[O14] Interpreting the use of Technical Language by Undergraduate Students of Physics

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Abstract
Within the realm of Higher Education in Ireland a significant amount of Physics Education Research (PER) has being carried out providing a quantity of data in areas such as Peer Learning, attitudes towards science, and teaching approaches (Problem Based Learning and Inquiry-Based Learning). However little research has been undertaken into students' use of scientific technical language in the classroom and during problem solving. This paper contains a description of such a study, involving the creation and delivery of Concept Mapping and semi-structured interviews in the University of Limerick (UL) to interpret students' use of scientific language pertaining to the topic of electricity.

Concept Mapping was originally developed by Novak and his research group as a means of representing frameworks for the interrelationships between concepts (Novak and Gowin, 1984). This approach was built upon the thinking of Ausubel's theory of meaningful learning (Ausubel, 1968). The Concept Mapping tool involves students representing their understanding of scientific concepts in a graphical way whereby concepts are connected creating a hierarchical, branching structure. While the Concept Mapping tool has being in existence for some time few empirical studies examining scientific technical language are to be found.

The sample was a homogeneous group of 77 students, aged 19-20 years, of mixed gender, enrolled in a four year science education degree programme. Most (75%) had not studied physics prior to enrolling in UL. The module selected for the study was a first year module in electricity and magnetism. Throughout the course of the study students were asked to construct three concept maps on "Electricity" and following the second and third map students were interviewed on the concepts related to the topic in the form of mathematical and qualitative problems.

Categories of student responses were generated from the interviews and analysed to identify the students' use of language during problem solving. This paper presents initial investigations into the use of the framework as a method in examining students' responses to qualitative and quantitative physics problems in interviews providing a developmental "snapshot" of scientific technical language used by physics students.

Introduction
In Ireland, as in other countries, the number of students studying science subjects, in particular the physical sciences, is decreasing. This year almost 57500 students sat the Leaving Certificate (LC) exams in June and from the cohort only 8% (4600) took higher level physics. This number represents a downward trend as the numbers fell from 5992 in 2008. This reduction in numbers studying science immediately limits the growth of Ireland's knowledge economy and every effort needs to be carried out to reverse the trend. Coinciding with the release of the LC results the examinations commission also publish the Chief Examiner's Report. Several conclusions are drawn and recommendations highlighted to both students and teachers. One of these states that "students should express their understanding of physics concepts in language that is clear, concise and correct" (Chief Examiner's Report, 2008). This reflects the importance of the present research study as it is first necessary to identify students' use of language in order to improve it and encourage the students to use 'clear, concise and correct' language.

The Language of Science

Almost all teaching and learning takes place using the medium of language, both verbal and non-verbal. The teaching and learning of science takes place by merging language with pictures, diagrams, charts and other specialised scientific and mathematical symbols (Lemke, 2001) and in order for people and students to understand what is being said they require shared understanding between speaker and listener, whether it is specific or non-specific language (Brown and Ryoo, 2008). Within every subject or domain lies a specific 'register' which is defined as "a set of meanings that is appropriate to a particular function of language, together with the words and structures which express these meanings" (Halliday, 1975, p. 65). The science, and particularly the physics, register is saturated with specialist and non-specialist terminology and words. Students will be familiar with much of its language as it is not unique to physics, but it is adapted to more specialised purposes in science. It is the 'double meaning' of the words that causes difficultly as the students are not aware of both meanings. This affects students' learning and consequently leads to misconceptions.

This research study was carried out to determine students' use of scientific language and to establish if there is a significant difference between expert and student (novice) use of language using concept mapping and interviews as vehicles for assessment and evaluation.

Concept Mapping

Concept Mapping is a student-centred learning tool which falls into the broad family of graphic organising tools that include 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 identify knowledge structures of an individual and is now often used as a tool to represent and assess changes in students' understanding of science (Horton *et al*, 1993; Novak, 1990).

