Comparing Two Extended Concept Mapping Approaches to Investigate the Distribution of Students’ Achievements

Didik Dwi PRASETYA†, ‡, Nonmember, Tsukasa HIRASHIMA†, and Yusuke HAYASHI†, Members

SUMMARY This study compared two extended concept mapping approaches and investigated the distribution of students’ understanding and knowledge structure. The students in the experimental group used Extended Kit-Build (EKB), where a learner extends a concept map built by kit-building, and those in the control group utilized the Extended Scratch-Build (ESB), where a learner extends a concept map made by scratch-building. The results suggested that the experimental group had better achievements in both the original material and the additional material.

key words: extended concept mapping, students’ achievements, understanding, knowledge structure

1. Introduction

Concept maps depict individual ideas that connect two concepts and form a proposition. A proposition is the smallest semantic unit in a concept map that presents particular meaning. Novak and Gowin proposed concept maps based on the assimilation theory, which emphasized meaningful learning [1]. Meaningful learning is a process of linking new information to relevant concepts contained in a cognitive structure. Meaningful learning has been recognized as one of an indicator of the success of education. Meaningful learning experiences can be improved by involving students actively in expanding the concept map [2], [3].

The expansion of the concept map encourages learners to increase their achievement through engagement in solving complex problems. An expanded concept map structure is efficient in organizing design work and building a pertaining knowledge base in a particular domain [4], [5]. During the elaboration activity, learners are tightly involved in compound experiences that are related to one another. The map expansion facilitates learners to integrate knowledge in student-centered learning situations actively.

Extended concept mapping is composed of two interrelated activities. In the first activity, the learners are requested to construct the concept map (original map) as usual according to learning material (original material). Next, learners are given a new material (additional material) related to the original one, and then they are requested to extend the prior original map based on the additional material that would yield an additional map. Extended concept mapping activity facilitates enhanced meaningful learning that occurs when learners link new concept maps to existing ones. In this paper, the extended concept mapping refers to a composite of the original map and the additional (partial) map. As long as the maps are stored in separate tables, it is possible to evaluate the distribution of students’ achievement for each section.

This paper investigates the difference between the effects of the two different methods of the original map building, one is scratch-building, and the other is kit-building [6]. The scratch-building or open-ended mapping is a usual method where a learner is allowed to make a node and link freely by him/herself. In the kit-building, a learner is provided a set of nodes and links and then requested to reconstruct a concept map using the components. The set of nodes and links are prepared by decomposing a teacher’s map of a target learning material. Several kinds of researches have already confirmed that the kit-building is sufficient for a learner to promote comprehension following the teacher map [7], [8]. This research examines that the concept map built by kit-building is useful as the original map to be extended by the learner.

In this study, a learner in the experiment group used kit-building to build the original map and used scratch-building to extend the original map. A learner in the control group used scratch-building both to make the original map and to extend it. The activity of the experiment group is called Extended Kit-Build (EKB), and the activity of the control group is called Extended Scratch-Build (ESB). We have already developed the ESB system [9] and confirmed that it is useful for learning. This study compared the performance of ESB and EKB to investigate the distribution of students’ understanding and knowledge structure in each subtopic of materials.

2. Literature Review of Extended Concept Mapping

Extended concept mapping is an activity for extending an existing concept map by adding new components based on the related information [4], [5]. The activity provides learners with the opportunity to review initial ideas and connections, eliciting missing ideas and relationships, adding new concepts and links, and revising knowledge integration [5]. The opportunity engages the learners actively in each phase of the knowledge integrating process, which is not perceived in the usual concept mapping. The added extension of the
map illustrates the ability of a learner to achieve enhanced meaningful learning.

A previous study [5] compared the performance of two collaborative critique activities using a Knowledge Integration Map (KIM) on “expert map” and “peer map” conditions. The results confirmed that the initial map that was expanded through two forms of collaborative critique and revision activity could increase and construct a more coherent knowledge structure. Based on these investigations, the extended mapping activity in this paper has been designed. The activity itself is the same one in EKB and ESB, and then the learning effect of ESB has also been confirmed [9].

3. Methods

3.1 Participants and Context Material

The present study involved 55 Informatics Engineering students (65.45% male, 34.55% female) from the Department of Electrical Engineering, State University of Malang, Indonesia. There were no significant age differences between students; thus, data on age were not provided. All participants are novices in the context of using concept mapping. The test of homogeneity of variances was performed before determining the control and experimental groups and showed equal differences ($p = .389 > .05$).

