

USING ENRICHED SKELETON CONCEPT MAPPING TO SUPPORT MEANINGFUL LEARNING

*Ton J. Marée, Eindhoven School of Education, Eindhoven University of Technology, Eindhoven, The Netherlands;
Jan M. van Bruggen, Centre for Learning Sciences and Technologies, Open Universiteit, Heerlen, The Netherlands;
Wim M.G. Jochems, Eindhoven School of Education, Eindhoven University of Technology, Eindhoven, The Netherlands.
Email: a.j.maree@tue.nl*

Abstract. There has been significant interest among researchers in the instructional use of concept maps and collaboration scripts. Some studies focus on students' collaboration on concept mapping tasks; others focus on scripts to structure learning tasks and guide interactions. Little is known about scripted collaborative concept mapping. This article reports a study in which we examine the effects on meaningful learning of scripting students' argumentative interactions during collaborative "enriched skeleton concept mapping". Each concept in the enriched skeleton concept map (ESCoM) contains "annotated factual multimedia information" and an embedded micro collaboration script.

The study was performed in a Biomolecules course of the Bachelor of Applied Science program. First-year students were randomly assigned to an experimental group of 44 students and a control group of 49 students. In the experimental group, students worked together in pairs on an ESCoM guided by embedded collaboration scripts. The control group received the regular course.

The results show that students were able to handle and appreciate the enriched skeleton concept mapping products and processes. Moreover, concept maps appeared to be scored reliable and validly. Finally, the regular course exam showed that the experimental group outperformed the control group. Enriched skeleton concept mapping resulted in a better understanding of the conceptual structure of the domain, the concepts and their relations.

1 Introduction

Students in higher education need to develop a focus on meaningful learning; memorization of facts and procedures is not enough for success (Biggs & Tang, 2007). Graduates from higher education need a deep understanding of concepts to generate new ideas, new theories, new products and new knowledge (Sawyer, 2006).

Meaningful and deep learning has been described as the ability to critically analyze, research and explain new knowledge, facts and ideas by connecting them with existing knowledge, concepts or principles and being aware of one's own development in the learning process (Ausubel, 1963; Biggs & Tang, 2007; Chin & Brown, 2000; Sawyer, 2006). When students are engaged in knowledge construction processes, like collaborative discourse and argumentation, this has a strengthening effect on meaningful and deep learning (Chi, 2009; Mayer, 2002; Nussbaum, 2008). Unfortunately, students in higher education often demonstrate a surface approach to learning (Biggs & Tang, 2007; Entwistle & Peterson, 2004). Moreover, students rarely take the initiative in knowledge construction processes to support meaningful learning (Chi & Ohlsson, 2005; King, 2007). In general, they have to be initiated by a teacher in a face-to-face learning process with students. Given the scarcity of teacher resources, there is a need to develop instructional interventions that are effective in provoking meaningful learning and efficient in requiring a minimum of teacher guidance.

We aim to support meaningful learning by visualizing the conceptual structure of a knowledge domain and regulation of the dialogue between the students. Our visual representation is an enriched concept map.

Students are often asked to start with a "blank sheet" and begin to construct a concept map for some topic. The concept maps are then developed, extended and refined as the students develop other activities on the concepts and increase their understanding (Novak, 1998, 2002; Novak & Cañas, 2008; O'Donnell, et al., 2002). However, to start with a blank sheet may have its drawbacks because asking students to draw a map from scratch may impose too high a cognitive demand to produce a meaningful representation of their knowledge (Schau, et al., 2001). Moreover, students may have misconceptions or faulty ideas about a topic that would impede their learning if they were to begin with a "blank sheet" (Boxtel, et al., 2002; Novak, 2002). For difficult topics, as determined by the teacher's experience, Novak and Cañas (2008) suggest using a "skeleton concept map" as an alternative to having students prepare a concept map from scratch. A skeleton concept map is a partial knowledge domain representation that contains only key concepts and some of the relations between them. The skeleton concept map offers students a foundation to elaborate on by using relevant resources and adding concepts and information resources to their concept map. In this study we provide students with an enriched skeleton concept map. See a part of the enriched skeleton concept map (ESCoM), Proteins, in Figure 1, as an example.

