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UNDERGRADUATE STUDENTS' ATTITUDES TOWARDS PHYSICS AFTER A CONCEPT MAPPING EXPERIENCE

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Abstract: Concept maps were first developed in the early 1970's as a data analysis tool. Since their introduction by Novak and his research team, they have been widely used for many purposes, including eliciting knowledge and evaluation of conceptual understanding. This paper highlights the benefit of Concept Mapping and describes the use of concept maps as a tool to improve students' attitudes towards physics in third level education. The fundamental question addressed is "do students' attitudes towards physics improve after an experience with Concept Mapping?" Concept maps were developed by students three times throughout the college semester. The students were then asked to complete a post-questionnaire to facilitate the determination of the effects the instructional tool had on their attitude towards physics and their learning. Qualitative and quantitative analysis of student maps was conducted to measure change in knowledge structure and also to examine the effects of students' attitudes on their cognitive development.

1 Introduction

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). The philosophy upon which this new thinking is based is David Ausubel's theory of meaningful learning (Ausubel, 1968). Ausubel initiated the constructivist theory, which holds that students are not "vessels to fill" with ideas, but that they produce and develop their own knowledge with an active process. This knowledge is then structured and stored in "semantic maps" (Colli *et al*, 2004) that are constructed and restructured every time students learn new knowledge. Individuals are encouraged to relate new knowledge to relevant concepts and propositions they already know. To engage in meaningful learning students must identify specifically relevant concepts and recognise non-arbitrary relationships between the concepts (Bascones & Novak, 1985). The underlying technique involved is tying new knowledge to relevant concepts and propositions already possessed (Austin & Shone, 1995).

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, Mintzes & Laws, 2004; Horton *et al* 1993). The maps provide a representation of knowledge and hence can be used to infer accuracy and depth of knowledge. In order to be effective, instructional concept maps should contain enough important concepts to characterize the subjects that are being represented (Schau & Mattern, 1997).

The concept maps have several components that as a whole represent the student's knowledge on a specific topic. The fundamental component of every concept map is the concept (node). Concepts are defined as "perceived regularities in objects or events that are designated by a sign or symbol" (Novak, 1991). They are generally isolated by circles and connected with lines (linking lines). These lines are labelled with "linking phrases", which describe the relationship between the two connected terms. The smallest unit of meaning of the concept map must contain two concepts and a linking phrase which is then identified as a "proposition". The 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 learner may perceive that studying science means simply memorizing facts (Dorough & Rye, 1997). Concept maps also allow the students to display concepts in both a horizontal and vertical fashion, thus facilitating the process of understanding interconnections and meanings in the map. Vertical linkages display how students differentiate concepts and the horizontal linkages display how the students connect and relate different areas of the topic.

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. Our research employed the Concept Mapping technique for studying the attitudes of third level physics students. We experimentally demonstrate the positive effects Concept Mapping has on the students' attitude towards physics.

2 Attitudes towards Physics

A plethora of research has being 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. 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.

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. Tinto, 2003 highlighted five conditions to help promote persistence within a course; expectations, support, feedback, involvement and learning. With the integration of these five conditions into the classroom the attainment of the students can be maximised. This paper highlights how the inclusion of Concept Mapping can offer the opportunity to integrate these five conditions into a physics classroom thus developing the students' knowledge and improve their attitudes towards physics.

3 Empirical Study

3.1 Profile of the Study Participants

This yearlong study was implemented during the academic years 06/07 and 07/08 in the University of Limerick. The study began in the spring semester of 06/07 and continued to the autumn semester of 07/08. During this period of time the students were enrolled in two physics modules; Light and Sound (Phase 1) and Electricity and Magnetism (Phase 2) respectively. Both modules were taught over a 15-week semester.

This study began with a cohort of eighty-eight first-year undergraduate students during phase 1 and dropped to seventy-nine in phase 2 as a result of non-completion. The cohort of students included a wide variety of abilities with students representing two courses; one for teachers of biological science and the other for teachers of physical science. Within this research group 75% of the students have not studied physics in school at senior level for the Leaving Certificate exam; hence have very little experience of the subject. Prior to this study the group completed one module in physics, Mechanics and Heat. As a result each student in the group possess a system of beliefs and intuitions about physical phenomena derived from extensive personal experience (Halloun & Hestenes, 1985). It is from these experiences that students develop a cognitive structure which may be valid, invalid or incomplete (Hanley, 1994). The learner will formulate existing physics structures only if new information or experiences are connected to knowledge already in memory.

3.2 Instructional Method

The instructional method employed during this study was based on the constructivist approach developed from Ausubel's theory of learning. The author believed that students must be active participants and engaged in their own learning in order for meaningful learning to occur.

