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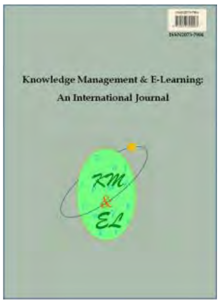

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Improving learning and understanding through concept mapping

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Abstract: It is widely accepted that concept maps are a meaningful learning tool. Even so, the use of concept mapping as a meaningful learning tool is probably less common than the use of concept mapping as an assessment tool. In first place, the easiest thing to with a student's concept map is to apply a rubric and give it a grade. And second, teachers often believe that by using a meaningful learning tool, their students are learning meaningfully while constructing their concept maps. We are then missing on the greatest power of the concept map, its use as a tool to learn meaningfully. In this paper we examine the difference between using concept maps for learning and for assessment, and propose steps on how to move towards the use of the tool to improve students' learning and understanding.

Keywords: Concept mapping; Meaningful learning; Assessment; Concept maps

Biographical notes: Alberto J. Cañas is co-founder and a Senior Research Scientist (emeritus) at the Institute for Human & Machine Cognition, in Pensacola, USA. For decades he has led the research team at IHMC that develops the CmapTools software toolkit, used extensively by concept mappers throughout the world, and has been principal investigator of research projects that involved concept mapping with organizations such as NASA, US Navy, NSA, the Government of Panama, and Microsoft. He has co-organized all International Conferences on Concept Mapping, has published extensively and has lectured throughout many countries in North and Latin America, Europe, Africa and Asia.

Priit Reiska is professor of Science Education in Tallinn University, Estonia. He has been 12 years vice rector for academic affairs in Tallinn University. He has worked earlier as physics teacher at school, laboratory assistant in university, researcher and senior researcher. His main research area is using of concept mapping in education, He has (co)organized three international conferences of concept mapping. He has published over 50 articles and 2 monographs, he has led or participated in more than 10 R&D projects.

Oleg Shvaikovsky is a co-founder and member of board and teacher of physics at St. John's School, the biggest Christian private school in Estonia. Oleg is an active EdTEch investor and entrepreneur with deep educational domain expertise. Oleg has been using concept mapping in the educational process for years. He is currently PhD student at Tallinn University.

1. Introduction

Novak and his research team developed concept mapping while analyzing a set of interviews with elementary school students with the intention of comprehending their understanding of science topics (Novak & Cañas, 2006). Soon the team recognized the power of the concept map as a tool to represent knowledge, and particularly as a tool for meaningful learning. Novak & Gowin's seminal book, Learning How To Learn (1984) was instrumental in popularizing concept mapping throughout the world, and together with Novak's later association with the Institute for Human & Machine Cognition and the development of the CmapTools software (Cañas et al., 2004) are seen by many as key in the extended growth in use and broadness of applications of concept mapping. But even within this growth, as a community -- the Cmappers community – we are aware that the use of concept mapping is not as ubiquitous and universal as we would like and expect it to be, as noted by Novak and Cañas (2010) and (Kinchin, 2001) and more recently by Moon and Correia (2022).

We are particularly interested in the use of concept maps as a learning tool. Given its roots, it is not surprising that the intended use of concept mapping has been mainly as a meaningful learning tool. Our concern is not only how broadly concept maps are used in education, but whether the intended use is being achieved. During the 1980s concept mapping's popularity flourished particularly within the education community, in conjunction with Ausubel's Assimilation Theory (Ausubel, 1968). Novak & Cañas (2010) report that the emphasis of use in education continued through last decade, and we continue to see that trend today. However, from the early start, concept maps became a popular assessment tool, from elementary school to graduate courses. And it is the specific distinction between the use of the concept map as a learning tool and the use as an assessment tool that we will discuss in this paper.