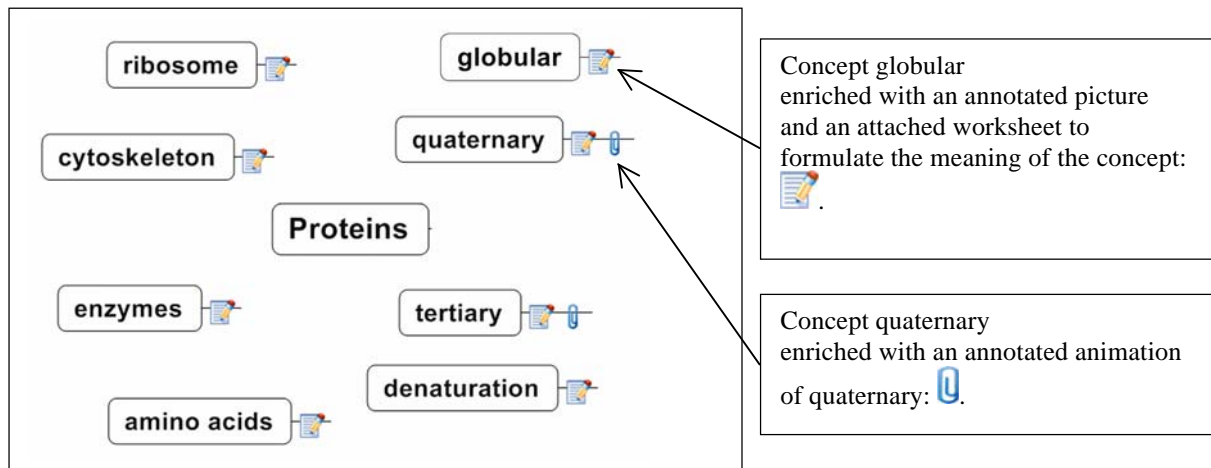


Figure 1. Part of the enriched skeleton concept map, Proteins.

ESCoMs, in contrast to the skeleton concept map of Novak and Cañas (2008), are the visualization of the conceptual structure of a specific knowledge domain, but without the visualization of the relations between the concepts. Each concept in the ESCoM contains (1) annotated factual information (pictures, text or animations) that elaborate on the concept and (2) an attached worksheet to formulate the meaning of the concept. The skeleton concept maps are enriched with multimedia content and a worksheet to provide scaffolds to improve students' knowledge construction. However, to support meaningful learning, we also have to stimulate a meaningful dialogue between the students while they work on the skeleton concept map. According to Nussbaum (2008) and Chi (2009), collaborative discourse and collaborative argumentation are important to meaningful learning because they force students to externalize their knowledge, monitor each other's learning and jointly negotiate the meaning. However, students do not collaborate well if left unaided (Weinberger, et al., 2007). Collaborative learning – be it face-to-face or mediated by a computer – needs to be supported by adequate scaffolds (Fischer, et al., 2007). Collaboration scripts form an important example of these scaffolds.

Collaboration scripts structure students interaction and scaffold collaborative learning through the use of roles, activities, and sequencing of activities (King, 2007). Collaboration scripts can guide students in meaningful discussions and can structure the process of argumentative knowledge construction Dillenbourg and Hong (2008) distinguish "macro scripts" and "micro scripts." Macro scripts are pedagogical models: they describe group formation and the collaboration process using phases, roles and activities. Micro scripts are dialogue models that structure interaction and foster argumentation, explanations and mutual regulation. A micro script may prompt a student to respond to the argument of a fellow student with a counter-argument (Weinberger, et al., 2007). It is expected that students will organize their interaction without the use of collaboration scripts since the scripts will become internalized through practice (Dillenbourg & Hong, 2008; King, 2007).

Until now, empirical research has focused on traditional concept mapping (Novak & Cañas, 2008; Tergan, et al., 2006; Torres & Marriott, 2010). This study aims at demonstrating the potential of the ESCoM with scripted collaborative concept mapping. Our strategy is to guide and support students' argumentative interactions during collaborative concept mapping with collaboration scripts to support students' meaningful learning. We use the skeleton concept map, enriched with multimedia content and an embedded micro collaboration script in the attached worksheet of each concept. The embedded collaboration scripts guide students' collaborative discourse and argumentation. Furthermore, collaboration scripts guide the students to concentrate on the meaning of the concepts and their relations.

This study addresses the following research question:

Does scripted collaborative concept mapping guide and support students' argumentative interaction, leading to better understanding of the conceptual structure of the domain, the concepts and their relations?

