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Use of Concept Mapping in Inquiry learning: An online based-learning environment

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Abstract

Inquiry learning is a specific type of active or engaged learning which is believed to lead to better conceptual understanding compared to direct instruction. Concept mapping is a tool that is often used to support meaningful learning. This study aims to find whether there is a difference in the learning outcomes when using CMs at the beginning - an approach that teachers frequently adopt - or at the beginning and at the end of the learning process. In addition, we assess the difference in quality between the first and second CM within the group that used CM twice, as well as the difference between the second CM and the CM from the group that uses this tool only once. Students were asked to participate in an inquiry based-learning environment.

The results showed that no statistical differences in the learning outcomes and quality of concept maps were found.

Keywords: Inquiry learning, concept maps, learning outcomes, quality.

Theoretical Framework

What is Inquiry Learning?

Usually, when acquiring conceptual knowledge, it is essential that students develop proper understanding. Conceptual knowledge has been defined as knowledge that represents organised connections between concepts, theory, and/or methods in the field and allows (causal) deductions (Bennet & Bennet, 2008). Learning at this level involves time and effort, and is connected to expertness, adaptability of use, instinct and application. This form of “active” or “engaged” learning has been found to encourage deeper conceptual knowledge than direct instruction (Hake, 1998). This is based on constructivism principle, which defends that students learn better when they generate their own knowledge (Balım, 2009). Nowadays, science education supports this model for learning because it encourages students to develop skills related to inquiry, critical thinking, questioning, and problem-solving. In addition, the introduction of some technologies into classroom have been found to enhance cognitive engagement, in addition to efficiency, reach, personalization, and quick updating. Some examples of this engagement are reflected in inquiry learning or collaborative learning (de Jong, 2019).

In *Inquiry Learning* (IL) “students investigate scientifically-oriented questions, conduct experiments, formulate explanations based on evidence, evaluate their explanations in light of alternative explanations, and communicate and justify their proposed explanations” (de Jong & Lazonder, 2014, p.372). It involves a question or problem that invites the learner to investigate the topic to study (Kuhlthau, 2010). IL can be implemented using supported learning environments that incorporate computer simulations, which are also suitable for collaborative learning. By doing so, instead of directly providing the learning content to the students, they must create it by themselves. This leads us to the main rationale of the IL principle: students learn better from created material rather than from received material (de Jong & Lazonder, 2014). IL enhances a deep learning (Hmelo-Silver, Duncan, & Chinn, 2007) because it fosters more robust long-term cognitive structures than traditional lectures (Schmidt, Loyens, Van Gog & Paas, 2007). Computer tools (like Hypothesis Scratchpad) in the learning environment can aid learners with managing complex concepts and taking the scientist’s role, acquiring knowledge regarding real problems (Stoddart, Abrams, Gasper & Canaday, 2000).

Science education has been recommended to use activity-based science teaching, which encourages students to explore their environment and discover nature, and increases and sustains their motivation, as in inquiry learning (Inyang, 1993). Meanwhile, the teacher facilitates and guides students towards their learning goals. Guided Inquiry accomplishes the actual academic objectives through enhancing and engaging learning, and is related to the students’ environment (Kuhlthau, 2010). The Guided IL principle states that students should be guided to ensure effective learning during scientific discovery in multimedia environments (de Jong & Lazonder, 2014). Similarly, teachers use guided IL to help students to understand and create their own perspectives through different source materials (Kuhlthau, Maniotes & Caspari, 2007), as well as to provide them with skills to confront the difficulties they may encounter (Kuhlthau, 2010). A proper guiding during the learning process usually favours better learning consolidation than providing direct instruction (Alfieri, Brooks, Aldrich, & Tenenbaum, 2011).

Processes involved

Inquiry-based learning is most of the time organized into inquiry phases that together form an inquiry cycle. However, different variations of this cycle can be found throughout the literature. Pedaste et al. (2015) made an analysis of a large set of articles describing inquiry phases and developed a synthesized inquiry cycle that combines the strengths of existing inquiry-based learning frameworks. They distinguish the following phases: Orientation, Conceptualization, Investigation, Conclusion and Discussion (de Jong et al., 2014, Pedaste et al., 2015).

During *Orientation*, learners familiarize themselves with the question to be examined. Orientation can take place in an ICT based learning environment or can be provided by the teacher or through self-study materials (Scanlon, Anastopoulou, Kerawalla & Mulholland, 2011). This phase aims to help students get used to the main elements and difficulties related to the topic at hand.

In the *Conceptualization* phase, students get to know the concepts regarding the topic to investigate and choose between two sub-phases depending on the nature of the inquiry task: a *Question* sub-phase and a *hypothesis* sub-phase. Both evidence-based are evidence-based and involve independent and dependent variables. However, the *hypothesis* sub-phase needs to find an explicit connection between the variables and inquire. Meanwhile, the *question* sub-phase is more indeterminate and asks for an analysis regarding the correlation between variables.

When students shift to the *Investigation* phase, they will follow one of two different sub-phases according to their election in the previous phase: *exploration*, if they formulated a question; or *experimentation*, if they formulated a hypothesis. In both sub-phases, students are required to plan and complete the experimental procedure. Meanwhile, in the *data interpretation* sub-phase, they attempt to explain the gathered data and understand the correlation between variables (Bruce & Casey, 2012; Lim, 2004). The *exploration* sub-phase involves the investigation of more than one combination of variables or possible correlation found in the *question* sub-phase; and the *experimentation* sub-phase studies the specific pair of variables or the possible connection found in the *hypothesis* sub-phase.

In the *Conclusion* phase learners represent their findings, and they state whether they answered the research questions, and whether they confirmed or rejected the hypothesis they formed previously (Scanlon et al., 2011). For an open research question, this phase aims to find an association between variables. However, for a hypothesis it intends to encounter the acceptance or rejection of such hypothesis.