Help-seeking is a desired study habit in e-learning, particularly when proximity with peers and instructors is minimal. Therefore, there is a vital interest among researchers and educators in understanding what influences online help-seeking, especially with regard to motivational factors. The present study investigated the differential influences of achievement goals and intrinsic/extrinsic motivation on help-seeking in e-learning. The purpose of this study was threefold. First, we attempted to compare the direct and indirect influences of approach goals on students' online help-seeking based on the 2 × 2 (Elliot & McGregor, 2001) and the 3 × 2 framework (Elliot, Murayama, & Pekrun, 2011). Second, we endeavored to examine the relationships between approach goals and students' personal goal orientation, namely, intrinsic/extrinsic motivation in e-learning. Third, we examined how online students' intrinsic/extrinsic motivation predicts their help-seeking behavior.

Our study addressed two areas that have not been adequately examined in earlier studies on the relationship between achievement goals and help-seeking (e.g., Arbreton, 1998; Linnenbrink, 2005; Newman, 1998, 2008; Ryan & Pintrich, 1997, 1998; Ryan, Pintrich, & Midgley, 2001). First, we tested the relationship with the online population based on the earlier studies which were mostly focused on traditional face-to-face class population. As e-learning and traditional face to face learning vary greatly in various facets including help-seeking, it's important to investigate whether the relationships found in face to face classes from previous results hold true in e-learning (Aleven et al., 2003). Second, we explored the relationship of both the old 2 × 2 and new 3 × 2 models and help-seeking to advance earlier studies which merely focused on the old model (Elliot & McGregor, 2001, Elliot, Murayama, & Pekrun, 2011). As Elliot and his colleagues proposed the new model and argued the conceptual difference between the earlier and newer constructs from the two models, it is important to cross examine the new model with the online population and explore the potential relationship between the new constructs of achievement goals and help-seeking.

2. Learning and assessment

Concept mapping has been shown to be effective when used as an assessment tool (Fischler et al., 2002; McGaghie, McCrimmon, Thompson, Ravitch, & Mitchell, 2000; Reiska, 2005; West, Pomeroy, Park, Gerstenberger, & Sandoval, 2000) and at all levels of education. Educators, however, argue that it takes too much time and effort to assess each student's concept map. As a result, the assessment consists of assigning a grade to the concept map. The use of concept mapping for assessment in large scale standardized tests is also complicated by the time it takes to assess each concept map manually. To address these issues, there have been efforts to automatically assess concept maps (Cline, Brewster, & Fell, 2010; Gouli, Gogoulou, Papanikolaou, & Grigoriadou, 2003; Hirashima et al., 2015; Taricani & Clariana, 2006). Additionally, assessment has also been based on having students find errors and filling-the-blanks in previously built concept maps without the need to have students construct the maps (Correia, Cabral, & Aguiar, 2016; Moon, Johnston, & Moon, 2018). In an effort to use concept maps for assessment, if educators move towards the lower left of Fig. 1, where students have less freedom to construct the content and the structure of the concept map, the result is increasingly less learning and less development of higher-order thinking on their part during the concept mapping activity (Cañas, Reiska, & Möllits, 2017).

As we have mentioned, educators intend to use the concept map as a meaningful learning tool and frequently use it only as an assessment tool where either the students build a concept map, hand it in, and receive a grade as assessment, or don't get to construct their own concept map at all. As a result, the educators believe they are using the concept map tool for meaningful learning, while little or no learning takes place on the part of the student because of using concept maps. We are not arguing that concept mapping should not be used for assessment. On the contrary, we believe that concept maps are an excellent way to assess a person's understanding of a topic, whether it's a student in a learning environment or an expert in a knowledge elicitation situation. We have developed tools for assessment, including a topological taxonomy for concept maps (Cañas et al., 2006) which is incorporated into CmapTools and the CmapServer for classification of concept maps for indexing and searching and has been used extensively for research, a semantic rubric (Miller & Cañas, 2008), and CmapAnalysis (Cañas, Bunch, Novak, & Reiska, 2013), and extensible software tool that can be used for large scale assessments and which has also been used extensively in research projects. But we are aware that these tools do not automatically lead to meaningful learning.