2 Method

2.1 Participants

All first-year students ($N=93$, 31 women, 62 men, aged 17 – 33 years, $M = 19.1$, $SD = 2.4$) of the Bachelor of Applied Science program at Fontys University of Applied Sciences took part in this study. Seventy-one percent of the students had a prior senior general secondary education¹ (the regular enrollment) with science orientation; 17% had a previous pre-university education,² and 12% had other previous education. In addition, two teacher-experts in the domain of Biomolecules of the Bachelor of Applied Science program took part in this study.

2.2 Design

The experiment was conducted in a Biomolecules course over a four-week period. The students were randomly assigned to four classes. Two classes of 44 students made up the experimental group. The other two classes of 49 students were used as a control group.

The control group received the regular course: one hour of lecture and three hours of tutorials per week. The lecture was structured as a linear sequence of slides the teacher used to explain the subject matter. The tutorials consisted of class discussions about questions from the textbook.

The experimental group was randomly divided into 22 pairs. They spent the same amount of time as the control group: two sessions of two hours per week. During the sessions, the students worked together on the ESCoM following the collaboration scripts. They had no teacher contact hours, and thus, neither lectures, nor tutorials.

In the week before the course, all students in the experimental group received a two-hour training session in the concept mapping tool, Mindjet's MindManager Pro. The students in the experimental group used a laptop with the concept mapping software tool installed. They learned how to add annotations and data to the concepts and how to create relations between the concepts. Additionally, they were trained to use the concept map in a shared workspace.

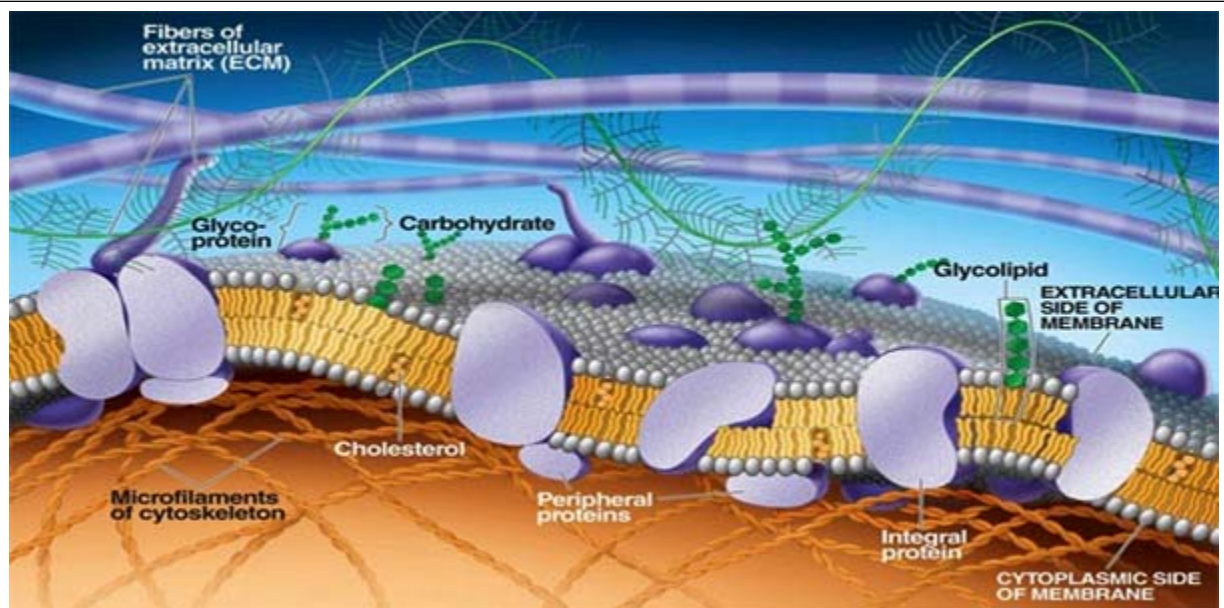
2.3 Instruments

The domain concept map was used as a master map for constructing the ESCoM and as a criterion map to compare the concept maps constructed by the students. The domain concept map was created by two teacher-experts in the domain of Biomolecules. The experts worked together and selected 46 concepts and added 44 relations they considered essential for the students as the domain knowledge representation of Biomolecules. The concepts and their relations were grouped in the domain concept map to represent the four subdomains in order to support students' orientation and navigation. Carbohydrates, Lipids, Nucleic acids and Proteins are the four subdomains of the domain Biomolecules (Campbell, et al., 2008). To each concept and relation, the experts added the information they considered essential for the students in a separate worksheet. We refer to this information as the "expert domain information" as a criterion to compare the concept maps constructed by the students.