This study was conducted in the Database 1 course, with the topic Relational Database. The material topic consists of two following subtopics: (1) original material: introduction to a relational database (consisting of 192 words) and relational keys (consisting of 139 words), (2) additional material: formal language (composed of 101 words) and commercial language (composed of 81 words). In the EKB, an experienced lecture provided the teacher's map for the original material includes ten propositions. The lecturer used a presentation and distributed printed handouts to students.

3.2 Procedures

Before the experiment was conducted, in a previous course meeting, participants in both groups had been given an introduction to concept maps, including usage practices. The experiment activities following the timeline in Table 1.

| Phase | Teacher's activity | Control group's activity | Experimental group's activity | Duration |
|-------|-------------------|--------------------------|-------------------------------|----------|
| 1     | Act as facilitator | Receive a pre-test       | Create concept map using k-  | 15'      |
|       | Gives a lecture   | Following the lecture    | scratch-building              |          |
|       | original material |                          |                               |          |
|       | Act as facilitator | Create a concept map     | Create a concept map using    |          |
|       |                   |                          | k-scratch-building            |          |
|       |                   |                          | building                      |          |
| 2     | Continuous a lecture | Following the lecture | Extend previous concept map   | 15'      |
|       | additional material |                          | using scratch-building        |          |
|       | Act as facilitator |                          | (open-ended)                  |          |
|       | Act as facilitator | Receive a post-test      |                               | 10'      |

In Phase 2, the teacher continuing lecturing on additional material (subtopic 2). The procedure and time allocation of the lecture were the same as in Phase 1. Furthermore, students in both groups were requested to expand their prior concept maps using the same open-ended approach. The students could add any concepts, links, and create propositions according to their understanding. Finally was the evaluation of students’ understanding of the course material through a post-test.

3.3 Measurements

Two measurements were involved in confirming the distribution of students’ achievements in each subtopic: 1) understanding test and 2) knowledge structure scores. Test of understanding was carried out using pre-test and post-test designed by expert teachers. There were eight multiple-choice questions, and four questions represented each subtopic of materials. The teacher had marked each question, where four items were related to the original material, and four items were associated with additional material.

Measurement of the distribution of knowledge structure was based on the number of propositions in the original and additional maps. The number of concept map components illustrates the amount of information collected and elaborated by learners [10]. For each existing proposition, it was identified by referring to the appropriate subtopic of materials. The calculation of the number of propositions in the subtopic was done manually by the class teacher.

The normality distribution and homogeneity of variance were examined to determine whether the data could be analyzed using a parametric test. Since the data were not normally distributed, the analysis was performed using non-parametric statistical tests.

4. Results

4.1 Analysis of Students’ Understanding

The pre-test was designed to diagnose whether students in both groups had an equivalent understanding. The Mann-Whitney U test was used to determine whether there were significant differences between the pre-test scores for both groups. Based on a $p$-value threshold of 0.05, the results in subtopic 1 ($p = .532$) and subtopic 2 ($p = .594$) indicated there was no statistically significant difference between students’ scores in the control and experimental groups.
Table 2  Descriptive statistics of the post-test scores in original and additional materials.

| Questions                  | Group  | N  | Min | Max | Median | Mean | SD  |
|----------------------------|--------|----|-----|-----|--------|------|-----|
| In original material       | Control| 27 | 75.00 | 100 | 100 | 95.37 | 9.90 |
|                           | Experimental | 28 | 75.00 | 100 | 100 | 96.43 | 8.91 |
| In additional material     | Control| 27 | 25.00 | 100 | 75.00 | 66.67 | 18.34 |
|                           | Experimental | 28 | 50.00 | 100 | 75.00 | 78.57 | 17.63 |

Table 3  The Mann-Whitney U test results of the post-test scores regarding material subtopics.

| Questions                  | Group  | N  | Mean Rank | Sum of Ranks | U  | Z  | p  |
|----------------------------|--------|----|-----------|--------------|----|----|----|
| In original material       | Control| 27 | 27.41 | 740.000 | 362.000 | -420 | .674 |
|                           | Experimental | 28 | 28.57 | 800.000 |          |     |    |
| In additional material     | Control| 27 | 23.50 | 634.50 | 256.500 | -2.250 | .024 |
|                           | Experimental | 28 | 32.34 | 905.50 |          |     |    |

The post-test design was adopted to investigate the students’ achievements after receiving the intervention. Table 2 presents the descriptive statistics of the post-test scores regarding material subtopics for two groups. The performance of students for the questions in the original material was almost the same. For questions in additional material, the experimental group’s performance was superior to that of the control group.