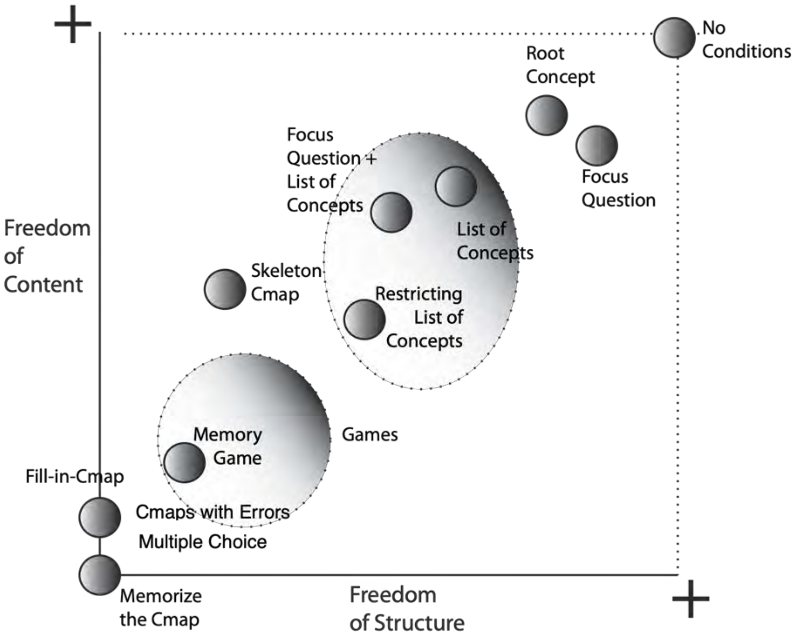

Fig. 1. The more we search for easier assessment through concept maps the more we move towards the lower left corner of the graph, where there is less learning and less critical thinking on the part of the students. Adapted from Cañas et al. (2017)

Having a student build a concept map, hand it in, grade it, and give it back with the grade does not imply learning is taking place. Of course, having this activity within a larger context of classroom work means there is learning taking place, but it's not due to the construction of the concept map. We believe this is a common confusion among instructors. Novak clearly refers to this issue when he states that adding a rubric for evaluating concept maps in his Learning How to Learn book was a mistake he regrets, as it was mistaken as a permission to instructors to use the rubric to assess students' concept maps. (Personal communication to A. J. Cañas)

The concept map is a tool, it is not a methodology. It's the educational methodology in which the concept map is used that, to a large extent, determines whether the concept mapping activity is part of a meaningful learning experience or not.

3. Concept mapping to improve learning & understanding

Most educators are what we call one-time concept mappers. That is, during the study of a topic they assign their students the construction of a concept map about the topic with the idea that students will learn the topic during the construction of the map. Concept mapping can be highly effective for learning a topic, but the mapping must be embedded into the learning process, it cannot be an independent activity, excluded from the learning process.

If concept mapping is introduced into a meaningful environment, where the activities organized by the teacher lead to meaningful learning, it's much easier for it to integrate as a tool for meaningful learning. If concept mapping is introduced into a rote-learning environment without any change to the environment itself, it tends to become a one-time concept map type of use.[1]

Novak and Cañas (2004) present a concept-map based learning environment in which concept mapping is a key, if not the centre, of learning. By using the features available in CmapTools, students, individually or in groups, can begin with the construction of a concept map showing their previous knowledge on a topic, and continue building a knowledge model that reflects their increased understanding as they study a topic. Experience has shown us that reaching the level of comfort and proficiency with concept mapping on the part of the students for a concept-map based learning environment takes time and effort (Cañas, Novak, & Reiska, 2015) and having the methodology that promotes the types of interactions suggest is not common (Cañas et al., 2017). Most classrooms are not ready for an introduction of concept mapping at this level, and thus require a change in the educational methodology. But this change can be in small steps, as we will describe below.

We present here three cases where the learning environment was changed by the instructors to implement concept mapping in a way that it improved learning and understanding on the part of the students. We have chosen these cases for several reasons. First, there is one from an elementary school, one from a high school, and one from university level. Second, we personally know some of the educators involved and know of the results first-hand, not from some literature review. Third, the decisions to change the educational methodology to introduce concept mapping were made by the educators themselves, not as part of some experiment. And finally, because these three examples were presented in Spanish at previous CMC conferences, they are probably not widely known.

