[O21] 'To teach is to learn twice': Do undergraduate science teachers improve their physics understanding by becoming Peer Leaders?

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Abstract
Physics Education Research (PER) has shown that students leave the physics classroom holding the same misconceptions about physics they had when they entered. PER has revealed that these misconceptions are often deeply held and are difficult to change. The research literature indicates that Peer Learning has advantages compared with traditional teaching and learning methods in producing conceptual change. There are a number of potential benefits for undergraduates acting as Peer Leaders in Peer Learning physics tutorials. These may include reinforced physics knowledge, improved self-confidence, enhanced learning experience, and improved social skills. Gartner, Kohler, and Riessman (1971) summarised a number of beneficial cognitive processes that occur when Peer Leaders' prepare for Peer Learning sessions. It is believed that in reviewing, organising and teaching the physics material, they may gain a better understanding of the subject.
This paper investigates undergraduate Peer Leaders understanding of introductory physics and examines the following questions: Does becoming an undergraduate Peer Leader provide the necessary motivation for overcoming misconceptions in fundamental physics? Do Peer Leaders experience similar misconceptions after they have reviewed, organised, and taught the physics material? Mixed methods data was collected on the Leaders' conceptual understanding of physics and on their expectations towards physics teaching and learning. The Peer Leaders selected for this study were third year undergraduate science teachers (N = 11) who had direct experience of the undergraduate physics course. Their responsibilities included training on how to become an effective Peer Leader, preparing and planning weekly tutorials, creating a cooperative learning environment and facilitating learning during the tutorials. The author's own conceptual test was administered as a pre and post and post-delayed test to the Peer Leaders, the results are reported. The change in the Peer Leaders' conceptual understanding is described and the benefits Peer Leaders claim to have experienced are also discussed.

Introduction
This paper reports on a Peer Learning programme that was implemented utilising undergraduate Peer Leaders in physics tutorials at third level. Third year science teaching students were recruited on a volunteer basis, were trained and utilised in first year introductory physics modules. The aim of the study was not to evaluate the effectiveness of the Peer Leaders in the first year class, but to investigate the effect of participation on the Peer Leaders and the experience they had by becoming a Peer Leader. In particular this paper sets out to answer the following research questions;

- Does becoming an undergraduate Peer Leader provide the necessary motivation for overcoming misconceptions in introductory physics?
- Do Peer Leaders experience similar misconceptions after they have reviewed, organised, and taught the physics material?

Context of the study
Various innovative teaching approaches are increasingly used within university courses to enhance the students' learning and the students' experience. Such innovations include peer, collaborative

or cooperative learning, in particular small group activities. The innovative teaching approach reported here is Peer Learning utilising Peer Leaders at the University of Limerick. Peer Learning typically involves students working in peer or cooperative groups with a teacher as a facilitator. Peer teaching involves students learning from and with each other in ways, which are mutually beneficial (Longaretti *et al*, 2002). The peer teacher serves as a role model having previous experience of the course. These peer teachers are called 'Peer Leaders' and include undergraduate teaching assistants and tutors (Whittman, 1988). Peer Learning groups are structured and managed to maximise the active and appropriate participation of all students in the group (Johnson *et al*, 1994). The selected first year undergraduate introductory physics module, Mechanics and Heat (PH4101), defined the context of the investigation. Students studying PH4101 (N = 153) attended two lecturers, one laboratory session and one tutorial per week for 12 weeks. The lecture and the laboratory were delivered through traditional teaching styles. The tutorial was delivered through Peer Learning. The students experienced Peer Learning facilitated by Peer Leaders in every tutorial.

Methodology

The Peer Leaders selected for this programme were third year undergraduate science teachers (N = 11) who had taken the module Mechanics and Heat (PH4101) in their first year of their degree course. The research participants (Peer Leaders) were recruited on a volunteer basis, through a recruitment flyer emailed to the class and through cooperation and discussions with their course leader. There were five tutorials per week, with two Peer Leaders per tutorial randomly assigned due to timetable constraints. The Peer Leaders were trained and meet weekly with the author. The author attended all the tutorials and worked closely with the lecturer during the project. In this study the lecturer carefully designed the tutorial sheets to match the needs of the Peer Learning tutorials, and on occasion visited the tutorials to meet with the Peer Leaders. The Peer Leaders who volunteered were not experts in the field nor were they expected to be. The only requirement was that they had previously studied the course. The quantitative and qualitative methods of data collection during this study were;

- The author's own specifically designed conceptual test.
- Questionnaire.
- Semi-structured interview.