This study was designed to be non-disruptive. The students were not assigned any extra hours during the week, with their weekly timetable consisting of 2 one-hour lectures, 1 one-hour tutorial and a two-hour lab session. Students were assigned into groups during their tutorials to promote well functioning groups. Roles of responsibility were allocated to students during problem solving, where typical roles included chair, timekeeper and a scribe.

At the onset of this research the students were given an intensive training course on the construction of concept maps. The training course included three components; 1) a PowerPoint presentation detailing the essential components of a map, 2) construction of concept maps both cooperatively and individually and finally 3) a discussion on the tool. Prior research indicates that Concept Mapping can be easily and quickly taught to students and that once taught, the techniques can be used with larger groups with minimal assistance from teachers (Quinn *et al*, 2004; Wallace & Mintzes, 1990)

For the purpose of this study concept maps were also used as "advance organisers" (Willerman & Harg, 1991). The concept maps were constructed by the researcher and presented to the students at the beginning of each new topic accompanied with an explanation of the relationships between the concepts. The maps provided the students with a greater direction for learning and a reference from which they could work from.

3.3 Data Collection

This study is of mixed method research design (Creswell, 2003). Data collections included students' concept maps and end of research questionnaires. During the course of the study students were asked to construct three concept maps individually. These maps were constructed during week 3, 7 and 11 of the semester. The level of direction provided to the students varied with each task (Ruiz-Primo, 2004). For each map the students were encouraged to make a list of all concepts that they believed important in the topic and to then generate a concept map linking these terms to form propositions.

Pre- and post-questionnaires were administered during phase 1 with only post-questionnaires administered during phase 2. The pre-questionnaire contained four parts; personal information, Concept Mapping training session, Concept Mapping instruction and finally the impact of Concept Mapping on the students learning. The post-questionnaire questions focused on examining the effect the tool had on students learning and whether or not their experience affected their subject choice for their degree.[1]

3.4 Data Analysis

A wide range of methods of scoring maps exist. The approach to concept map scoring employed in this study represents a distinct departure from traditional methods. In the past scoring of maps focused on characteristics such as hierarchy and branching (Novak & Gowin, 1984) however in this study the scoring system focused on the degree of accuracy of the relationships described in each propositions.

The concept maps were analysed using a criterion/expert map. The criterion map (Figure 1) for each phase of research was constructed by the author specific to the module and course outline. The propositions included in the maps were specific to the objectives set out in the module. Throughout the data collection, the students never saw the criterion map. A scoring rubric was generated where a three-point coding system was developed for propositions such that a correct link guaranteed a code 3, propositions that represented a lack in appreciation was coded 2 and links with no labels was awarded a code 1. In this study the principle underlying the development of a scoring rubric was that concept map scores should reflect the degree to which students mastered the expected learning outcomes. The maps were graded to examine the development of student knowledge throughout the course of the study, and were based on the number of correct propositions within the map. The students' attitudes towards physics were assessed using the questionnaire where they were asked both closed and open-ended questions to measure a change in their attitude, if any. (Figure 2)

After completing this Physics module, how do you feel about Physics in general?

Has you attitude towards physics: Improved
Disapproved
Remained unchanged?

Explain your answer:

Figure 2: Question used in post-questionnaire to determine if there was a change in attitude after the Concept Mapping experience.

[1] The biological science students participating in this study were required to select a science major (Physics or Chemistry) at the end of their first year of undergraduate study