3.1. Elementary school: Evelio D. Carrizo School, Panama sources

In 2005, Elvira de Coloma, sixth-grade teacher at the Evelio D. Carrizo school located in the Herrera province in Panama, introduced concept mapping and a meaningful learning methodology into her classroom (Rodríguez & Coloma, 2006). Elvira had taken part in a two-week workshop as her school joined the Conéctate al Conocimiento, a national project in Panama (Tarté, 2006) which aimed at introducing technology, concept mapping and meaningful learning into the public elementary schools of the country. When she returned to her school, Elvira -- a quiet teacher during the workshop -- decided on her own that she was going to try out this new educational methodology to which she had been introduced and evaluate on her own whether it would improve her students' learning. Elvira taught Natural Sciences, Mathematics, Social Sciences and Spanish (language). She decided that she would change the learning environment and introduce concept mapping only for the Natural Sciences subject, while retaining her traditional

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[1] As an anecdote, the first author has found that during concept mapping workshops with Finnish educators, having the participants understand how to use concept mapping as a learning tool has been easier, given the world-class educational system we all recognize in Finland, than when working with educators from Latin American countries, where rote-learning and memorization are still much engrained into the educational system.

teaching style in the other subjects. This way she could compare the results. It just happened that Elvira had been the fifth-grade teacher for the same group of students.

Rodríguez & Coloma (2006) report a dynamic learning environment during the Natural Science classes, where students would work in teams on the construction of their concept maps, discussions and interactions were frequent out among students, and students would iteratively carry out their research on the subject and then come back to refine their maps and thus reflect their increased learning and understanding. Students referred to themselves as researchers, but only for the Natural Sciences classes. Emphasis was in the learning process, not in the final product.

Table 1 shows the average grades for 2004 (when the students were in fifth grade), and 2005, where concept mapping was used in Natural Sciences. The increase in learning took place only for the natural sciences subject. Rodríguez & Coloma (2006) do clarify that Elvira changed the assessment method for Natural Sciences to, for example, open questions, as opposed to the traditional assessment she used in other subjects (concept maps were not used for assessment). But it was the teacher who decided how she did her assessment. Rodríguez (coauthor of the paper), a member of the Conéctate al Conocimiento team, did not find out about her effort until she had completed the evaluations. The results also show that in natural sciences, all students did well after concept mapping and a new methodology were introduced, while for other subjects the distribution of grades remained similar to that of 2004.

Table 1
Comparison among final group averages for 2004 and 2005 for the subject of natural sciences, Evelio D. Carrizo School, Herrera, Panama (experiment done by classroom teacher)

Subject	Final group average 2004	Final group average 2005	*P* value
Natural sciences (using concept maps)	4.21	4.72	0.0112 (significant)
Social sciences	4.24	4.38	0.3987 (not significant)
Spanish	4.22	4.21	0.9505 (not significant)
Mathematics	4.28	4.34	0.7274 (not significant)

We cannot attribute the improvement in learning that took place solely to the use of concept mapping. It's more likely that it was the change in methodology, that was itself triggered by the introduction of concept mapping and the intention of using the tool in a meaningful learning environment, was the main factor that led to the improvement. However, we do believe that the introduction of concept mapping into the learning process and not as an assessment tool did contribute to the improvement in learning.

3.2. High School: Instituto Educativo Integral, Costa Rica

Otto Silesky-Agüero is the Principal of the Instituto Educativo Integral, a high-school in Costa Rica for the attention of students who, due to their cognitive styles, present some difficulties in adjusting to traditional educational institutions (Silesky-Agüero & Badilla, 2008; Silesky-Agüero, Chacón-Zúñiga, Muñoz-Jiménez, Rodríguez-Acuña, & Segura-Monge, 2006). In 2003, Otto and his team decided to integrate concept mapping and

CmapTools into a new pedagogical approach. Concept mapping became the center of the school's 4 main axis: meaningful learning, personalized instruction, a methodological strategy that includes the instructor as a coach guiding the learner, and attention to learning difficulties in students.

