

Integrating Concept Mapping into Higher Education: A Case study with Physics Education Students in an Irish University

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Abstract

In Ireland (as in many countries) higher education has changed considerably. In the last 40 years enrolment numbers in tertiary education has grown extraordinarily with the age participation rate rising from 11% in 1965 to an estimated 57% in 2003. This relates to an increase of 21,000 students in 1965 to over 137,000 by 2003 (Department of Education and Science Ireland). Despite the significant increase in class size the basic methods of teaching remain largely unchanged (Hay et al, 2008). It is assumed that traditional teaching and assessment strategies are sufficient. However in order to adapt to the students learning needs the teaching strategy must also change. This paper provides an account of one such strategy - Concept Mapping - and shows how it can be introduced into the physics classroom in tertiary education using it as both an instructional and assessment tool.

Concept Mapping was originally developed by Novak and his research group as a means of representing frameworks for the interrelationships between concepts (Novak & Gowin, 1984). Since then it has a long tradition in the educational context as a cognitive tool for enhancing learning. The concept maps have several components that as a whole represent the student's knowledge on a specific topic. The underlying technique involved is tying new knowledge to relevant concepts and propositions already possessed. Most of the studies conducted on the subject of Concept Mapping have been concerned with the use of the tool with instruction and assessment (Stoddert, 2006; Cassata *et al*, 2004; Ruiz-Primo & Shavelson, 1996; Austin & Shone, 1995; Horton *et al*, 1993). The tool has being used widely in primary and second level education, however very little in tertiary science education until recently (Hay et al, 2008).

The study was carried out over two academic years in the University of Limerick, facilitated by students in Science Education courses. The results presented in this paper are part of the larger two year research study; however this paper focuses on the data gathered from phase 2 of the research. Training was provided at the beginning of the study to enable students to clearly understand the method of constructing concept maps. Throughout the study students were asked to construct maps at different intervals allowing the author to identify progression of the students' knowledge. The module studied was also delivered through concept maps where they were used as 'advanced organisers' in both lectures and tutorials. Results indicated that the students reacted positively to the concept mapping tool as investigated through the use of a questionnaire. The maps signified that as the students engaged in meaningful learning;

they progressively restructured their knowledge, ultimately creating complex frameworks of interrelated concepts with many levels of hierarchy and branching.

Background

In recent years extensive research has been carried out to evaluate and highlight the declining numbers of graduates in science related courses nationally and internationally. Overall figures in Ireland reveal that one fifth (22.2 %) of students enrolled in science courses do not complete their course in Ireland. In an attempt to combat this problem several initiatives have been put forward and introduced into classrooms. Most of these initiatives require time and resources that are not readily available to the teacher and as a result have failed to improve the current situation of low science graduates. However concept mapping is a technique which appears manageable within present classroom constraints and multiple research studies argue its advantages in the classroom, both as an instructional (Novak & Gowin, 1984; Freeman, 2004; Taber, 1994) and assessment tool (Moneira, 1985; Barenholz & Tamir, 1992; Markham et al, 1994; Austin & Shone, 1995). This paper reports some of the findings from a two year investigation into the use of Concept Mapping in a physics module in third level education. It focuses on two matters related to the introduction of concept mapping; firstly the effect of the tool on undergraduate students attitudes of and learning of physics and secondly the extent to which students continued to use the map in their own teaching following experience with concept maps. The following two research questions will be answered in this paper:

1. Did Concept Mapping have an affect on the students' attitudes towards and learning of physics? If so, to what degree?
2. To what extent did the students continue to use the concept mapping tool in their own teaching following the study?

Introduction

Concept Mapping is a practical learning tool which falls into the broad family of graphic organising tools that includes mind mapping and spider diagrams. However the characteristics of Concept Mapping set it apart from the others. Concept Mapping was firstly developed by Novak and his research group in Cornell University in the early 1970's as an approach to identifying knowledge structures of an individual. It is now used as a vehicle to represent and assess changes in students' understanding of science (Horton et al., 1993; Novak, 1990).

