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Developing Pre-service Primary School Teachers' Conceptual Understanding of Energy and Forces

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Abstracts

The aims of this research were to investigate pre-service primary school teachers' (PPST) scientific knowledge and cognition of key concepts in the topics of energy and forces and the design, implementation of Conceptual Understanding Lectures in Science Education Modules at an Initial Teacher Education College in the Republic of Ireland.

Diagnostic tests (multiple choice) were developed which tested and challenged the PPST conceptual understanding and misconceptions in science (Heat, Light, Forces). The tests provided the opportunity for the PPST to; experience an explicit confrontation with their pre-knowledge; become aware of their own knowledge and understanding; uncover any misconceptions they may have and; possible misconceptions of children they may be teaching in the future. Results of this study highlight that the participating PPST held many alternative and common misconceptions in the topics of energy and forces. The study also identified similarities between PPST alternative conceptions and that of pupils' they will be teaching in the future.

The lectures adopted a constructivist teaching and learning approach, allowing pre-service teachers to experience constructivist learning in science. The PPST carried out peer learning, inquiry based activities which were designed to reinforce their knowledge of specific concepts in energy and forces and to eliminate any misunderstandings they may hold. A context-based teaching approach was incorporated into the lectures, presenting scientific concepts in everyday life. The variety of teaching methodologies (Analogies, Concept Cartoons, Problem Based Learning, Investigations) implemented in the lectures modelled active methodologies that the PPST could also emulate in their own teaching.

The diagnostic tests were administered again at the end of the lectures. The results show that the Conceptual Understanding Lectures were successful in increasing the PPST conceptual understanding of key concepts in Energy and Forces. The lectures moved away from a traditional style of teaching to a more constructivist approach to teaching, modelling active teaching and learning methodologies, required in the primary science classroom allowing for the development of both the PPST' subject matter knowledge and pedagogical content knowledge.

1. Pre-Service Primary Teachers Education

The requirements to gain entry into any Initial Primary Teacher Education College in the Republic of Ireland, does not include the study of a science subject at Senior Cycle in post-primary education. Therefore many pre-service teachers have very poor backgrounds in science on entering initial teacher education, with a very small minority studying chemistry and physics at second level education [1,2,3]. A report by Waldron et al. (2009) investigating pre-service primary teachers' attitudes towards history, geography and science in primary teacher education colleges in the Republic of Ireland and Northern Ireland, recommended that a review of undergraduate primary teacher preparation courses in Irish colleges needs to be carried out, in order to ensure that the best balance between pedagogical content knowledge (PCK) and subject matter knowledge (SMK) is provided [4]. In the study by Waldron et al. (2009), both first and final year students also recognised the importance of developing a strong knowledge base in science. The report concluded that science education modules need to develop a strong knowledge base in the students and strengthen the students' conceptual understanding in science [3]. The Teaching Council in Ireland has also set out criteria and guidelines for programme providers in initial teacher education stating that pre-service

teachers need to begin their teaching careers with high levels of beginning competencies in all subject areas [4]. Therefore initial teacher education programmes need to develop a strong knowledge base in science among pre-service teachers and strengthen their conceptual understanding in science so that they will be able to teach science concepts in a meaningful way [5].

2. Pre-Service Primary Teachers Knowledge and Confidence in Science

It has been found in many research publications that even though pre-service primary teachers often feel confident in the teaching of science they can have a poor knowledge and understanding of scientific concepts [6]. PPST hold shared views of science quite different from those generally accepted by the scientific community. Not only do they lack a strong knowledge base in science but PPST can hold many misconceptions or misunderstandings concerning fundamental science concepts [6,7,8,9]. Recent research studies investigating PPST in Ireland also found this to be the case [2,5,10]. The PPST showed a lack of knowledge and understanding of science and held many inaccurate conceptions in biology and physics both before and after their Science Methods Modules, therefore not demonstrating a sufficient understanding in science to implement the Irish science curriculum in a competent manner [5].

2.1 Pre-Service Primary Teachers Misconceptions in Science

Research has indicated that teachers' conceptual development in different topics of science does not progress beyond 'children's science' [11,12]. Murphy and Smith (2012) and Liston (2013) found in their studies that high percentages of Irish PPST will enter the teaching profession with similar inaccurate conceptions of science as the students they will be teaching. PPST and practicing teachers may find it difficult to recognise areas of uncertainty in their own understanding of science concepts. Therefore addressing pre-service teachers' inaccurate understandings is necessary in Initial Teacher Education as most often misconceptions of key scientific concepts and principles held by pre-service teachers and adults in general are often left unchallenged [1,2,5,10]. This research set out to to investigate PPST scientific knowledge and cognition of key concepts in the topics of energy and forces and the evaluation of an intervention programme involving the design and implementation of Science Education lectures for pre-service primary teachers incorporating peer learning, inquiry based activities which were designed to reinforce their knowledge of specific concepts in energy and forces and to eliminate any misunderstandings they may hold.