In this study we provide students with an ESCoM. The ESCoM provided to the students was derived from the domain concept map by deleting the relations. Each concept in the ESCoM contains (1) annotated factual information (pictures, text or animations) that elaborates the concept, and (2) an attached worksheet containing a "5-step collaboration script." See the concept membrane in Figure 2, as an example. Each new relation contains a "3-step collaboration script." Additionally, the experts filled in the annotated worksheets of three concepts and their two relations as a working example for the students.

¹ In Dutch "hoger algemeen voortgezet onderwijs" (havo)

² In Dutch "voorbereidend wetenschappelijk onderwijs" (vwo)



Worksheet with the associated collaboration script for concepts.

1. Student A and Student B: Formulate individually the meaning of the concept.
 - 1a. Meaning Student A: < . . . >
 - 1b. Meaning Student B: < . . . >
2. Student A and Student B: Discuss and pose critical questions regarding the meaning of the concept and formulate parts of the agreements and disagreements: < . . . >
3. Student A and Student B: Improve your formulations by additional descriptions, elaborations and/or comments: < . . . >
4. Student A and Student B: Formulate jointly the meaning of the concept upon which they agree: < . . . >
5. Student A and Student B: Formulate jointly an example set of characteristics of this concept in a cell or organism: < . . . >

Figure 2. The concept membrane with (1) a picture with specific terminology as annotated factual information, and (2) an attached worksheet containing the associated 5-step collaboration script for concepts. The students have to fill in the blanks < . . . > in the worksheet.

The collaboration script guides students' argumentative interactions. Moreover, the script structurally supports students in critically analyzing, elaborating and explaining the meaning of the concept to support meaningful learning.

For each new relation that the students added, they filled in an attached worksheet according to a "3-step collaboration script" (Figure 3).

Alternate to the lead role.

1. Lead: formulate the meaning of the relation: < . . . >
2. Alternate student: Formulate parts of the agreements and disagreements and proceed with the formulation of the lead by additional descriptions, elaborations and/or comments: < . . . >
3. Lead and alternate student: negotiate a common description of the meaning of this relation: < . . . >

Figure 3. An attached worksheet containing the associated 3-step collaboration script, for relations. The students have to fill in the blanks < . . . > in the worksheet.

Students' appreciation of the concept mapping products and processes were measured using a 28-item questionnaire on a 5-point Likert-type scale, addressing four topics, which took about 15 minutes after the last peer group session. The first topic referred to the adequacy of the domain representation in the enriched skeleton

concept map, related to the information in their textbook, *Biology* (Campbell, et al., 2008). The second topic referred to the effectiveness of the learning activities during the peer group sessions, and the third topic referred to student motivation. Finally, the fourth topic referred to the support offered by the embedded scripts in students' interaction.

The similarity between the quality of the content of a given concept map and a criterion map has been examined (Albert & Steiner, 2005; Ruiz-Primo, et al., 2001; Schau, et al., 2001). Two experts assessed the quality of the annotated content on the students' concept map worksheets. They used a rating scale ranging from 1 (no similarities) to 5 (a great deal of similarities and a complete and correct description of essential information).

In addition, the experts rated the quality of the dialogue with respect to content annotated on each step in order to assess whether the micro scripts guided students to meaningful dialogue and argumentation. The experts used a rating scale ranging from 1 (no dialogue), 2 (moderate dialogue) to 3 (meaningful dialogue).

Finally, the two groups took a test as part of their regular biomolecules examination. The regular exam was composed of 15 multiple-choice items that students answered during a 45-minute period. Exam scores from the course Cell Biology (used as an introduction to Biomolecules) were used to statistically control for differences in students' prior knowledge.

3 Results

The overall means and the standard deviations for the biomolecules exam scores are shown in Table 1.

	<i>N</i>	<i>M</i>	<i>SD</i>
Experimental Group	41	6.44	1,10
Control Group	45	6.08	1.61

Table 1: Biomolecules exam scores

The reliability of biomolecules multiple choice exam is modest: $\alpha = .64$, and sufficient for this study.