Concept maps have been defined as two-dimensional, hierarchical, node-linked diagrams that depict verbal, conceptual, or declarative knowledge in succinct visual or graphic forms (Quinn et al., 2004; Horton et al., 1993). A concept map is a visual representation of an individual's knowledge structure on a particular topic. The maps contain several elements, which as a whole organise and represent students' knowledge. They include concepts which are defined as "perceived regularities in objects or events that are designated by a sign or symbol" (Novak, 1991). The concepts are usually enclosed in circles and linked together using linking phrases that identify the relationship between adjacent concepts. The smallest unit of meaning of a concept map is a proposition which includes two concepts linked together using a linking phrase. Figure 1 below is an example of a concept map which explains what concept mapping is and exemplifies the above characteristics.

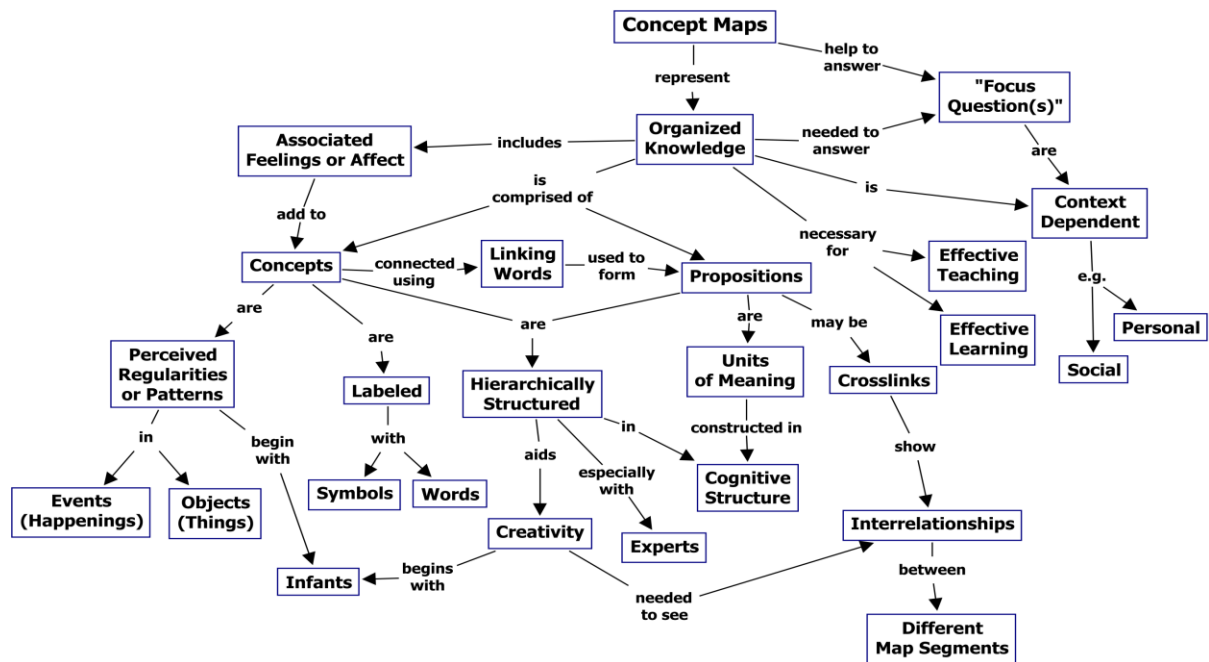


Figure 1: A concept map showing the key concepts involved in concept mapping. Concept maps are hierarchical structures which identify relationships between concepts using linking phrases (Novak & Gowin, 1984)

Concept maps bring to light individual differences in learning; different people will have different types of concept map, even in the same subject area. The underlying technique involved in Concept Mapping is tying new knowledge to relevant concepts already possessed by the student. Each individual concept map is unique due to each person's own experiences. As new information is learned, the network changes and more linkages are formed between the concepts.

Concept Mapping – Why use them?