Last, the *Discussion* phase consists of the students' sharing the outcomes found, either with their classmates or with the teacher. This phase is divided in two sub-phases. In the *communication* sub-phase, students can explain their results and conclusions to other students (Scanlon et al., 2011), as well as listen to their classmates' results and conclusions (Bruce & Casey, 2012). Meanwhile, the *reflection* sub-phase enables students to display the accomplishment of the investigation and provide recommendations for improvement (Lim, 2004). Additionally, this phase includes giving and receiving feedback. Also, both the *communication* and *reflection* sub-phases can take place during all the investigation process.

Problems students may encounter.

Various authors have acknowledged numerous learning benefits to IL (de Jong & Lazonder, 2014; Kuhlthau, 2010; Stoddart et al., 2000; de Jong et al., 2014, Pedaste et al., 2015). The effectiveness of this kind of learning is usually assessed through domain knowledge post-tests (Lazonder & Harmsen, 2016). However, the advantages of IL may be negatively affected if students do not receive proper guidance and supervision during the process (Mayer, 2004). IL consists of many different processes (Orientation, Conceptualization, Investigation, Conclusion and Discussion) and subprocesses, and students must manage them and regulate their own learning. Research indicates students have difficulties with almost all subprocesses of the IL cycle (de Jong & Van Jolingen, 1998).

One obstacle to the effectiveness of IL is its high complexity. It is possible that learners can follow the basic inquiry process, but do not yet have the skills to apply it in more difficult situations (de Jong & Lazonder, 2014).

The effectiveness of IL can also be undetermined by some obstacles students may find during the process, e.g.: creating hypotheses, constructing explanatory and clear experiments, giving meaning to the data, elaborating conclusions regarding their hypotheses, as well as for directing and controlling their learning process (de Jong & van Joolingen, 1998).

Other possible reasons for decreased effectiveness of IL might have to do with the individual characteristics of the students: they may be able to perform correctly the required tasks, but not to take any initiative by themselves. Moreover, students might not be very sure about when and how they should execute an activity or learning process. Additionally, in other situations, students may not be capable to perform the activity on their own or the activity might be too difficult to perform from memory (de Jong & Lazonder, 2014).

As previously stated, IL asks for the learning content not to be provided to the students. However, if prior knowledge (and instructional support) are missing, the usefulness of IL is less perceived by the students, and the effectiveness of their task performance may decrease (Mulder, Lazonder & de Jong, 2015). If learners lack prior knowledge or cannot find the answers by themselves, this data can be communicated before or during the process. Afterwards, students then participate in an inquiry-based learning environment, where they learn while interacting with such information (Hmelo-Silver et al., 2007).

Students may find different kind of problems during their immersion in inquiry-based learning environments. The benefits of IL only remain when the inquiry process is properly organised and supported (Mulder et al., 2015).

Supporting IL

The effectiveness of IL is subject to the disposal of proper support (Lazonder & Harmsen, 2016). Different types of support can be given during IL, such as directive support and non-directive support. Directive support leads students to a specific objective, like providing them a ready-made hypothesis to research. Non-directive support assists students in carrying out some actions, but without telling them what to do, like in *scaffolds*. They aid students immerse in a learning process by organizing and assisting the activities included in such process. They are useful when the process is too complicated or when students are not prepared to perform the tasks by themselves. Some methods of scaffolding are a Hypothesis Scratchpad and Concept Mapping (Zacharia et al., 2015). This study focuses on Concept Mapping.

Concept Maps (CMs) are visual illustrations of learning composed of concepts — often represented in ovals or boxes — and the connections between them —shown by lines. Words written over the lines clarify the connection between such concepts. CMs help to organise relevant information regarding a topic. They can include explanatory examples of the represented concepts, which are usually not enclosed in circles or boxes, as they just refer to specific situations or elements (Cañas et al., 2003).

CMs can have diverse structures according to terms and their connections — such as spider or hierarchy maps (All et al., 2003). However, the structure is usually related to the context and topic of study, so CMs should be created according to the specific question to solve, in addition to the user's vision (Jonassen, Reeves, Hong, Harvey & Peters, 1997). Hence, the organization of a map varies among students, depending on their understanding and the learning content (see Figure 1 for an example of a CM).