Fig. 2 shows the results of the school's percentage of students that passed Costa Rica's national standardized tests for high school graduation. Note that in 2003, the first year with the new methodology, approval rate went down. But the schools' instructors understood that a change in methodology at the school level was not easy to implement, and that in fact it was harder for the faculty than for the students. They decided to continue implementing the change. By 2007, 100% of the students passed the tests, including the mathematics test that countrywide was generally considered as tough. The results were unthinkable a few years earlier, considering the schools' student population. The combination of a change in educational methodology empowered by the use of concept mapping throughout the classroom work, led to significant improvements in the students' learning.

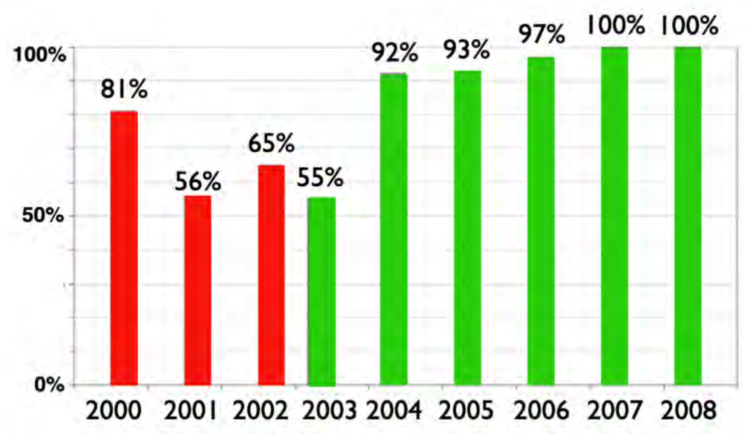

Fig. 2. Student's results in Costa Rica's high school graduation standardized tests before and after implementing a new methodology together with concept mapping at the Instituto Educativo Integral in 2003

3.3. University: Universidad Extremadura, Spain

The third example is an experience led by A.L. Pérez Rodríguez and M. I. Suero Pérez, together with their research team, at the Universidad de Extremadura, Spain to improve learning with concept mapping through what they call 'reconstructive collaboration' of concept maps (Pérez Rodríguez, Suero López, Pardo Fernández, & Montanero Fernández, 2006), part of their extensive research and practice in concept mapping (Pérez, Suero, Montanero, Pardo, & Montanero, 2000; Pérez Rodríguez, Peña Bernal, & Mahedero Balsera, 1979).

During their Physics Didactics course, a last-year course of the undergraduate Physics program, students were asked to individually construct a concept map about electrical current. Then, using CmapTools (Cañas et al., 2004) Annotation feature, each student was assigned to revise each other's Original Cmap, and provide comments and advise on how to improve them. For each student's map, all students analyzed, studied and commented on all proposed changes and for each map a student was assigned to put them together into a Map in Revision. The creator of each map had to then study all suggested changes, accepting some, rejecting others, but always justifying the decision, resulting a Revised Map for each student. Then, a Consensus Map was constructed, and the maps for all students were linked so they could be compared, original and suggested changes and modifications could be compared. This whole process was rich in interactions and discussions regarding the different maps and the proposed modifications.

Students who participated in this experience and those in a separate control group were given a 7-question test a year later to determine the degree of retention of learned basic concepts about electricity. Table 2 presents the results, where students that were part of this learning experience had 17% higher retention that students that learned through the traditional method.

Table 2
Summary of correct answers on the test by control and experimental groups

% Correct answers	1	2	3	4	5	6	7	Average
Control group	52%	56%	61%	46%	54%	52%	68%	56%
Experimental group	68%	66%	72%	72%	75%	73%	82%	75%
Improvement	1%	10%	11%	16%	21%	21%	14%	17%

This experience shows how a change in methodology that is based on feedback, discussions, and argumentation during the construction of concept maps can lead to improvements in learning. It's important to point out that feedback and discussions were among students themselves.