The philosophy upon which Concept Mapping is based is David Ausubel's theory of meaningful learning as contrasted with rote learning. Ausubel (1968) initiated the constructivist theory where he believed that students are not vessels to be filled with a lot of notions, but that they create and develop their own knowledge in an active process. Ausubel believed that the mind is organised in a top-down fashion and that students relate new information to previous knowledge contained in their cognitive structures. These new concepts are then sorted, related, and then added to the existing hierarchies to create meaning. Hence, meaningful learning takes place when a learner is able to organise, relate and include concepts into his or her cognitive structures.

Concept mapping in its pure form treats teaching and learning as a student-centred process. This process of constructing a concept map is a powerful learning strategy that forces the learner to actively think about the relationship between the terms. This makes Concept Mapping especially suited to studying science as the learners often perceive, incorrectly, that studying science means simply memorizing facts (Dorough and Rye, 1997).

With concept maps, information can be presented in a condensed manner, without the loss of complexity and meaning. The visual presentation allows the students and

teachers to identify the information without the dense presentation of words and verbal compositions (Gul and Boman, 2006).

The Learning of Physics

For decades researchers have been trying to understand why students are not choosing physics as a school subject and subsequently in third level education. The traditional approach to teaching physics is based on the “instructor’s view of the subject and the instructor’s perception of the student” (McDermott, 1993). Teachers are eager to transmit their knowledge to the students and believe that “students are younger versions of themselves” (McDermott, 1993). This is the onset of the problem. In Ireland every student that takes a science course must complete core modules of physics and chemistry. Only a small minority of the students will continue to study the subject and major in it, thus the trouble with the traditional approach is that it ignores the possibility that students may have a very different outlook to that of the instructor. Students enter the science classroom with preconceptions, not only related to physical phenomena but also about physics as a discipline and how to learn it (Hammer, 1989; Redish et al, 1997). When students enter a science classroom each does so with a system of beliefs based on their own experience. Each student will have assumptions about the lesson and what they are expected to do. Students perceive physics as being difficult, dull and demanding with little active involvement with the learning process (Woolnough, 1994). The students are unsure of how to approach the subject and believe it is a collection of facts and formulas and as a result they do not attempt to relate concepts and decipher the underlying connections between them. McDermott (1993) identified a list of generalisations concerning teaching and learning of physics, one of which stated that “teaching by telling is an ineffective mode of instruction for most students”. In order for students to develop an understanding of the topic or domain they must be actively involved in their learning. It is important to design initiatives and procedures carefully, based not only on what the teacher knows about learning, but also to take into account the characteristics of physics as a subject. Our ability to understand and remember new information critically depends upon what we already know and how our knowledge is organised (Clifton and Slowiaczek, 1981). The concept mapping tool can facilitate this and in essence can help students understand and apply their knowledge to solve problems.

Attitudes towards Physics

Much research has been carried out in recent years concerning attitudes toward science/physics and the relationship between these attitudes and science achievement (Gungor *et al*, 2007; Papanastasiou & Zembylas, 2002; Reid & Skyabina, 2002). Several factors have been highlighted as main contributors to the negative attitudes that students possess towards the science subjects. These factors are related to school and science classes; the individual and even external factors relating to the status and rewards that different countries bestow onto physics-based careers (Woolnough, 1994).

For the purpose of this paper, attitude is defined as the favourable or unfavourable response to things, places, people, events or ideas (Koballa, 1995). In Ireland, students’ attitudes towards physics have declined increasingly over the last two decades with the popularity of Leaving Certificate Physics declining from 21% to 15% since 1985 (Central Statistics Office). Students who decide to continue their

studies in the field of physics are further hindered by the high drop-out rates within the discipline. As mentioned earlier, within the universities in the Republic of Ireland 22.2% fail to graduate in science courses, compared to 7.1% in the Law domain (Flanagan et al, 2001). Since only those students who take physics at senior level in secondary school and subsequently third level are eligible to pursue careers in the discipline, concerns have been raised about the nation's economic future and the number of science graduates entering the workforce. To combat the negative attitudes towards physics and the enduring problem of high drop-out rates with physics courses new initiatives must be implemented into the classroom.