3. Methodology

1. Diagnostic tests (multiple choice) were developed with the aim of testing prior knowledge, understanding and misconceptions in science (Heat, Light, Forces). The students completed these conceptual understanding tests individually at the beginning of the lecture.
2. The PPST carried out peer learning, inquiry based activities.
3. The diagnostic tests were administered again at the end of the lectures.

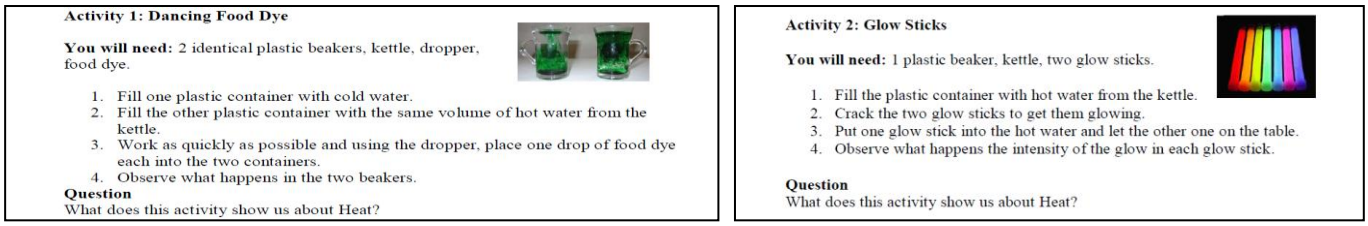
3.1 Example of questions on Heat and activities used to overcome misunderstandings.

Q. When you open the door and stand in front of a fridge. Cold air moves outwards from the fridge on to your face: A: True B: False C: I don't know

Pre- Workshop	% Correct	% Incorrect	% I Don't Know
	39	59	2

Table 1. Pre-workshop answers to question 1 in diagnostic test on Heat (N=249)

They then carried out the following activities (Fig. 1.). The group discussed what happens when we open the window in a warm classroom. From the above activities and discussion they were able to say that heat is a from of energy, heat always moves from a hotter area to a colder area and then were able to correctly explain what was happening when you open a cold fridge. Table 2 below shows that the PPST increased their understanding about Heat after carrying out the above activities.



Activity 1: Dancing Food Dye

You will need: 2 identical plastic beakers, kettle, dropper, food dye.

1. Fill one plastic container with cold water.
2. Fill the other plastic container with the same volume of hot water from the kettle.
3. Work as quickly as possible and using the dropper, place one drop of food dye each into the two containers.
4. Observe what happens in the two beakers.

Question
What does this activity show us about Heat?

Activity 2: Glow Sticks

You will need: 1 plastic beaker, kettle, two glow sticks.

1. Fill the plastic container with hot water from the kettle.
2. Crack the two glow sticks to get them glowing.
3. Put one glow stick into the hot water and let the other one on the table.
4. Observe what happens the intensity of the glow in each glow stick.

Question
What does this activity show us about Heat?

Fig. 1. Activities to develop the pre-service primary teachers' understanding of heat.

Post-Workshop	% Correct	% Incorrect	% I Don't Know
	99	1	0

Table 2. Post-Workshop answers to question 1 in the diagnostic test on Heat (N=249)

Q. If I leave two blocks of ice on the table, one block of ice is covered with wool and the other is not wrapped with anything: A: The block of ice wrapped in the wool will melt more quickly. B: The block of ice that is not wrapped with anything will melt more quickly **C:** They will both melt at the same rate.

Pre-Workshop	% Correct	% Incorrect	% I Don't Know
	28	68	4

Table 3. Pre-workshop answers to question 12 in the diagnostic test on Heat (N=249)

They then discussed a concept cartoon by Naylor and Keogh (2000), where children were debating would the snowman melt if they put a coat on it and carried out an investigatuon to test their predictions using ice cubes. Table 4 below shows that the PPST increaserd their understanding about insulators after carrying out the above activities.

Post-Workshop	% Correct	% Incorrect	% I Don't Know
	100	0	0

Table 4. Post-Workshop answers to question 12 in the diagnostic test on Heat (N=249)

3.2 Example of questions on Light and activities used to overcome misunderstandings.
Q1. If you were sitting in a completely dark room could you see?:
A: Yes B: No C: I don't know
Q2. If a white cat was sitting in a dark room could you see it?
A: Yes B: No C: I could only see its eyes D: I don't know

Pre-Workshop	% Correct	% Incorrect	% I Don't Know
Question 1.	31	67	2
Question 2	28	67	5

Table 5. Pre-workshop answers to question 1&2 in the diagnostic test on Light (N=153)

They discussed a concept cartoon from Naylor and Keogh (2000) on this scenario. They then were asked to complete the following activity (Fig. 2.) and discuss in their groups how we see things. They observed a picture of the character Superman and discussed his xray vision and does light beam out

of our eyes. Table 6 below shows that the PPST increaserd their understanding of how we see things after carrying out the activities.