4. Implementing concept mapping to improve learning & understanding

The three experiences described in the previous section show how a change in educational methodology accompanied with the integration of concept mapping can lead to an improvement in learning by students. However, we are aware that for most instructors, taking such steps is difficult, whether they are large steps because they are in a rigid rote-learning environment, or smaller steps. On the other hand, concept maps, understood to be a tool for meaningful learning, are attractive – and teachers want that their students learn meaningfully. The easiest first step of course is to assign students to construct maps, possibly without providing much training or practice, and not knowing that becoming a good Cmapper takes time and effort (Cañas et al., 2015). As a result, many teachers fall into the one-time concept mapper, but believing that because they use a meaningful learning tool their students are learning meaningfully while constructing their maps.

In Cañas and Reiska (2018) we presented the argument that the type and level or depth of interventions introduced by instructors during the concept map construction process has an impact on the amount of subject matter learned by students and on the degree of development of higher-order thinking skills. But we don't need to be concerned initially with complex interventions: we propose that whatever place the teacher is in within a continuum between a rote-learning environment and a meaningful-learning environment, there are small steps that he or she can take to start using concept mapping as a learning tool.

One characteristic that the three examples we examined in the previous section had in common was that students receive feedback on the concept maps they construct, and they can reconstruct and refine their maps based on the feedback. This feedback can lead to interaction between the teacher and the students and/or among students. Interactions lead to more questions, discussions, and argumentation. And it can all start with small steps.

As an example, the following is a partial list of possible small steps that can be taken by teachers. Which steps are appropriate, and the speed of progression, will possibly be different for different teachers. It would be key that teachers take steps with which they feel comfortable and that can lead to success, where they see that the step had a positive impact in learning.

1. Individual mapping

(1). Let the students create individual maps and give them individual feedback

- Pros: individual feedback, written or oral, is always beneficial for learning
- Cons: individual feedback is time consuming

(2). Let students create individual maps and after that let them in pairs or in small groups to discuss their maps

- Pros: discussion is beneficial for learning; not time consuming for teacher
- Cons: just discussing might be too abstract and complicated for the students; without the teacher's feedback still some misconceptions or misunderstandings might not be cleared

(3). Let students create individual maps and after that organize them in pairs or in small groups to discuss their maps and create a joint map

- Pros: Creating the joint map help enhance discussion and focus on topic; not time consuming for teacher
- Cons: without the teacher's feedback still some misconceptions or misunderstandings might not be cleared

(4). Let students create individual maps and after that organize them in pairs or in small groups to discuss their maps and create a joint map, and teacher will be part in the discussion or will give feedback to the students

2. Group mapping

Let students create maps in pairs or small groups and afterwards give them feedback

- Pros: Creating the joint map helps to enhance discussion and focus on topic
- Cons: Still time consuming to the teacher

3. Long-term mapping

Create a map at the beginning of the learning sequence and develop it during the learning sequence. Can be combined with the options described in 1 and 2

- Pros: Learning process, which is build on appropriate use of concept mapping leads to meaningful learning
- Cons: might be a longer process for the teacher, because it requires the reorganization of teaching to make it suitable for concept mapping-based learning process

These steps are a good starting point. Teachers can then move on to take advantage of the different conditions under which the construction of concept maps take place, e.g., the importance of the focus question, the use of a root concept in the Cmap, the possibility of providing the student a list of concepts, etc., and how they can lead to different types of maps (Cañas, Novak, & Reiska, 2012). As the students become good Cmappers (Cañas et al., 2015), they will not only improve learning through their mapping, but will continue developing higher-order thinking skills (Cañas et al., 2017).

6. Conclusion

After decades of use all over the world and all levels of education, concept maps are known to be a meaningful learning tool. We believe they are, and we have personally experienced it with our students. But we also see how, frequently, concept maps are used only as an assessment tool, and the teachers believe that because they are using a meaningful learning tool, their students are learning during the construction of the map, when they are not. And although we agree that concept maps are an excellent assessment tool, our main interest lies in how to improve learning. We propose that with small steps, any teacher can move towards using concept maps for improving learning, by incorporating them into activities that involve meaningful learning, however small these activities are. As the teacher becomes more comfortable and sees the benefits in the students' learning, he/she will take larger steps. On our part, we need to provide the environment, support, and tools so teachers can take these steps.

Author Statement

The authors declare that there is no conflict of interest.

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