The author's own specifically designed conceptual test was used to assess the Peer Leaders' understanding of Mechanics and Heat. The conceptual test was administered as a pre, post test and post-delayed test to the Peer Leaders. The Peer Leaders were asked questions regarding everyday examples and they had to apply their reasoning to them. The test contained three sections.

Section 1: Open ended everyday occurrences of physics phenomena.
Section 2: Multiple-choice (FCI) Force Concept Inventory (Hestenes et al, 1992); students were asked to reason out their selected answer.
Section 3: Mathematical manipulation of physics problems.

The Peer Leaders were asked to reason out all their answers and the test took approximately 40 minutes to complete. When administering the test, the author clearly stated that the students were to answer the questions based on what they thought was happening. No reference was made by the author to the use of any physics laws or their applications to everyday life. Section 1 contained 22 questions, which probed, from different perspectives, the cognitive link Peer Leaders possess of basic Mechanics and Heat (i.e. forces of friction, exerted force). All questions were qualitative but contained different levels of conceptual difficulty. The subjects received the questions in a random sequence. Table 1.0 illustrates a sample questions from Section 1

Table 1.0. Sample question from Section 1

Section 1	Q9. We know that the Earth pulls on the Moon. Does it follow that the Moon also pulls on the Earth?
Conceptual dimension	This question is located in the conceptual dimension of Newton's 3rd law and addresses the subcategory 'continuous forces'.
Misconceptions probed	Greater mass implies greater force - relating to action/reaction pairs.

Students were asked to respond to six FCI questions (numbers 6, 8, 11, 13, 18, 21, 28 in the numbering system of the original authors) in Section 2. The questions selected from the original FCI were picked at random. The FCI test is widely used to gauge the initial physics knowledge state of undergraduate students, as well as to quantify the effect of instruction on the knowledge state of the students (Hestenes et al, 1992). In addition to answering the multiple-choice FCI questions the Peer Leaders were instructed to reason out their choice of answer. Section 3 investigated their mathematical reasoning in physics problems such as interpretation of a graph. The author administered the questionnaires pre, post and post-delayed (18 months after post test). The questionnaire contained ranking questions on what benefits the Peer Leaders thought they might acquire from participating in the programme. They had to rate their confidence in different statements relating to teaching physics and they also had to rank the same statements after they had completed the programme stating whether they had experienced any of the benefits expected. The semi-structured interviews were used primarily to give the Peer Leaders feedback on their conceptual tests while also challenging them about their responses. The structure of the interviews involved the author giving feedback while at the same time progressing into a Socratic dialog where the Peer Leaders were asked to reason out their answers in their pre, post and post-delayed tests.

Results

The case study of volunteer Peer Leaders (N = 11) whose pseudonyms were Kieran, Lynn, Martha, Nicola, Owen, Paul, Quinn, Ross, Sandra, Tina and Una, is summarised in Table 2.0.

Table 2.0. Background of the Peer Leaders involved in the study

Name	Tutorials attended	Degree Course	LC Subject Taken	Grade MH
Kieran (✓✓×)	6	P	Phys + Bio	A
Lynn* (✓✓✓)	6	B	Phys + Bio	C
Martha (✓✓×)	5	B	Bio	C
Nicola (✓××)	6	B	Bio	C
Owen (×××)	6	B	Bio + PhysChem	C
Paul (✓✓✓)	8	P	Bio + PhysChem	B
Quinn (✓✓✓)	8	B	Phys	B
Ross (✓✓×)	8	B	Bio	C
Sandra (✓✓✓)	7	B	Agri Sci	D
Tina (×✓✓)	6	B	Bio	D
Una (✓✓✓)	8	B	Bio	C

Note. All Leaders' names are pseudonyms. Symbols within parentheses indicate students' who completed (✓) or did not complete (×) sections 1, 2 and 3, pre and post respectively. * Lynn a mature student studied Physics and Biology in the UK and took A-levels.