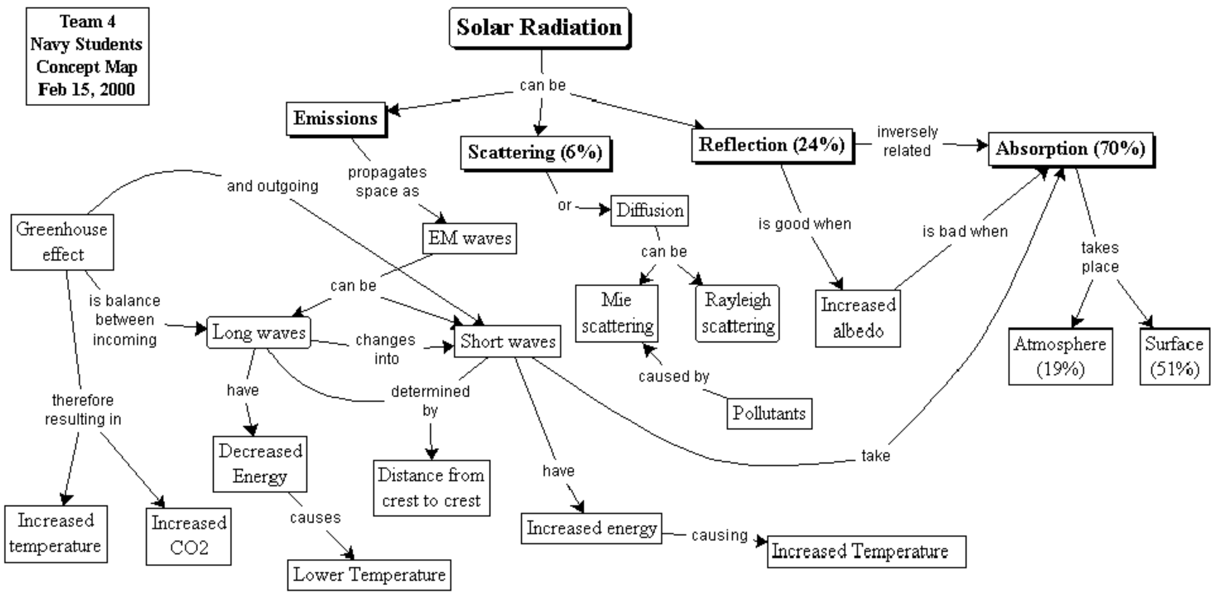

Figure 1. Example of a Concept Map.

Processes CM can support in IL

When immersing in IL, students can find different kind of problems. Such problems can be assisted by CM through different processes. Each of those processes has been found to include a variety of benefits, which are described below.

1) *Scaffold for comprehension*. Students learn better when they associate and visualise the concepts regarding the knowledge to acquire, and when they create their own comprehension of the topic based on their previous knowledge, abilities, manners and thoughts (Hanson, 2006). CM helps to improve conceptual understanding (Adodo, 2013). The student must attempt to clarify definitions, through the classification of relevant concepts, connections and organization regarding the specific topic to study (Novak & Gowin, 1984; as cited in Cañas et al., 2003). CM enhances learning of interrelationships between numerous concepts (Cañas et al., 2003), as students can explain their understandings and associate clear ideas (Markow & Lonning, 1998). It

also assists students and teachers to recognize misconceptions, as well as to find information more quickly (Cañas et al., 2003). Identically, CMs can help to identify the gaps in students' knowledge, improvement in their understanding and reorganization of their learning (Novak, 2010). Also, this tool has assisted teachers and students to structure the knowledge in the provided discipline or topic (Adodo, 2013). One of the obstacles that hinders the effectiveness of IL is its high complexity (de Jong & Lazonder, 2014). Hence, these characteristics of CM can help to mitigate this barrier. Additionally, this tool enables students to regulate their learning, give them more determination in their learning methods and immerse them in cognitive, affective, and psychomotor learning (All & Havens, 1997). These benefits connect with a more thorough comprehension of the topic, transfer to practice and learning retention at a long term (Hicks-Moore, 2005). According to IL, learning is better consolidated when students transfer their acquired knowledge to practice (Hanson, 2006).

2) *An instrument for integrating educational practices*, as it can be employed to summarize and reflect what students have learned — it is frequently utilized for taking notes or a study support (as revised in Novak & Gowin, 1984). Students learn better when they associate and visualise the concepts regarding the acquired knowledge. CM can favour learning in IL by making visual representations of the content to study (Hanson, 2006).

3) *An instrument for enriching the conditions for learning*. CM enhances meaningful learning (Cañas et al., 2003), which occurs when students integrate and associate the acquired content into their prior knowledge (Novak, 2010). Different reasons explain this. First, CMs help to make knowledge more explicit, through adequate language and examples. Second, it assesses students' prior knowledge, misunderstandings, and depth of their significant learning (Watson, Pelkey, Noyes & Rodgers, 2014). Third, CMs assist students to acquire new concepts into such prior knowledge, increasing their motivation to learn (Cañas et al., 2003). These characteristics can contribute to mitigate the complexity students may encounter around IL. In addition, CM might help students to integrate the knowledge acquired in the inquiry tasks with their current knowledge (Mulder et al., 2015).

4) *A help or substitute to usual writing assessment.* When immersing in IL environments, students can find some difficulties during the process, such as high complexity of the content (de Jong & lazonder, 2014), or other obstacles, e.g.: constructing explanatory and clear statements, giving meaning to the data, elaborating

conclusions, etc. (de Jong & van Joolingen, 1998). CM plays an important role here, since it has been considered a helpful assessment tool for instructional activities (Adodo, 2013; Novak & Cañas, 2006). This tool can be used in formative or summative assessment processes. In formative assessment, students create CMs in different moments of the learning process, and instructors use this map to evaluate the student's comprehension and to adjust the course. Meanwhile, summative assessment may be used at the end of a course unit to define the students' comprehension, and to assign grades (Cañas et al., 2003). As previously mentioned, CM can help to recognize possible misconceptions (Cañas et al., 2003) or knowledge gaps (Novak, 2010) students may present during the inquiry process.

5) *An aid for critical thinking.* CM enriches questioning, argumentation (Cañas et al., 2003) and exploration (Adodo, 2013), which makes it a practical tool for IL (de Jong & Lazonder, 2014), as students learn better when they stablish conclusions by exploring available data, theories and examples (Hanson, 2006). It encourages students to produce and acquire new knowledge, what concludes in the profound and larger sequence of learning and, thus, enhances critical thinking (Conceicao & Taylor, 2007). According to IL, students usually learn more when they think about what they have learned and by enriching their task performance (Hanson, 2006). When students correct their CMs other concepts and/or connections may appear (Novak & Cañas, 2006), what helps students to bring into line the inquiry tasks they are performing with their current knowledge (Mulder et al., 2015). Additionally, this tool favours problem-solving skills or student learning achievement (Santiago, 2011). CM encourages proper comprehension between the students (Vacek, 2009). It also fosters metacognition — learning to learn and thinking about knowledge —, and evaluates students' comprehension of the learning goals, the concepts and the association between them (Martínez-Cañas & Ruíz-Palomino, 2011).