Concept maps have being 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 domain. The maps contain several elements, which as a whole organise and represent students' knowledge in a hierarchical manner, with the most inclusive concepts on the top and the more specific concepts on the bottom of the map. A typical map consists of four key elements: concepts, linking lines, linking phrases and propositions. Concepts 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, joined together by linking lines. The smallest unit of meaning of a concept map is a proposition which includes two concepts linked together using a linking phrase.

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 and as new information is learned, the network changes and more linkages are formed between the concepts.

Research Study – Research Aims and Profile of the Participants

This paper presents results from a larger PhD research study that has been undertaken at the University of Limerick since 2006 and which examines the use of Concept Mapping in third level physics education. The research questions that will be answered in this paper include:

1. Do physics students in third level education use technical language when describing physical phenomena?
2. Is there a significant difference between the language used by experts and novices?

The students involved in this research (N = 77) were enrolled in a four-year science education degree course in the University of Limerick. Two degree programmes were represented, Biological Science Education and Physical Science Education. All the students had completed one physics module prior to the study, however only 25% of the cohort studied physics in second level education. The results presented in this paper focus on the work carried out in Phase 2 of this study during which the students completed a module on Electricity and Magnetism.

Methodology

During the 15-week semester the entire cohort were asked to construct three concept maps specific to the domain Electricity. The students were familiar with the Concept Mapping tool as they had used it in their previous physics module on Light and Sound, and received an intensive training session at the onset of the primary research study. The level of direction varied throughout the semester as the students received instructions, probing words, and questions for the first map but only instructions for the final map (Figure 1). Ten volunteers were then recruited to participate in semi-structured interviews following the second and third map. The author also recruited 'experts' in order to compare their use of language to that of students (novice) when problem solving. For the purpose of this study "experts" are defined as anyone who has completed a physics degree and is either in the process of getting or has qualified with a PhD in physics.

In total there were six "experts" interviewed; four from University of Limerick (UL) and two from Dublin Institute of Technology (DIT). The expert interviews were carried out at the end of the research study at a time that was convenient to them and both interviews were carried out simultaneously.

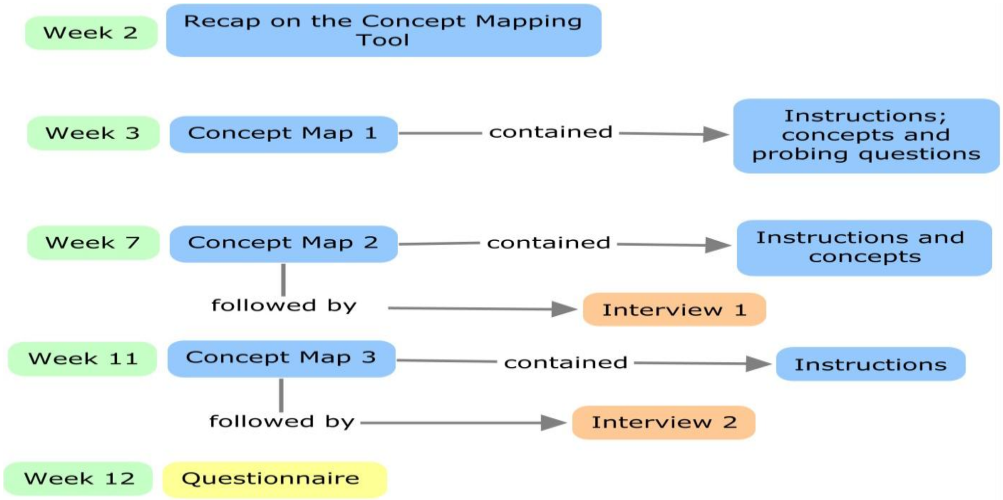

Figure 1: Structure of Phase 2 of research study

The interviews were transcribed verbatim from the voice-recorder and used in conjunction with the students' written solutions to ensure all data was accounted for. In total there eight qualitative questions asked and evaluated; six from interview 1 and two from the second interview session. The questions used for the interview were generated from the students' concept maps. The author analysed each concept map and generated a list of misconceptions and noted areas where the students did not expand on. The author calls this the Concept Mapping Filtering Process (CMFP), (Figure 2) whereby the outcomes of the concept maps are filtered to generate mathematical and qualitative problems specific to the students' misconceptions and understanding.