Analysis of covariance demonstrated a significant experimental effect on the biomolecules exam scores between the experimental group and the control: ANCOVA, $F(1,86) = 6.35$, $MSE = 9.86$, $p = .014$, $\eta_p^2 = .071$.

The domain concept map, which contains 43 concepts and 44 relations, was used as a criterion map to assess the concept maps constructed by the peer groups. The quality of the content of the 43 concepts the peer groups added to their concept map was rated independently by the two experts. They used a 5-point rating scale ranging from 1 (no similarities) to 5 (a great deal of similarities and a complete and correct description of essential information). The inter-rater reliability between the experts was rather strong ($r = .74$). The quality of content of the 44 relations was also rated independently with a strong inter-rater reliability of: $r = .82$.

The overall means and the standard deviations for quality of the contents scores of the 19 peer groups' concept maps are shown in Table 2.

	<i>N</i>	<i>M</i>	<i>SD</i>
Quality of the contents of the 43 concepts	19	3.91	0.41
Quality of the contents of the 44 relations	19	4.44	0.34
Quality of all the 87 contents	19	4.12	0.33

Table 2: Quality of the contents of the concepts and relations of the 19 peer groups.

The quality of the dialogues of the 43 concepts the peer groups added to their concept map was rated independently by the two experts. They used a 3-point rating scale ranging from 1 (no dialogue) to 3 (meaningful dialogue). The inter-rater reliability between the experts was rather strong ($r = .72$). The quality of dialogues of the 44 relations was also rated independently with a rather strong inter-rater reliability of: $r = .73$.

The overall means and the standard deviations for quality of the dialogue scores of the 19 peer groups' concept maps are shown in Table 3.

	<i>N</i>	<i>M</i>	<i>SD</i>
Quality of the dialogues of the 43 concept	19	2.06	0.46
Quality of the dialogues of the 44 relations	19	1.39	0.41
Quality of all the 87 dialogues	19	1.80	0.37

Table 3: Quality of the dialogues of the concepts and relations of the 19 peer groups.

The correlations between all of the 87 quality of contents and quality of dialogue scores were rather high ($r = .62$). The biomolecules exam scores were rather strongly correlated to the quality of all the content scores of the peer group concept maps ($r = .57$).

Evaluation results shows (1) the adequacy of the domain representation in the ESCoM ($M = 3.77$ on a 5-point scale, $SD = 0.36$), (2) the effectiveness of the learning activities during the peer group sessions ($M = 3.06$, $SD = 0.60$), (3) student motivation ($M = 3.26$, $SD = 0.56$), and (4) the support of the embedded scripts in their interactions ($M = 3.32$, $SD = 0.64$).

4 Conclusion and discussion

The objective of this study was to examine the effects of guiding and supporting students' argumentative interactions during enriched skeleton concept mapping on meaningful learning. The following conclusions can be drawn. First, enriched skeleton concept mapping resulted in significantly better understanding of the conceptual structure of the domain and the concepts and their relations, as evidenced by the exam scores. Second, concept maps appeared to be scored reliable and validly, as illustrated by the high levels of inter-rater reliability. In addition, strong evidence is provided for content validity of the concept maps, as illustrated by the rather strong correlations between the exam scores and quality of the content scores of the concept maps. Finally, students were able to handle and appreciate the enriched skeleton concept mapping products and processes, as shown by the results of the evaluation questionnaire. Apparently, they were able to control their progress in the scripts and the overall progress in the concept map.

Even though the results of this study show positive effects of the enriched skeleton concept mapping method, there are some caveats to consider. First, scoring the concepts and relations took considerable time. However, scoring all the concepts and relations may not be necessary in educational practice. Ruiz-Primo, et al. (2001) suggested that concept maps can be reliably scored from one random sample of concepts. Further research is needed on developing a procedure to score the concepts and relations more time efficiently. Second, the quality of students' argumentative dialogue with respect to the annotated content was rated on a 3-point scale. Further research should concentrate on text analysis mechanisms to assess the quality of the argumentative dialogue. Finally, this study demonstrated the potential of our method of the enriched skeleton concept map with scripted collaborative concept mapping in educational practice. Further research is needed on developing a procedure for this method to become widespread in educational practice.

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