The Students and the Study

The students involved in this research (N = 84) were enrolled in a four-year Science Education degree course in the University of Limerick. The study was carried out over two academic years during which the students completed two physics modules; Light and Sound (Phase 1) and Electricity and Magnetism (Phase 2) respectively. All the students had completed one physics module prior to the study, however only 25% of the cohort studied physics at second level education. As the students were enrolled in a Science Education degree two periods of teaching practice are included in their timetable, one at the end of second year, and one at the beginning of fourth year. The students involved in this study were in the second year of their degree during phase 2 and completed a six-week teaching practice (TP) block following the study. It is the result from this phase that will be presented in this research report.

The structure of both phases was very similar, the main difference being that at the beginning of Phase 1 the students were given an intensive training course on concept mapping. The training course was designed to teach students the individual elements of concept mapping and how to construct a map. The one-hour session was divided into four main sections; a PowerPoint presentation, group concept map construction, individual concept map construction and a discussion. The PowerPoint presentation was fifteen minutes in length and defined what concept mapping is, and included several examples from various domains. In learning the technique it is crucial that students construct a map in a domain that is very familiar to the students. With this in mind the students worked in groups to construct a map on their understanding of 'Living Things' followed by individual maps on any concept that interested them, which ranged from a sport to a famous person. These exercises were very beneficial and by the end of the session the students were fully aware of the components of concept mapping and their structure.

Throughout the course of both phases the students were asked to construct three concept maps specific to the module. Figure 2a, 2b and 2c below is an example of the three maps drawn by one student during Phase 2. The key concept changed during the semester with the students defining their understanding of *electricity* in the first two maps (Fig 2a and 2b) and on *electrical circuits* in the final map (Fig 2c). This was carried out in order to gather information on the students' knowledge of the entire module. The level of direction varied for all three maps whereby the students received instructions, probing questions and seed terms for to help them to construct the first map. This was reduced to probing questions and instructions for the second map and finally for the third map the students were only provided with instructions. For each map the students were encouraged to first make a list of all the concepts that they

believed were important to the domain and then to link these concepts in a hierarchical structure in a way that will represent their understanding.

Concept Mapping was also used during instruction as advanced organisers. According to Ausubel (1968), advanced organisers facilitate learning by creating a framework in the students' cognitive structure in which the new learning material can be integrated. The author used the maps as advance organisers during the tutorials sessions at the onset of new topics in order to provide a reference for the students.