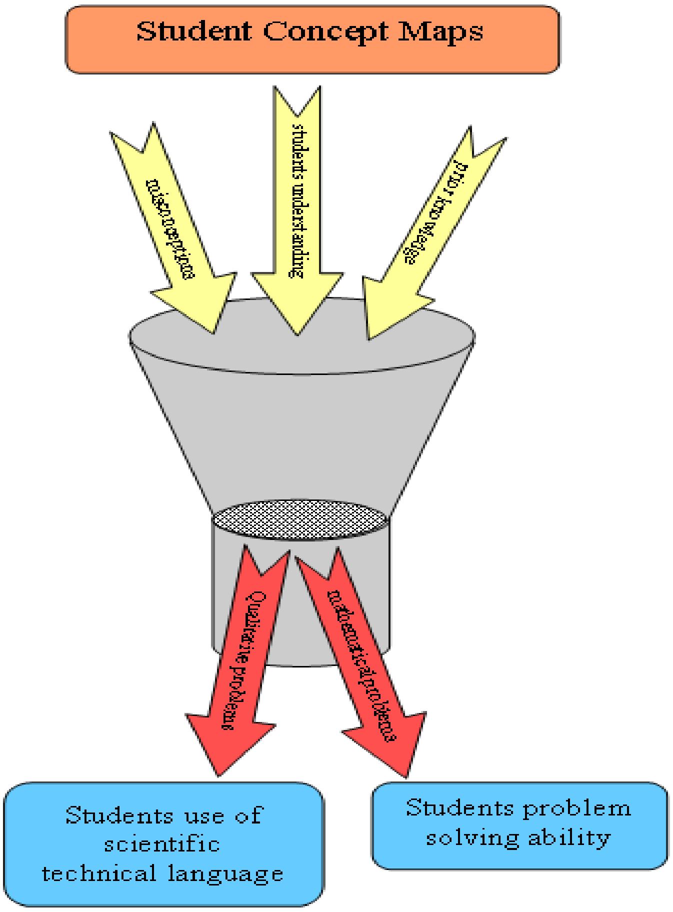

Figure 2: Concept Mapping 'Filtering' Process. The student concept maps provide the researcher with an insight into their understanding while also providing a snapshot of students' misconceptions and concepts they do not fully understand. The author filters out the important information from the maps which in turn forms the basis of interview questions.

Research Findings

The analysis of the interview transcripts revealed a hierarchical set of categories that describes the interviewees' use of technical language when solving physics problems (Table 1). As mentioned earlier there were eight theoretical questions asked in the interviews. These questions were further broken down into subsidiary questions to analyse the language, depending on the concept involved and in which context resulting in a total of 28 subsidiary questions. Criterion referencing was used to generate the highest level within the hierarchical categories of responses. Three university physics books which were on the recommended reading list for the Electricity and Magnetism module were used to determine the 'criterion' language. From these recommended texts the author identified the scientific language for each subsidiary question that was used to describe the associated concept. For the majority a proposition was identified. Having developed the categories the author then categorised the students and experts responses accordingly.

Table 1: Categories of Scientific Technical Language and their characteristics

Category	Key Characteristics
Scientific	• Qualitatively explains the concepts as is in the criterion books • Uses concise, accurate and clear language
Intermediate	• Qualitatively explains the concepts using language which is not the criterion language but uses language which correctly explains the phenomenon • Language used is similar to that of transitional language; showing some level of understanding and influence of education • The student response is a step towards the correct response
Instinctive	• Qualitatively explains the concepts correctly using non scientific language • Descriptions students would use prior to instruction; use of intuitive natural, colloquial language

The following example illustrates the students' responses and how the language was categorised. Figure 3 is an example of one of the problems the students were presented with during the interview.