6) *A facilitator of the interaction between students.* IL asks students to be dynamically involved in the task and create their own learning (Hanson, 2006). Similarly, for CM to be effective, students need to be active at their own learning and interact with the learning material towards the subject. Such interaction can be facilitated when an agent enhances active discovery and structure, e.g. by formulating questions, asking for explanation and rationalization, enhancing association between concepts, critical thinking, etc. (Cañas et al., 2003). One possible agent that provides this interaction would be the teacher who, according to Guided IL, should facilitate

learning during students' task performance to ensure a better learning consolidation (Hanson, 2006). The same author remarks that another agent could be a collaborative group, as students learn better by debating, when they work collaboratively to understand the learning content and to resolve the problems (Hanson, 2006). Last, a facilitator of this interaction would be a device (like expression builders that help students formulate research questions and hypothesis, or data interpretation tools) (Cañas et al., 2003). IL, collaborative learning and CM can be combined and linked to collaborative CM. Some authors found that collaborative CM favours discussion in the communication among students (Chinn, O'Donnell & Jinks, 2000). It supports processes such as brainstorming, as the precision and visualization of knowledge might ease students to understand the topic, favouring debate about it (Cañas et al., 2003). Additionally, this relates to IL in a sense that students learn better when they debate their opinions (Hanson, 2006). The representation of this tool can help members of a group to make consensus about the generation of a CM (Cañas et al., 2003).

In addition, CM has been attributed as adequate for low-achieving students. It encourages them to learn through the dynamic and systematic learning procedure usually common in high-achieving students, who are active and use a questioning and tidy approach to learning (Cañas et al., 2003). Comparably, CM asks lower-achieving students to be determined and apply a structured way to learn, as high-achieving students do (Aziz & Rahman, 2014). However, if students are not familiarised with the use of CMs, an excess of cognitive load may be produced, which would obstruct learning. Therefore, at the beginning, it is recommended to support these students in the use of this tool. For example, by providing them with a CM where the connections among concepts is already given and asking them to write the missing concepts in the blanks.

CMs can be represented paper or computer-based (Aşıksoy, 2019). Computer-based CMs are easy to organize and present, highlight the important information, add comments, establish connections among concepts. Additionally, they help users to make a mental picture of the representation and interact with the content (Lin, Chang, Hou & Wu, 2015), enhance their skills regarding the generation of models and to reflect the findings from an experiment (Chang, Sung & Chen, 2008). Previous research showed that CM has improved science curriculum (Adodo, 2013), and has been used in different subjects, for example, chemistry (Markow & Lonning, 1998), ecology and environmental education (Brody, 1993), history (Baldissera 1993), and mathematics (Khan, 1993).

The present project

Despite all the benefits CM has for IL, there it is still little research about the effectiveness of this tool regarding its frequency of use. This study aims to combine the learning benefits of CM on an IL environment with the frequency of use of this tool. More specifically, this tool will be used in two different moments: at the initial stages - an approach that teachers frequently adopt – and at the beginning and the end of a learning environment. By doing so, it will be observed whether the effectiveness of CM increases when using it more frequently. A main research question will be followed: *What is the difference in the effectiveness of using* CMs *at the beginning and at the beginning and end of the learning process regarding the learning outcomes?* It is also unknown whether the quality of CMs improves, according to such frequency. Hence, two subsequent sub-questions will also be studied: *What is the difference in the development between the second CM and the first CM within the group that used CM twice?;* and *What is the difference in the quality of the second CM and the CM from the group that uses this tool only once?*. Three hypotheses will be formulated. First, the condition that uses CM at the beginning and at the end will have better learning outcomes than the group that uses it only at the initial stages. It is expected that students who adjust their CMs will have more opportunities to improve their representation of conceptual knowledge (Novak & Cañas, 2006) and to make connections with their prior knowledge (Mulder et al., 2015), what will result in a higher learning consolidation. Second, the development of the second CM will be higher than the first CM in the group that uses CM twice. At the end of the lesson, students should have more knowledge of the topic. Hence, their CM may include more concepts and/or connections between them at this stage than at the beginning (Novak & Cañas, 2006). Third, the second CM will be more evolved in the group that uses CM twice than such of the one using it only once. It is expected that students who do the CM also at the end will include more learning content than those who use CM only once (Novak & Cañas, 2006).

Method

Participants

The sample included 50 international students of the first and second years from the University of Twente, in the East of the Netherlands, 15 males and 35 females aged from 18 to 38 years old (*M=23.20; SD= 4.46)*. The participants were expected to have no knowledge about the topic of the Environmental Education. Students with a background in such topic were excluded to participate in the study. Participants were new with the CM tool from Go Lab. They were requested to sign a consent form explaining the nature of the research, the possibility to withdraw and the privacy of their data. Thereafter, participants were randomly assigned to one of the two groups explained in the subsequent section.

Design

The study applied an experimental design with the use of CM as the independent variable and learning outcomes and quality of the CMs as the dependent variables. The independent variable had two levels: Using the CM at the beginning of an instructional lesson or using it both at the beginning and at the end. Learning outcomes regarding the instructional lesson were assessed individually by a post-test after the participation in the online simulation. The quality of the CMs was assessed based on the content presented by the students. A pre-test in this case was not administered since that assessment may have provided details about the domain, and participants may have obtained hints about what they should learn for the later post-test.

Participants were randomly assigned to one of the two conditions: CM only at the beginning (1-CM-condition), and CM both at the beginning and at the end of the process (2-CM-condition). Amidst the 50 participants, 25 of them used the CM only at the beginning, while 25 used CM at the beginning and the end of the instructional lesson.