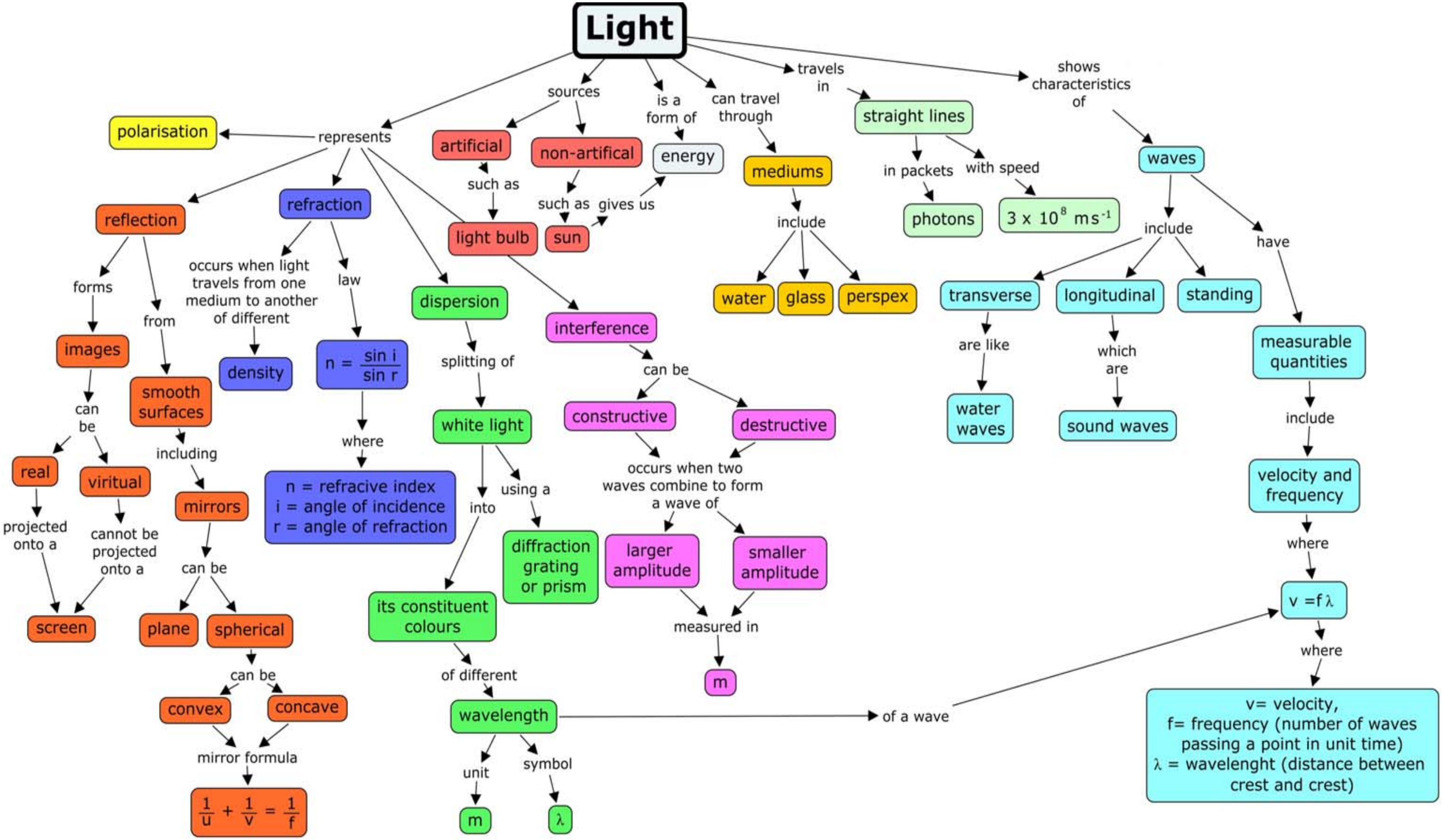

Figure 1: Criterion Map developed by the author on the concept of “Light” which was used during Phase 1 to score the students’ maps.

4 Results

4.1 Effect of Concept Mapping on Students Attitudes

These results focus on research carried out over two semesters, each containing a phase of study, during which the students were enrolled in two undergraduate modules; Light & Sound and Electricity & Magnetism respectively. When asked to complete the questionnaire following their year-long experience of Concept Mapping, 59% of the cohort stated that they agreed that their attitude towards physics had improved after their experience, Table 1.

	Improved	Disimproved	Remained Unchanged
Phase 1 - Light and Sound Spring Semester 06/07	62%	7%	31%
Phase 2 - Electricity and Magnetism Autumn Semester 07/08	59%	8%	33%

Table 1: Students Attitudes towards Physics after Concept Mapping

Statistical analysis was carried out to determine if the results gathered in the change in attitudes were significantly different. In order to evaluate the data independent tests had to be carried out as there was a large difference in the number of students who completed the questionnaire following the second phase. There was not a significant difference in the percentages, ($p > 0.05$). However it must be stated that 62% of the students believed that their attitudes towards physics improved after their first experience of Concept Mapping.

The students were asked to expand on why they believed their attitude improved / disimproved / remained unchanged. Table 2 represents responses to the open-ended question.