Question 3: Van de Graff Generator.

Look carefully at the diagram and describe it.

Explain what is happening.

Why is it important that the student stands on a plastic mat insulated from the ground?

Figure 3: Question 3 Interview 1

This question was further broken down into two subsidiary questions as a result of the students responses:

1. Describe the movement of charge in the Van der Graff Generator?
2. What is the purpose of the insulating mat?

The following table (Table 2) represents the student responses concerned with the first subsidiary question. From the criterion books the scientifically correct proposition required to answer this question is **"transferred"**, i.e. charge is transferred in a Van der Graff generator.

Student	Proposition used in answering the question	Category of Language
1	running	Intermediate
2	going	Intermediate
3	travelling	Intermediate
4	flowing through	Instinctive
5	passes	Instinctive
6	flowing through	Instinctive
7		No Response
8	spreads out/going through	Intermediate
9	runs through	Intermediate
10	passing	Instinctive

As mentioned above no student used scientific language in answering this subsidiary question. Five of the ten students used intermediate language when answering and these responses were categorised as intermediate language because the student showed a degree of understanding though their language was not scientifically correct.

The ten students interviewed used scientific language at some stage of their reasoning, with seven students using it 50% or more. Both the students and experts used all three levels of language when problem solving, however the frequency with which the students use scientific language differs slightly to that used by the experts. When answering four of the subsidiary questions the students did not use any scientific language (Figure 4) whereas the 'experts' used scientific language in answering every question (Figure 5). The students used instinctive language when answering 15 questions however the experts used instinctive language in only 7 cases out of the 28. Statistical analysis was carried out to test for significance between the students' and experts' use of language for each subsidiary question for each level of language. In total the Fisher test was carried out on 84 data sets however significance was only found in two of these, for question 1B ($p = 0.036$) and 3A ($p = 0.044$) respectively. Both of these questions were associated with the movement of charge and the required proposition was "transferred".

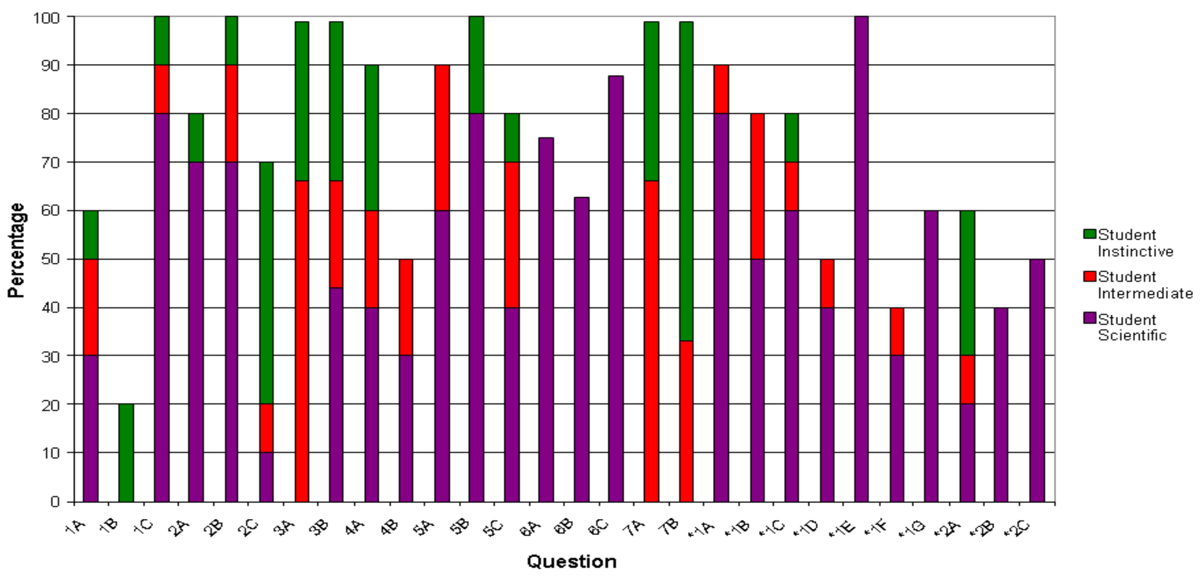

Figure 4: Percentage breakdown of Language used by Students during Problem Solving