Materials

The major instrument for this project consisted of an inquiry-based learning environment about Environmental Education created with Graasp (graasp.eu), an authoring system for developing interactive computer-based learning environments. A lesson on Island Biogeography Theory was developed. Participants were expected to have no prior knowledge about this topic, but still feel familiar with it. The learning environment from both versions consisted of various phases. First, in the *Introduction*, students were addressed to join the lesson, and they were requested to fill in questions regarding their demographic data and knowledge in biology. During *Orientation,* explanations about Island Biogeography Theory were administered through a text and a video. In *Prior Knowledge,* students were invited to create an initial CM about their understanding referring to the information they were provided within the Orientation phase. In the *Investigation* phase, an online lab about Island Biogeography was implemented. An extra phase for the 2–CM– condition was added, *Adjust Concept Map.* Within this phase, students were newly invited to develop the CM, based both on the knowledge from the *Orientation* and *Investigation* phases. The final phase for both conditions was the *Test.* Within this phase, students were asked to fill in a learning outcomes post-test regarding the topic provided within the learning environment. The links to both versions of this ILS — 1-CM-condition and 2-CM-condition, respectively — can be found below:

http://graasp.eu/ils/5c4055f48e853c8532257333/?lang=en

http://graasp.eu/ils/5c6ab8678e853c8532913a4c/?lang=en

The sub-instruments that composed this learning environment are described below.

Explanatory handout. Participants were provided with a printout regarding information and instructions about the lab (see Appendix 1).

Background information questions. To gather background information about the participants, they were asked to answer five questions before being introduced to the instructional lesson. Two questions asked them for demographic data (gender, age), and the other three for knowledge in Biology: 1) whether they had Biology in their high school final test; 2) whether they had knowledge about the theory of Island Biogeography; and 3) whether they had knowledge about the Theory of MacArthur and Wilson (see Appendix 2).

CM tool. The CM tool used within this environment used boxes to write the concepts and arrows to indicate the connections between them. Within this tool, participants could represent their understanding of the lesson. Participants were asked to use this tool to organise the learning content (Adodo, 2013) and the connections among its concepts (Cañas et al., 2003). In addition, they could summarise and reflect their learning (as revised in Novak & Gowin, 1984). In addition, it was useful as a learning assessment for the reviewers (Adodo, 2013; Novak & Cañas, 2006). Such device included instructions on how to construct it, and it can be found in the link below (see Figure 2 for an example): http://graasp.eu/applications/5c405743a17fe340ea17a66c

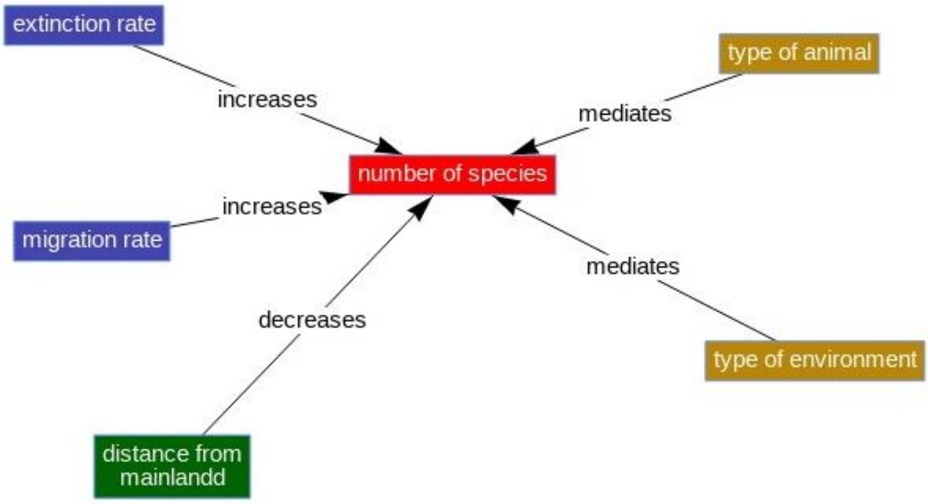

Figure 2. Concept Map tool.

Online lab. Students participated in a lesson about Environmental Education, which included an online lab from Virtualbiologylab.org. This lab consisted of a simulation of the Island Biogeography Equilibrium theory, from MacArthur & Wilson (1963). Within the simulation, it was possible to examine the relation between the island size and its distance from the shore and the biodiversity. Additionally, it was possible to compare such connections using both diverse species (e.g., mammals or reptiles) and habitats (e.g., desert or subtropical). Participants could run virtual experiments manipulating the following elements: island size, distance from the mainland, habitat type (Tropical, Sub-tropical, Temperate, Desert or Savanah), and species groups (birds, mammals, arthropods, reptiles) (see Figure 3 of the lab). Within the learning environment, it was possible to observe the number of different species on each island, and the number of individuals of each species. Participants were asked to discover the relationship between all these variables. The lab can be viewed in the following link:

http://virtualbiologylab.org/NetWebHTML_FilesJan2016/IslandBiogeographyModel.html

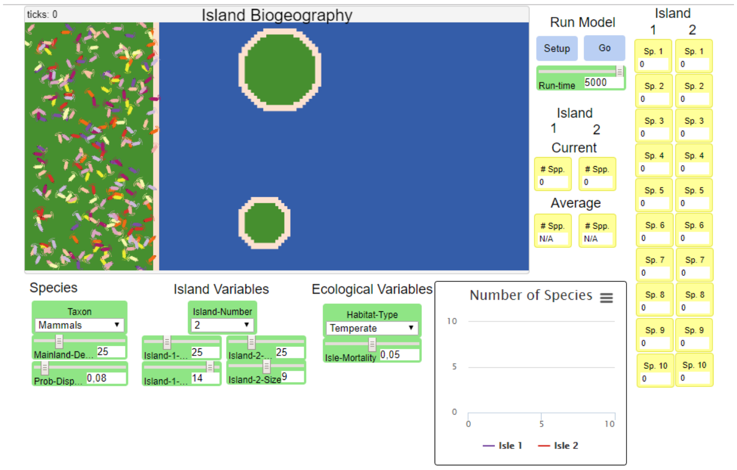

Figure 3. Lab on Island Biogeography.