The degree of differences between post-test scores attainment was further measured using the Mann-Whitney U test. Table 3 exposes the statistical analysis results of the post-test scores regarding material subtopics. For questions in the original material, there were no significant differences between the post-test scores of the two group experiments. Pearson’s r value was −.057, which denoted a small effect size in the comparison result. For questions in additional material, a significant difference was found with Pearson’s r of −.305, indicating a medium effect size.

Even though for questions in the original material, there were no significant differences, but the average mean of the experimental group was slightly higher than the control group. In addition, the comparison of the scores of the two groups also had effects, even in the small effects size category. Based on the results of the post-test scores, the experimental group achievement in the original and additional subtopics was more distributed than the control group. In particular, in expansion activities, students in the experimental group obtained higher scores.

4.2 Analysis of Knowledge Structure

Similar in post-test analysis, propositions in expansion activities consist of two parts: propositions on the original map (subtopic 1) and the additional map (subtopic 2). Descriptive statistics of the number of propositions regarding material subtopics are shown in Table 4. There was an exciting pattern found in the obtained data. For the propositions in the original map, the average number of propositions of the control group was higher than the experimental group. However, for the propositions in the additional map, there was a drastic change, where the average number of experimental group propositions was more elevated.

Table 5  The Mann-Whitney U test results of the number of propositions regarding material subtopics.

| Proposotion | Group  | N  | Mean Rank | Sum of Ranks | U  | Z  | p  |
|-------------|--------|----|-----------|--------------|----|----|----|
| In original map         | Control| 27 | 27.80 | 966.50 | 167.50 | -3.591 | .001 |
|                           | Experimental | 28 | 20.48 | 573.50 |          |     |    |
| In additional map       | Control| 27 | 21.60 | 451.00 | 73.000 | -5.155 | .000 |
|                           | Experimental | 28 | 38.89 | 1089.00 |          |     |    |

Table 4  Descriptive statistics of the number of propositions in original and additional maps.

5. Discussions

5.1 The Distribution of Students’ Understanding

The present study compared ESB and EKB concept mapping to reveal the distribution of students’ achievement on the topic Relational Database. The EKB approach has proven to be able to maintain the superiority of a KB reconstruction method. This finding is consistent with Hirashima’s [7] suggestion that the map rebuilding approach encourages learners to reach a maximum understanding of...
a particular subject. Statistical analysis results reported that groups that use EKB were not merely able to achieve higher average scores but also more equitable distribution in each subtopic of materials.

In Phase 1, the existence of the kit helps students to arrange concept maps in a structured way. In Phase 2, both groups were asked to expand concept maps, and no kit was provided for the experimental group. In principle, the kit is a key concept that uncovers and correlates new ideas in other subtopics. Although students in the experimental group add new concepts and links according to their understanding, the role of the core map structure in the previous phase was still felt. It was proven that the performance and distribution of understanding in the experimental group were superior.

5.2 The Distribution of Students’ Knowledge Structure

A kit is a crucial component that plays an important role in re-constructional concept mapping. A kit is a collection of key concepts defined by the teacher [6], which are intended to assist students in building knowledge structures. The existence of a kit in Phase 1 triggers students to uncover key concepts in Phase 2 and connect them between subtopics. Therefore, experimental groups that use EKB could achieve a higher total map size scores and were evenly distributed across all subtopics materials.

The results of experiments on the original map reported that control groups that used scratch-building were able to achieve a higher number of propositions than experimental groups that utilized finite concepts and links. However, for the additional map, the control group could not maintain its achievements while the experimental group remains consistent. The additional map is a core component in extended mapping that describes students’ enhanced meaningful learning [1], [2], [5]. The EKB approach is proven to promote the attainment of a broader knowledge structure than ESB.

6. Conclusion and Future Work

This study compared the ESB and EKB concept mapping to investigate the distribution of students’ understanding and breadth of knowledge structure. The distribution of attainment on original and additional materials was further investigated. The results reported that EKB not merely outperformed ESB in terms of total understanding score and number of propositions but also had a more even distribution of mastery in all material subtopics. The EKB map that used a kit component facilitates students to have a good memory and integrate one subtopic with other subtopics easily.

Further works should involve a higher number of post-test questions to express students’ understanding of comprehensively. Measurement of knowledge structure should also use not only a quantity measure but also include quality measurements.

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