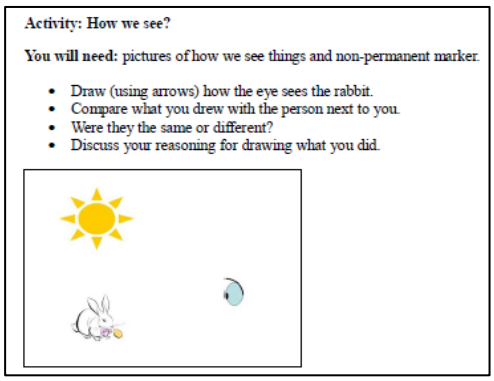


Fig. 2. Activity to develop the pre-service primary teachers' understanding of how we see.

Post-Workshop	% Correct	% Incorrect	% I Don't Know
Question 1.	93	7	0
Question 2	96	4	0

Table 6. Post-workshop answers to question 1&2 in the diagnostic test on Light (N=153)

4. Summary of results

Concepts on Heat (N=249)	**% Correct Pre-Lecture**	**% Correct Post-Lecture**
Heat is a form of energy	39	**99**
Heating materials to a specific temperature	58	**99**
Mixing liquids of the same temperature	96	**99**
Mixing liquids of different temperatures	69	**75**
Movement of heat	55	**70**
How fans work	51	**96**
Conductors v's Insulators	13	**59**
How insulating materials work	63	**94**

Table 7. Pre-service primary teachers' answers to the pre and post-workshop diagnostic test on Heat.

Concepts on Light (N=153)	**% Correct Pre-Lecture**	**% Correct Post-Lecture**
How light travels from its source	74	**97**
Seeing in the dark?	31	**93**
Seeing a white cat in the dark?	28	**96**
How the eye uses light to see	41	**95**
Movement of light from source to a screen	47	**80**
Reflection (types of surfaces)	68	**86**
Reflection (reflected images in mirrors)	75	**95**

Table 8. Pre-service primary teachers' answers to the pre and post-workshop diagnostic test on Light.

Concepts on Forces (N=297)	**% Correct Pre-Lecture**	**% Correct Post-Lecture**

Does mass affect rate of speed of a falling object?	81	**96**
Forces being exerted by stationary objects	82	**99**
Gravity on the moon	31	**95**
Forces always act in pairs	6	**92**
Forces acting on a moving object	83	**98**
Forces acting on a stationary object	68	**82**

Table 9. Pre-service primary teachers' answers to the pre and post-workshop diagnostic test on Forces

5. Discussion

Results of this study highlight that the participating PPST held many alternative and common misconceptions in the topics of energy and forces [1,5,10]. The study also identified similarities between PPST alternative conceptions and that of pupils' they will be teaching in the future. The results highlight major implications for the design and delivery of future Science Education Modules in Initial Teacher Education Colleges. Pre-service teachers need to be challenged conceptually, questioning their scientific thinking and allowed time to reflect on their misconceptions. They need to become aware of their own and possible pupil preconceptions so that they can eliminate any possible misconceptions they may have and what they might possibly pass onto their pupils.

Primary teachers' inadequate subject knowledge and understanding of science may affect their teaching methodologies and their ability to teach science effectively [5,13]. Teachers therefore need a breadth of knowledge to meet the needs of the Irish Primary Science Syllabus which involves the study of key concepts in Biology, Chemistry and Physics. Initial teacher education programmes need to develop a strong knowledge base in science among pre-service teachers and strengthen their conceptual understanding in science so that they will be able to teach science concepts in a meaningful way. The tests provided the opportunity for the PPST to; experience an explicit confrontation with their pre-knowledge; become aware of their own knowledge and understanding; uncover any misconceptions they may have and; possible misconceptions of children they may be teaching in the future. They developed scientific knowledge by carrying out scientific inquiries based on the scientific concepts and ideas questioned in the diagnostic tests. The strategies (peer learning, inquiry based activities) used in this intervention provided an overlap between methods used in probing understanding and developing understanding.

The results show that the Conceptual Understanding Lectures were successful in increasing the PPST conceptual understanding of key concepts in Energy and Forces. The variety of teaching methodologies (Analogies, Concept Cartoons, Problem Based Learning, Investigations) implemented in the lectures modelled active methodologies that the PPST could also emulate in their own teaching and so the lectures moved away from a traditional style of teaching to a more constructivist approach to teaching, modelling active teaching and learning methodologies, required in the primary science classroom. This intervention programme allowed for the development of the PPST SMK and PCK in an undergraduate three year course with very limited time allocated to science.

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