Learning outcomes test (post-test). To assess the knowledge gained through this lesson, students were administered with a learning outcomes test after their participation in the lesson. The questions for this test included open answers (e.g.: *Please, name two aspects that influence the species richness*), multiple choice answers (e.g.: *Large islands have _______ species richness than small islands: Lower, higher, same*), and true-false answers (*How does the island size affect the extinction rate? Select the correct statement: Big islands have lower extinction rates than small islands; small islands have higher immigration rates than big islands*). The maximum score was 10 points (see Appendix 3).

Analysis

The data obtained in post-test and the CMs were analysed through an independent samples T-test method in SPSS.

Learning outcomes. To determine whether this learning was more significant in 1-CM or 2-CM condition, an independent samples T-test was applied. To assess whether one group learned more from the learning environment than the other, the mean scores of the tests were compared between the participants from both conditions. To assess if there were equal variances between the scores of such the learning outcomes test, Levene's test was applied.

Concept Maps. CMs represented students' understanding of the learning content. CMs from both conditions were analysed according to the variables they included, which were as follows: Proper concepts from the domain, the links between them, defined connections (*incoming species depends on size of the island*) and specific connections (e.g.: *larger size of the island increases number of species on island*). Each of these variables received 1 point regarding the number of times they appeared in the CM. To be scored, concepts had to be linked to other concepts. Examples were scored according to their presence (1 point) or absence (0 points) in the CM. Other more complete scoring systems were found, with extra elements to be measured: Hierarchy, processes, complexity, conceptual development and representation of knowledge (Kinchin Hay & Adams, 2000). However, this method for scoring was not chosen for this study since not enough data from the participants were available to analyse such elements.

To assess the differences in the quality between the first and second CM within the 2-CM-condition, a paired samples T-test was applied. The mean scores from the second CM and the CM from the 1-CM-condition were compared through an independent samples T-test. This way, it was assessed whether there was a difference in the quality of the CM between both groups.

Procedure

Before introducing the session, students were informed about the nature of the project. They were solicited to sign a consent form regarding their personal privacy, as well as their possibility to quit if they chose it. Additionally, they were randomly assigned to one of the experimental conditions, 1-CM or 2-CM condition. Subsequently, they were provided with a handout in which information about the project was transmitted. Next, they were immersed to the lesson of Island Biogeography. Participants of one condition used the CM only at the beginning of the lesson to represent their understanding, while the other participants used it also at the end of the experiment. Afterwards, students were administered with a post-test to measure the acquired knowledge in Island Biogeography during the experiment. To conclude, they were interrogated about their experience in the experiment.

Results

Learning outcomes post-test

An independent-samples T-test was conducted to compare the use of the CM between 1-CM and 2-CM conditions in learning outcomes post-test. There was a not significant difference in the scores for the 2-CM and 1-CM conditions; t(48)= -1.05; p =0.917 (p>0.05) (see Table 1). Levene's test resulted in equal variance, with F=0.072; and p =0.917 (p>0.05). Therefore, equal variances between both groups were assumed. Hence, no difference in learning outcomes among the two groups were found.

Table 1. Mean scores and standard deviations on the post-test for learning outcomes between 1-CM group and 2-CM group (maximum = 10 points).

	1-CM group		2-CM group	
	M	SD	M	SD
Learning outcomes post-test	8.28	1.31	8.32	1.38
Minimum score	6		5	
Maximum score	10		10	

CMs

Regarding the group who used the CM both at the beginning and at the end, a paired-samples T-test was applied to determine whether the quality of the CM improved from the second to the first CM. The results showed a non-significant difference in the quality of the first CM and the second CM, since t(24)=-0.94 and p=0.36 (p>0.05). However, these results were not significant.

An independent-samples T-test was conducted to compare the quality of the CMs in the second CM from 2-CM-condition and the CM from 1-CM-condition. There was a not significant difference in the scores for the 2-CM and 1-CM conditions; t(48)= -0.66, p = 0.51 (>0.05) (see Table 2).

Table 2. *Mean scores and standard deviations on the first and second CM from 2-CM group and CM from 1-CM group (minimum = 3 points; maximum = 28 points).*

	1-CM group		2-CM group			
	CM		1st CM		2nd CM	
	M	SD	M	SD	M	SD
CMs scores	18.40	14.16	18.36	13.85	20.92	12.62
Minimum score	3		4		0	
Maximum score	54		49		46	

p=0.51 (>0.05)

Discussion

The main goal of the study was to measure the effect of CM on learning outcomes of two different condition groups. The first condition group developed the CM at the beginning of the lesson (1-CM-condition), whereas the second condition group developed the CM at the initial stage and at the end of the lesson (2-CM-condition).

Additionally, the quality of the second CM and the first one was compared. Last, the quality between that second CM and the CM from the 1-CM-condition were compared. An inquiry-based learning environment about Island Biogeography Theory was presented. Afterwards, the students had a learning outcomes post-test. About these objectives, three hypotheses composed this study. First, 2-CM-condition would get better learning outcomes than 1-CM-condition. Second, the quality of the second CM would be higher than the first CM in the 2-CM-condition. Third, the quality of the second CM would be higher than the CM from 1-CM-condition. All hypotheses were rejected, so null hypotheses were accepted. Different reasons might explain these results.