Improved	Disimproved	Remained Unchanged
▪ I enjoy it more working with the maps, more interesting. ▪ Tutorials make it easier to understand because we could see how to connect up theory and equations. ▪ It was interesting; it's good to have something to look at rather than notes. ▪ I find it easier to understand and I find the calculations much easier to work out, I can see where the equations fit in. ▪ I always liked physics until the L.C results and now I'm starting to like it more (Got an E in the LC) ▪ At the start of the year I felt that physics was impossible, now although I still find it difficult I enjoy it. ▪ I am more interested in it now, before I just learned stuff off for the exam but now I'm actually interested. ▪ I never thought I would like physics because I am not very maths orientated but now I find it interesting. ▪ Maps make it look less complicated, they explain it better.	▪ The lectures put me off studying so I didn't try hard enough. ▪ The other physics module we are doing now is really turning me off physics (Modern Physics)	▪ I am no better or worse at physics this year than last year. ▪ It's still difficult. ▪ I always thought physics was alright, I can do it if I study. ▪ I still find it difficult to learn from the lectures but the tutorials help to put things into practice. ▪ I have not got a great interest in it, didn't do it for the Leaving Certificate. ▪ Still feel the same about physics, maybe would like it more if I studied it for the Leaving Certificate

Table 2: Sample responses on the effect Concept Mapping had on Students Attitudes

Within the questionnaire students were asked to comment on the use of concept maps in the physics classroom and to declare whether or not they believed them to be beneficial. Student responses were extremely positive and several students suggested that they would use the tool during their teaching practice. The following represents a sample of responses to the question “Do you feel that Concept Mapping is beneficial in the physics classroom?”

- Yes because it is a good form of revision and gives pupils an easily remembered chart.
- Yes because it is a good way of revising and reflecting on what you know
- Yes because it makes you gather your thoughts and link ideas together.
- Yes because it helps you piece all the concepts together and make sense of them.
- They are good visual aids
- Yes because you can link formulas, theory and diagrams together to see their relationship.
- Yes it helps join what you learn in tutorials and lectures
- Yes it helps in brainstorming
- Yes as it makes linkages between different aspects and topics
- Definitely because it provides a summary that is easy to read
- Yes because it connects prior and new knowledge
- Yes because it allows you to lay out everything you know on a topic and you will have it for revision.

4.2 Effect of Concept Mapping on Students Cognitive Development

The students’ cognitive development was evaluated based on the individual concept maps. Due to the large cohort in this study a sample of maps were chosen to facilitate appropriate analysis and evaluation. In order to include a sample of mixed abilities ten student maps were chosen at random. The author ensured that from the sample group analysed the ratio of male to female was 1:1. Table 3 represents the percentage scores the students achieved in their maps over the two semesters. Sex of the students has being identified as male (M) and female (F).

	PHASE 1			**PHASE 2**		
Student	Map 1 (%)	Map 2 (%)	Map 3 (%)	Map 1 (%)	Map 2 (%)	Map 3 (%)
A (F)	5	18	28.5	6	18.5	35
B (F)	10	15	25	8	16.5	25
C (F)	12.5	14	20	12	17.5	30
D (M)	11	41	49	19.5	16.5	36
E (M)	14	20.5	41	14	15	26
F (F)	12.5	16	29	2.5	15.9	33
G (M)	9	9	28.5	5	16.5	25
H (M)	14	19	31	7	19	24
I (F)	3.5	20	28.5	11	28	25
J (M)	12	14	37.5	12	28	41

Table 3: Concept Map scores for both phases

5 Conclusions

The relationship between Concept Mapping and attitude towards physics was explored for a group of college science education students over two semesters. The main findings from this year-long study suggest that there is a strong indication that students’ attitudes towards physics improve after working with and experiencing concept maps. Following their experience of the tool 59% of the students stated that their attitude towards physics improved, with 8% stating it disimproved and 33% of the students identifying that their attitude remained unchanged. 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. It may then be argued 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 second finding that emerged from this study is that the improvement in cognitive development, as can be seen in the map scores, is not directly related to the reported improvement in attitudes. From the ten sets of student maps analysed there was an increase in the cognitive development, irrelevant to the students' attitude towards physics. Statistical analysis was carried out on student map scores and results indicate that there was a significant difference in map 1 and map 3 scores for both phases, ($p < 0.05$).

Further analysis of the questionnaire reveals that students believe Concept Mapping is very beneficial in the physics classroom and that they will use the tool themselves during their own teaching practice. They felt that it would be a very "useful resource that could be used summarising classes or as a study aid". Students also expressed concern about time constraints. Some felt they could not give it enough time to construct the maps during the half hour session, 'It took a lot of work, with making a list of concepts first and then drawing the map". The author could not afford to give the students any more time to construct the maps as it would take from their scheduled tutorial times. Providing the students with the concepts is a possible solution to this and would provide the student teacher with further opportunities to develop their mapping skills and hence their teaching abilities.

This paper's preliminary findings suggest that the Concept Mapping method employed is effective in increasing students' attitude towards physics in third level, providing beneficial teaching and learning opportunities to student teachers. This study presents initial investigations in the field and research is ongoing, with a much more data available which have not et received analysis. Further work into quantifying the effect of Concept Mapping on the development of student's cognitive knowledge is at hand.

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