are required to link provided instance and property nodes to a partially constructed skeleton concept map. Lower classes or instances inherit properties from higher classes, so if learners can correctly link all relations, each instance will have the appropriate properties. Errors are thus apparent in each instance. EBS for concept maps generates strange behavior when there are differences between the instance properties of a correct map and a learner map. Figure 2 shows an example of EBS.

Figure 3 shows the architecture of our environment. Existing learning support environments diagnose differences between erroneous learner concept maps and correct ones, and give feedback based on the differences. Biswas [1] developed an environment that generates graduated hints using qualitative process theory. Our EBS generator specifies the differences of instance properties, and generates EBS using two databases. We describe behaviors by property in a property database, and when the behaviors are visualized in a process database.

This study focused on biology in junior high school. Figure 2 shows a visualization of ‘pine.’ In this case, though pine has a ‘vascular bundle’ property, the learner linked to the ‘thallus’ property (undifferentiated plant form). Our environment therefore visualized the pine growing like a moss.

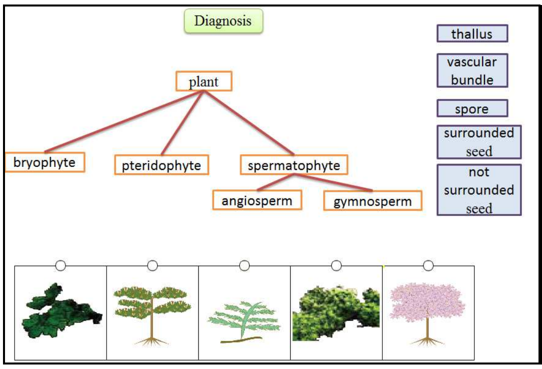


**Fig. 1. Concept map interface**

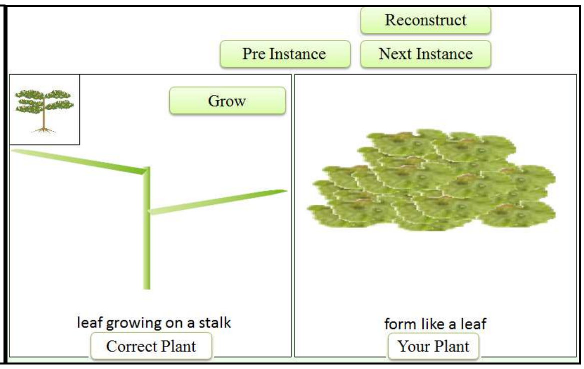


**Fig. 2. An example of EBS**

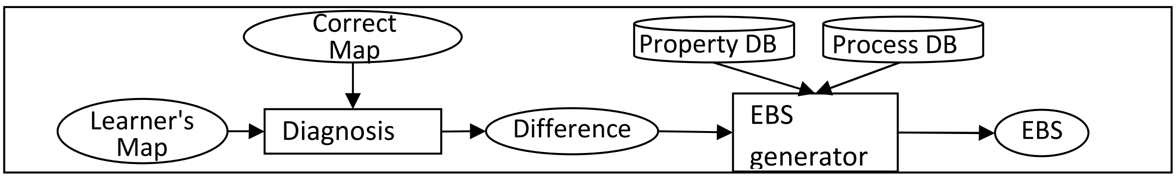


**Fig. 3. Environment architecture**

# 2. Evaluation

To evaluate whether using our learning environment promoted semantic understanding of class structure , we used the environment with 29 first-year and 31 second-year junior high school students, and investigated changes in results. The procedure was as follows:

1. Explanation of concept maps with examples (5 min)
2. Pre-test (10 min)
3. Use of the proposed environment (20 min)

4. Post-test (10 min)

Learners were required to construct concept maps about plants and animals. The pre- and post-test required the same tasks. The plant task, called the ‘learning task,’ was learned using our environment. The animal task, called the ‘transfer task,’ was not learned. No advice about constructing concept maps was given during system use, pre-testing, or post-testing.

Table 1 shows transition of the average number of correct properties for all instances of the learning and transfer tasks. Table 2 shows the results of analysis of variance with task (learning and transfer) and time (pre-test and post-test) as factors. Table 1 shows improving results from pre-test to post-test for all first and second year students. Table 2 shows that significant differences were acquired for the time factor, but not the task factor or interaction. The improvement between learning and transfer task scores suggests that learner knowledge of the domain and comprehension of class structure were promoted.

**Table 1. Average scores (Max: 10)**

| | Learning Task (Plant) | | Transfer Task (Animal) | |
|---|---|---|---|---|
| | Pre-Test | Post-Test | Pre-Test | Post-Test |
| First Year | 4.0 | 7.2 | 4.8 | 6.0 |
| Second Year | 2.4 | 7.2 | 1.6 | 7.5 |

**Table 2. Analysis of Variance**

| | Factor of Tasks | Factor of Tests | Interaction |
|---|---|---|---|
| First Year | $p < 0.01$ | n. g. | n. g. |
| Second Year | $p < 0.01$ | n. g. | n. g. |

## 3. Conclusion

We developed and evaluated a learning environment that visualizes strange behavior resulting from learner errors in constructing concept maps. Implementation of our environment indicated that junior high school students improved their understanding of the meaning of class structure.

## Acknowledgements

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