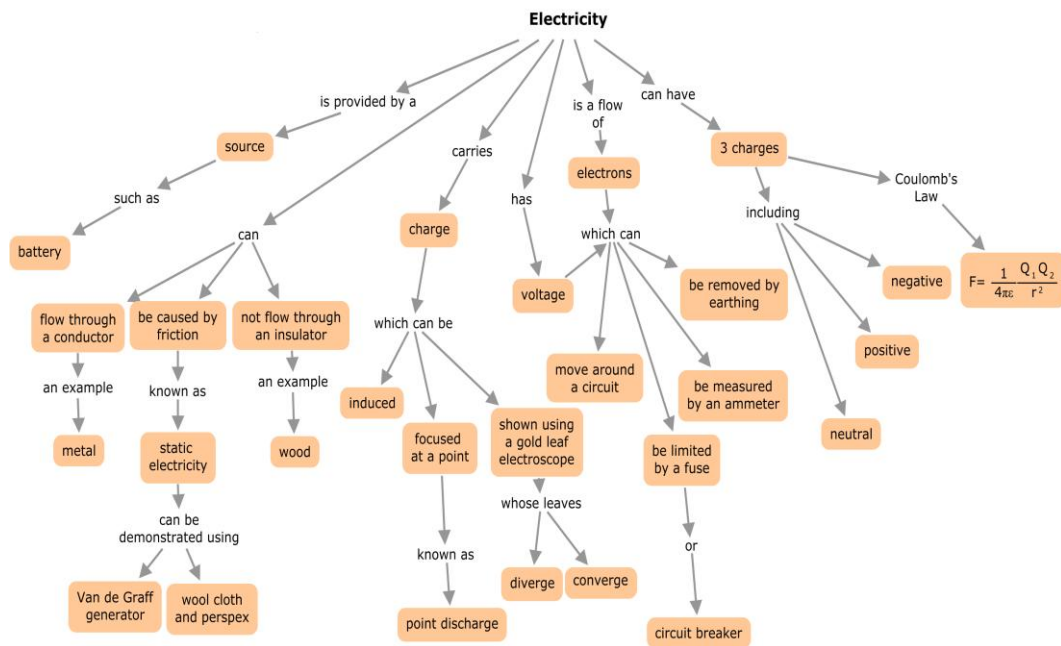


Figure 2a: Student Map number 1

Evaluation

In order to examine and evaluate the students' views of concept mapping and the use of the tool in the physics classroom two questionnaires were administered to the students. The first (Q1) was a four-page questionnaire administered at the end stage of the study, prior to the end of term exams. The students were questioned on several aspects of the concept mapping tool and its use in the classroom including personal information, the concept mapping tool itself and finally the impact of concept mapping on their learning. To answer the second research question of this paper, the students were asked to complete a second questionnaire (Q2) following their return from teaching practice, six months after the end of the research study. The focus of this questionnaire was to determine if the students used concept mapping during their teaching practice and if so, to what extent and when. Statistical analysis was carried out on the student responses which are presented in the following section. Qualitative data was also generated from the questionnaires and were recorded.

Results

The students' attitudes towards physics were assessed using the questionnaire (Q1) where they were asked both closed and open-ended questions to measure a change in their attitude, if any. Following the second phase of the research study 59% of the study cohort agreed that their attitude towards physics improved after their experience with Concept Mapping. A mere 8% stated that their attitude disimproved following the intervention with 33% of the students' stating that their attitude remained unchanged. The students who stated that their attitude towards physics 'disimproved' all made reference to another physics module (Modern Physics) that they were completing in parallel to the Electricity and Magnetism module. Therefore one can suggest that it was the Modern Physics module that was affecting the students' attitude towards physics.

In order to evaluate the impact of the concept mapping tool on their learning of physics, the students completed a post-questionnaire following the study. This was investigated in part three of the questionnaire. Each student was asked to state, using a Likert Scale, whether he/she agreed or disagreed that after his/her experience with concept mapping he/she was able to:

- A.** Understand the theory more easily
- B.** Identify physics concepts
- C.** Link prior and new knowledge
- D.** Answer problems more easily
- E.** Summarise material efficiently
- F.** Represent your knowledge clearly in simple English
- G.** Organise your knowledge into general and specific domains
- H.** Identify your misconceptions of Physics easier

The following figure represents the students' responses (Fig 4). From the diagram it is evident that a percentage of the students strongly agreed that Concept Mapping impacted positively on all aspects of the learning of physics. When taking the "strongly agree" and "agree" responses into account the percentages increased significantly: 85.3% agreed or strongly agreed that concept mapping helps them to link prior to new knowledge (C); 91.2% agreed or strongly agreed that the tool allows

them to summarise material efficiently (E) and 82.4% of the cohort agreed or strongly agreed that the tool provides them with a vehicle to represent their knowledge clearly (F). However 20.6% of the cohort disagreed that concept mapping can help them to answer problems more easily (D).