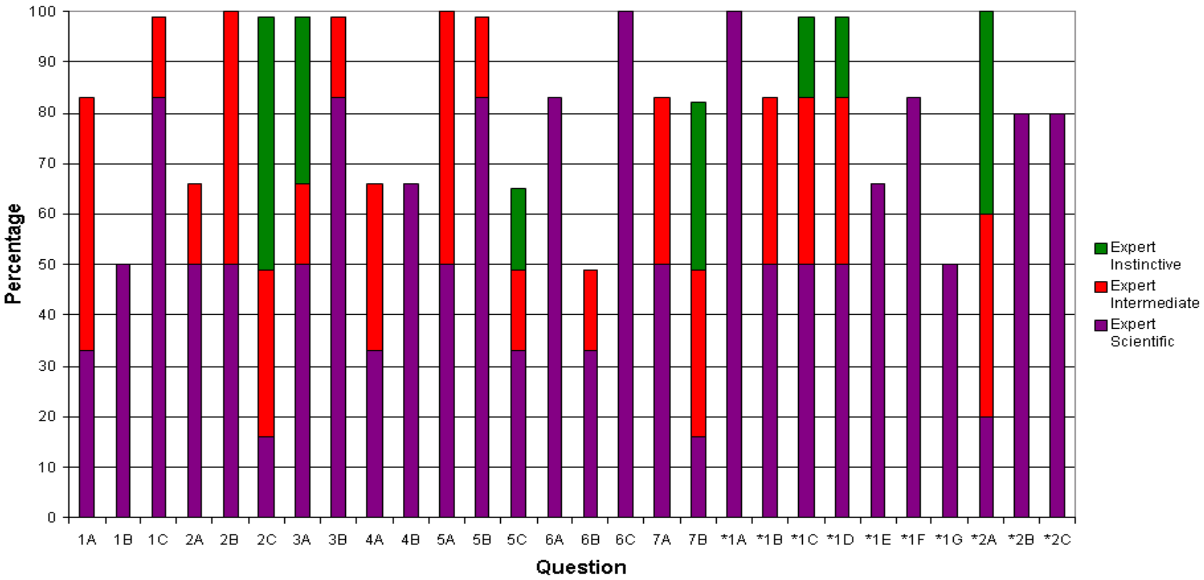

Figure 5: Percentage breakdown of Language used by Experts during Problem Solving

*(Note: The questions with a * represent the questions that were asked in the second interview)*

Conclusions

The traditional viewpoint is that language plays a passive role in science; it is simply the vehicle whereby meaning is conveyed from one speaker to another, a process whereby one is 'trying to find the right words' (Ford and Peat, 1988). However this is now under scrutiny because in order for the listener to understand what the speaker is conveying, both the speaker and the listener must have a shared understanding of the language and concepts (Brown and Ryoo, 2008), therefore the listener is as active as the speaker in understanding the context of the message (Ford and Peat, 1988). The importance of being able to understand and explain, in clear and correct scientific language, scientific concepts is fundamental to science literacy (Glynn and Muth, 1994).

The results of this investigation clearly affirm that students use several categories of language when solving qualitative style problems, which include scientific, intermediate and instinctive. Each category holds specific characteristics defined by the students' ability to explain a physical phenomenon. From the ten students interviewed scientific language was the dominant language however only two used scientific language 60% or more in their solutions. Every student used intermediate and instinctive language at some stage during their problem solving. There was very little significant difference between the language used by the experts and the students, which suggests that the language used in the teaching of science by the teacher is fundamental to students understanding of science and their use of scientific technical language.

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