Rejection of the first hypothesis — The 2-CM group would get better learning outcomes than 1-CM group.

Results indicated that there were no statistical differences in learning outcomes between 1-CM and 2-CM conditions. This is not what was expected. In previous research, CM was found as most effective when used as a continuum, rather than occasionally. When used during the thorough process, CM helps to ensure learning consolidation. This way, students first live an instructive experience — e.g.: a lecture. Subsequently, they use CM to consolidate their learning (Cañas et al., 2003).

In addition, participants typically achieved high scores on the learning outcomes post-test. Some key factors might have favoured such high scores. The lesson was considerably brief, and the learning outcomes post-test was directly afterwards. Moreover, the topic was reported to be considered as relatively easy. The questions may have been found easy and intuitive as well. In addition, this study did not administer a pre-test. Therefore, supplementary information about participants' pre-existing knowledge was missing. Participants maybe possessed intuitive understanding.

Rejection of the second hypothesis — The quality of the second CM would be higher than the first CM in the 2-CM group; and third hypothesis — The quality of the second CM would be higher than the CM from the 1-CM group.

In the 2-CM group, some participants did the same CM for both moments, and did not include many elements. This is not what was expected. What could be the reasons why the second CM was not better than the first one? As previously mentioned, the topic was considered easy and was unrelated to participants' studies. In addition, participants signed up in the experiment to receive university credits to complete their studies. Consequently, motivation was rather external than internal. CM tool maybe was found as time-consuming to acquire, reflect and generate (Schau, Mattern, Zeilik, Teague, & Weber, 2001), in addition to not entirely relevant, since not every student reacts positively to CMs (Santhanam, Leach & Dawson, 1998).

On the contrary, other participants developed quite detailed CMs — e.g.: including examples in boxes. What could be the reasons for these large differences between the CMs? It is important to mention that, when applying CM, students are immersed in a creative process (Cañas et al., 2003). In addition, students usually differ in their "learning styles." The switch from rote learning to inculcate meaningful learning may be difficult (Kinchin, 2001). Some participants may have had more tendency to meaningful learning, while others tended more to rote learning. Participants from the first group may have been more prepared and preferred to represent their understanding visually without any difficulty. Meanwhile, participants with rote learning might have been found demanding to immerse themselves in the creative process of CM. It might have been challenging for them develop a proper CM (Cañas et al., 2003), and probably felt insecure about their performance (de Jong & Lazonder, 2014). They may have lacked experience employing CM and been unaware of the learning benefits of this tool (Santhanam et al., 1998). Nevertheless, this did not mean lack of understanding of the learning content, as reflected in the learning outcomes post-test.

Other possible reason for these differences in the development of the CMs could rely on the participants' perceived utility about CM. Despite the learning benefits attributed to this tool, its usefulness may differ according to the learners' objectives — e.g. answering a question, solving a problem or discovering more about the configuration of a specific topic (Cañas et al., 2003). It is possible that participants from this study had different goals and — e.g. receiving university credits, learning for the test, learning at a long term — and, hence, they developed a more simple or complete CM accordingly.

Implications.

Theoretical implications.

Although the previous hypotheses were rejected, the results might serve upcoming studies. The feedback provided by the participants suggested that learning through this simulation was more engaging and that they would retain the content better than if they had just received an explanation. This could relate to the IL principle: students learn more when creating knowledge than if they passively receive it (de Jong & Lazonder, 2014; Balım, 2009). Moreover, according to Guided IL, guiding students in multimedia environments ensures effective learning (de Jong & Lazonder, 2014), rather than receiving direct instruction (Alfieri et al., 2011). CM, used in the study, aids students to represent and structure their findings (Chang et al., 2008; Adodo, 2013) and understandings (Markow & Lonning, 1998; Adodo, 2013). In conclusion, CM is equally useful as a learning assessment for students and researchers (Adodo, 2013; Novak & Cañas, 2006).

Practical implications.

Before implementing the lesson, teachers should collect information about students' prior knowledge. Students could be introduced to a topic in which they have not or limited knowledge about, so they are more challenged (Afamasaga-Fuata'i, 2004). With longer lessons, more learning content could be included in CM. Moreover, students would get more learning benefits from it. Additionally, CM enhances critical thinking, questioning and problem-solving skills (Balım, 2009). Additionally, teachers could administer CM during the entire unit, so learning is more consolidated (Cañas et al., 2003).

Furthermore, they should evaluate periodically the students' performance at CMs. By doing so, a better consolidation and appropriate use of the technique would be ensured and guaranteed. When correcting CMs, other concepts and/or connections may appear. Usually, good CMs grow from three to many corrections (Novak & Cañas, 2006). Last, teachers could develop a more valid and reliable learning assessment.

Limitations and future research.

The expected hypotheses were unconfirmed. However, some aspects that could help subsequent research were discovered.

In this study, a small sample size of social science students participated. Moreover, the topic at test was unrelated to their course content. Furthermore, as the time for interaction with the environment was limited, the lesson was brief and had low complexity. Therefore, there was not enough data about the participants' knowledge of the topic, so a limited scoring system for the CM had to be used. This might have influenced the outcomes from the study. If more time is available, a more lasting, complex and relevant lesson should be created — e.g. Physics for third year of Secondary students. By doing so, participants could represent more learning content in the CM. Hence, a more complex scoring system for this learning tool could be used, measuring the following elements: Hierarchy, processes, complexity, conceptual development and representation of knowledge (Kinchin et al., 2000). In addition, since the learning outcomes post-test was administered after the lesson, it is considered that this factor favoured that participants remembered the content easily. Hence, it is recommended for future studies to give more space between the lesson and the learning assessment. Moreover, a prior knowledge pre-test should be administered, so this information can be compared with the learning outcomes post-test and it is possible to observe participants' learning from the IL environment. In addition, as CM has been found to favour learning retention at a long term (Hicks-Moore, 2005), it would be interesting to apply a learning retention test sometime after the lesson, to assess whether participants remembered the lesson at a longer term.