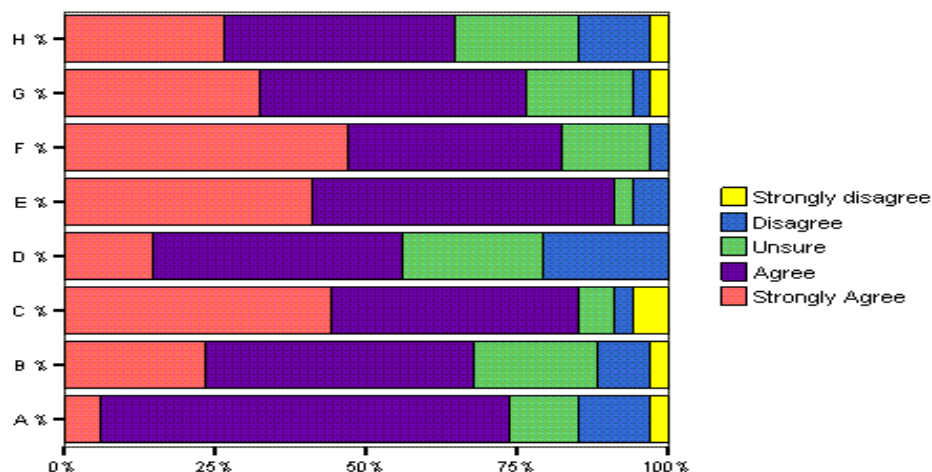


Figure 4: Students responses on the effect Concept Mapping had on their learning of physics

This paper also examines whether or not science education students use concept mapping in their own teaching following experience with it. As mentioned above the students completed a final questionnaire (Q2) following their return from teaching practice. This questionnaire was short in length and 53 students completed it. The main questions asked in the questionnaire were centred on the students' use of Concept Mapping during the six-week teaching practice experience. Almost 63% of the students stated that they used the tool at some point during their teaching practice (Fig 5). The author analysed further where the students used it in their teaching: 13.2% used it as an assessment tool; 32.2% of the students used it during instruction and 18.9% used it both in assessment and instruction (Fig 6). When analysing the qualitative data from the questionnaire it is evident that students used the tool for revision purposes, either before topics to identify pupil's prior knowledge or afterwards for summarising content and assessment.

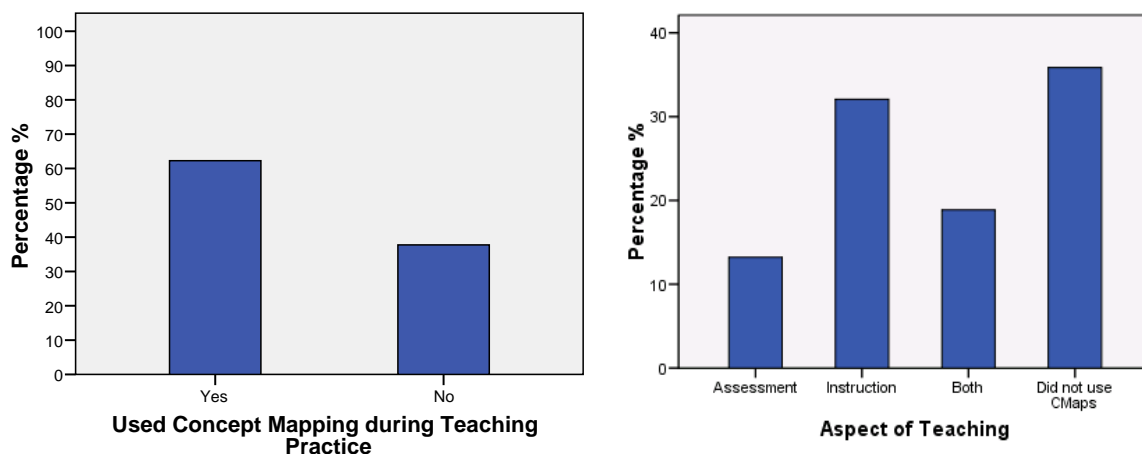


Figure 5: The percentage of students that used Concept Mapping during their Teaching Practice

Figure 6: The areas the students used concept mapping during their Teaching Practice

The final point, to which the author wants to draw attention to in this paper relates to the student teachers views and opinions concerning the practical use and integration of the tool in the classroom. The students were asked in the final questionnaire to rate the opinions, using a Likert Scale, on aspects including the training of the tool to secondary level students, the benefits of the tool as both a mode for revising new content and representing the areas students found difficulty. The following figure presents the data collected from the students (Fig 7).