Legend:
B = Biological Science with Physics; P = Physical Science; LC = Leaving Certificate (Irish State Examination, Senior Level); and MH = Mechanics and Heat Module

Quantitative analysis of the Conceptual Test

The effect of participation on the Peer Leader was investigated through the author's own conceptual test. Table 3.0 illustrates the mean matched results from the Peer Leader group and the individual section pre and post results. Of the eleven volunteers recruited, only five Peer Leaders completed all three sections of the Mechanics and Heat Conceptual Test. There was a significant difference (Wilcoxon, N = 5, z = -2.032, two-tailed p = 0.042) between pre and post total test scores (+ 12.92 % change). There was a significant difference between pre and post results in Section 1 (Wilcoxon, N = 9, z = -2.312, two-tailed p = 0.021) and Section 3 (Wilcoxon, N = 6, z = -2.201, two-tailed p = 0.028). There was no significant difference between pre and post results in Section 2 (Wilcoxon, N = 9, z = -0.351, two-tailed p = 0.726).

Table 3.0. Pre and Post Test Results

Total Test	(Wilcoxon, N = 5, z = -2.032, two-tailed p = 0.042)	significant difference
Section 1	(Wilcoxon, N = 9, z = -2.312, two-tailed p = 0.021)	significant difference
Section 2	(Wilcoxon, N = 9, z = -0.351, two-tailed p = 0.726)	no significant difference
Section 3	(Wilcoxon, N = 6, z = -2.201, two-tailed p = 0.028)	significant difference

Table 4.0 illustrates the mean matched results from the Peer Leader group and the individual section pre and post-delayed results. There was a significant difference (Wilcoxon, N = 5, z = -2.023, two-tailed p = 0.043) between pre and post-delayed total test scores (+ 5.55 % change). There was a significant difference between pre and post-delayed results in Section 1 (Wilcoxon, N = 6, z = -2.366, two-tailed p = 0.018). There was no significant difference between pre and post-delayed results in Section 2 (Wilcoxon, N = 9, z = -0491, two-tailed p = 0.624) and Section 3 (Wilcoxon, N = 6, z = -0.524, two-tailed p = 0.600).

Table 4.0. Pre and Post-delayed Test Results

Total Test	(Wilcoxon, N = 5, z = -2.023, two-tailed p = 0.043)	significant difference
Section 1	(Wilcoxon, N = 6, z = -2.366, two-tailed p = 0.018)	significant difference
Section 2	(Wilcoxon, N = 9, z = -0491, two-tailed p = 0.624)	no significant difference
Section 3	(Wilcoxon, N = 6, z = -0.524, two-tailed p = 0.600)	no significant difference

All Leaders experience some % change in Section 1 pre, post and post delayed test results as can be seen in Fig. 1.0. and Fig 2.0.

Fig. 1.0. Peer Leaders' individual test scores Section 1 Mechanics and Heat test. All Peer Leaders experienced some positive % change. Quinn and Una obtained the highest % change.