Participants may have been unfamiliar with CMs and, therefore, they may have not been prepared for using this tool. Hence, it is important that in future research CM is introduced properly for learners to perceive its benefits and use it in a long term. CM should be introduced at the beginning of education —, before learning techniques are fixed —, or in later university years — to resolve significant problems from work life (Santhanam et al., 1998).

In the present study, participants were presented with an inquiry-based learning environment. Participants were assigned to two conditions, and in both they were asked to use CM to represent their understanding of the learning content. Since there was not a condition that did not use CM, it is not possible to draw conclusions about its effectiveness as a learning tool in general, but only about the effect in timing. To gain a more detailed understanding of students' perceived usefulness on CM, questionnaires on the usage of this tool can be administered. Furthermore, having an expert map would be helpful (Coleman, 1998; Osmundson et al. 1999).

Conclusion

The present study rejected the three hypotheses formulated at the beginning. First, 2-CM-condition would get better learning outcomes than 1-CM-condition. Second, the quality of the second CM would be higher than the first CM in the 2-CM-condition. Third, the quality of the second CM would be higher than the CM from the 1-CM-condition. Results showed no statistical differences in the learning outcomes post-test among participants from 1-CM and 2-CM condition.

However, other benefits were found. IL principle was fulfilled, as students stated that they engaged in the lesson and learned from it more than if they had just received the content passively. Also, some of them found the CM tool as useful for representing their learning and understanding.

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Appendices

Appendix 1. Handout for participants.

Handout

You are going to participate in an experiment about Environmental Education and, more specifically, about the Island Biogeography model. You will find connection among the island size and the distance among the mainland. You will have to experiment with the commands to see the effects on the species. Before you start, some explanations are provided below.

Why do many more species of birds occur on the island of New Guinea than on the island of Bali? One answer is that New Guinea has more than fifty times the area of Bali, and numbers of species ordinarily increase with available space. This does not, however, explain why the Society Islands (Tahiti, Moorea, Bora Bora, etc.), which collectively have about the same area as the islands of the Louisiade Archipelago off New Guinea, play host to many fewer species, or why the Hawaiian Islands, ten times the area of the Louisiades, also have fewer native birds.

Two eminent ecologists, the late Robert MacArthur of Princeton University and E. 0. Wilson of Harvard, developed a theory of "island biogeography" to explain such uneven distributions. They proposed that the number of species on any island reflects a balance between the rate at which new species colonize it and the rate at which populations of established species become extinct.

Video called *Theory of Island Biogeography.* The link for the full video can be found here: https://www.youtube.com/watch?v=5PyrRtSytmM

The script used for this project can be found below:

The **theory of Island biogeography** explains the concepts of species richness, or the number of species on a particular Island. For this concept, an **island** is any ecosystem that is drastically different from its surrounding ecosystems. For example, an oasis in a desert is an island, an Alpine zone is an island, even a pond is an island.

MacArthur and Wilson first published the theory based on a study about Pacific Birds they found that large islands, such as Sumatra Borneo and Papua, had about 700 different species of birds present whereas tiny islands like Christmas island only had about ten. MacArthur and Wilson labelled Papua as the mainland of their study, and they found that Islands closer to Papua had greater species richness than Islands further away. There are several factors that influence species richness.

The first is **immigration**, which is represented by the number of species that migrate to an island.

The second is **extinction**. These species don't necessarily die out, but may be forced off the island due to the competition. These rates can be modelled on a graph to determine the species richness of the island.

The intersection of the number of species incoming and the number of species leaving the island is called the **equilibrium.** The equilibrium quantity indicates the species richness of the island geographic features, such as island size.

And **Island location** affect immigration and extinction rates and thus the species richness of islands.

Appendix 2. Prior knowledge survey.

Survey

1. What is your gender?
2. What is your age?
3. Did you have biology in your high school final exam? (Yes/no)
4. Do you know the theory of Island biogeography? (Not at all/ A bit/ Yes I know this theory)
5. Do you know the theory of MacArthur and Wilson? (Not at all/A bit/Yes, I know this theory).

Appendix 3. Learning outcomes post-test.

Test

- Please, define the concept of island biogeography theory. (1 point) (This theory explains the concepts of species, richness or the number of species on a particular Island).
- Please, name two aspects that influence the species richness. (2 points) (Two of these: Emigration, extinction, island size, island location).
- Please, define the concept of equilibrium. (1 point) (The intersection of the number of species incoming and the number of species leaving the island).
- How does the island size affect the extinction rate? Select the correct statement (1 point):
  - Big islands have lower extinction rates than small islands. (True)
  - Small islands have higher immigration rates than big islands. (False)
- Select the FALSE statement (1 point):
  - Small islands have lower immigration rates than big islands. (True).
  - The higher the immigration rate, the higher the equilibrium rates. (False)
- Large islands have ______ species richness than small islands (1 point):
  - Lower
  - Higher (correct).
  - Same.
- How does island location influence the species richness of the islands? (2 points) (It affects immigration and extinction rates)
- Regarding the distance between the mainland and other islands, islands close to the mainland have… (1 point):
  - Lower immigration rates than remote islands.
  - Higher immigration rates than remote islands (True).
  - Equal immigration rates than remote islands.
- Justify your answer in the previous question (1 point). (Islands close to each other make it more possible for the species to migrate to that islands than to further islands).