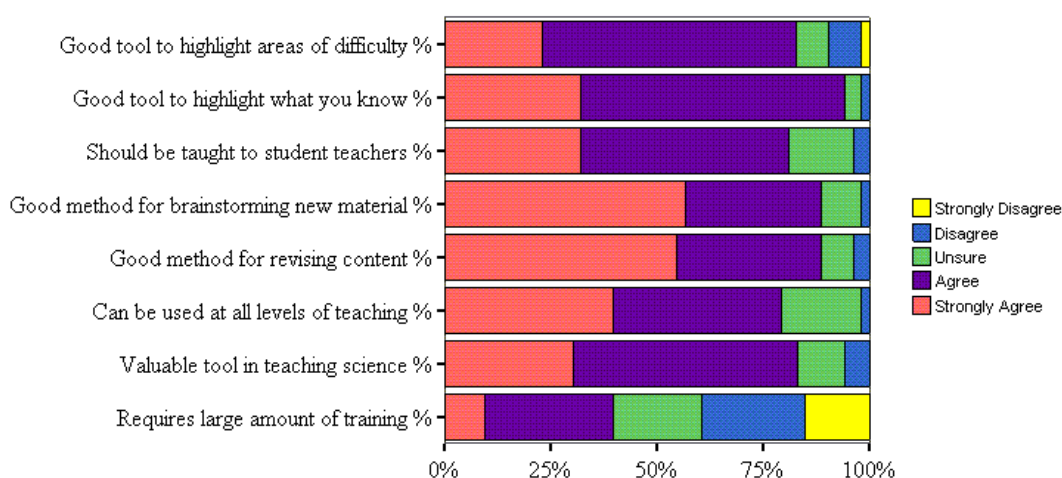


Figure 7: Students opinions on the practical use of the tool in the classroom

Overall the students agreed and strongly agreed with all the aspects, highlighting the advantages of as a teaching tool in the science classroom. Almost forty percent of the students agreed (or strongly agreed) that Concept Mapping requires a large amount of time. As the training is a key element for the success of concept mapping in a classroom it is essential that teachers and facilitators set enough time aside at the beginning of the session/semester to train the students. 75% of the cohort also believed that Concept Mapping should be taught to student teachers during their degree course however one student noted that “more training is needed to help us explain it to Junior Certificate students”.

Conclusion and Future Implications

There is no shortage of new developments in the world of education and specifically physics education to help teachers teach new information to the students that promotes meaningful learning. New initiatives and projects ideas relate to the integration of inquiry based learning, ICT and student-centred learning. This paper has focused on one such initiative that encourages student activity in the classroom that was developed from the constructivist approach. The value of the tool has been documented in various papers and presentation since it was first introduced in the late 1970’s and again here in this paper.

This study suggests that Concept Mapping can serve as a useful tool in physics education by helping students to understand concepts more easily, link prior to new knowledge and represent their understanding of those concepts.

The relationship between Concept Mapping and attitude towards physics was also explored for this group of science education students. The findings suggest that students' attitudes towards physics improve after working with and experiencing concept maps. Those students whose attitude disimproved had not studied physics at Leaving Certificate level. From those students who believed their attitude remained unchanged, only one had studied physics at Leaving Certificate. The results implies that the students' attitude towards physics improved because of the incorporation of Concept Mapping into the modules as all those whose attitudes improved had not studied physics at Leaving Certificate; their only experience of physics prior to this study was their first year module Mechanics and Heat.

The use of Concept Mapping in the physics course is evaluated positively by the student teachers. This is confirmed by the results of the quantitative data of the second questionnaire (Q2) administered to the students. During Teaching Practice experience 63% of the students stated that they used the tool in some shape during their six weeks. The data also revealed that almost all the students in the group agreed that concept mapping is a beneficial tool in the classroom, whether integrated as an assessment or instructional tool. The success of the tool however lies in the training provided to the students.

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