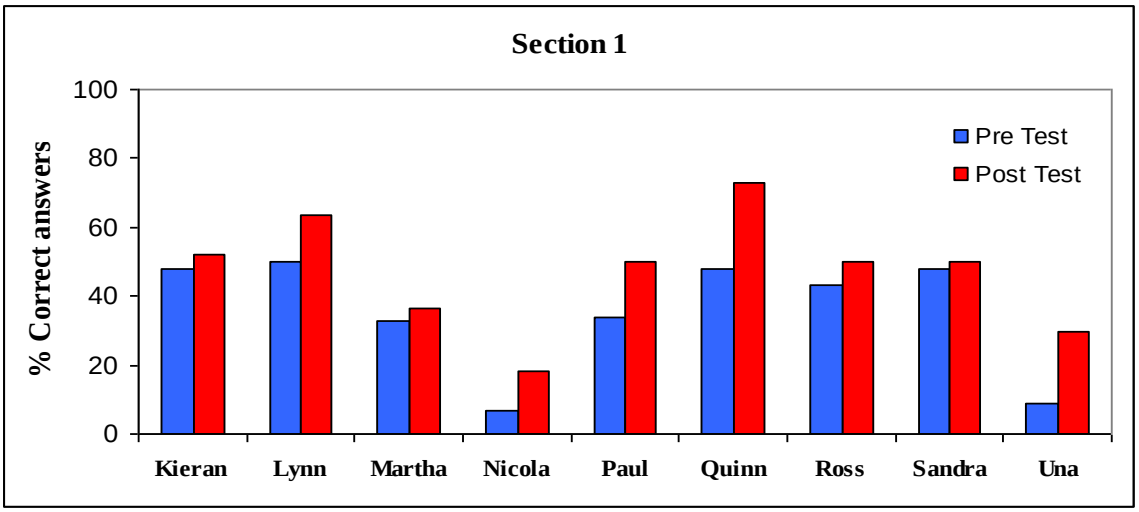
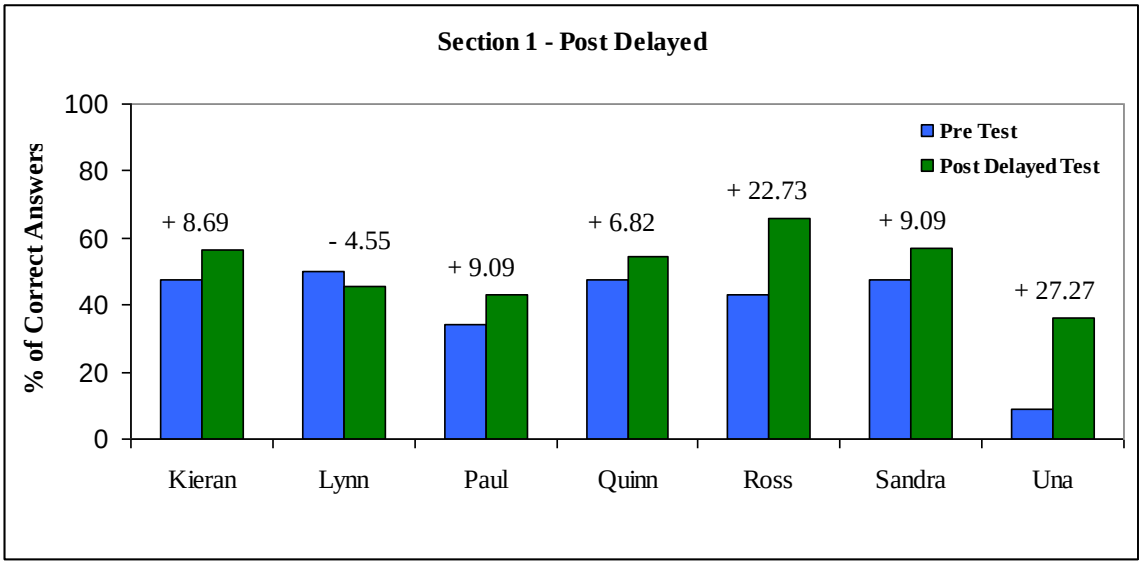


Fig. 2.0. Peer Leaders % of correct answers and % change in Section 1 of the Mechanics and Heat test. All Peer Leaders except for Lynn experienced some positive % change from pre to post-delayed test. Ross (22.73 %) and Una (27.27 %) obtained the greatest positive % change.



There was no significant difference between the numbers of misconceptions pre to post test or pre to post-delayed test. Table 5.0 illustrates the Peer Leaders' number of misconceptions from pre to post test and pre to post-delayed test in Section 1

Table 5.0. Number of Misconceptions: Section 1

pre to post	(Wilcoxon, N = 9, z = -1.055, two-tailed p = 0.291)
pre to post-delayed	(Wilcoxon, N = 9, z = -1.581, two-tailed p = 0.114)

Qualitative analysis of the Conceptual Test

The open-ended responses provided information about misconceptions held by the Peer Leaders, the following are an example of the Leaders misconceptions to the sample question illustrated in Table 1.0;

- 'Yes, there is a pull on the Earth by the moon but it is weaker then the gravitational pull by the Earth on the moon.' (Paul, pre Q9)
- 'The Earth has a magnetic attraction which pulls the Moon towards it' (Sandra pre Q9).

Interview Findings

The conceptual tests and the semi-structured interviews provided evidence that the Peer Leaders held a naïve view of force as a property of objects. The interviews also provided evidence of a change in the Peer Leaders conceptual understanding as they worked through the questions in the interview. Quinn demonstrates his confusion over his understanding of force and Newton's third law during the discussion of Q8, 'does the baseball possess a force?'. The following extract provides evidence of Quinn's change in understanding of force.

Interviewer (I): In a game of baseball a baseball is hit with a baseball bat. Does the speeding baseball possess force?
Quinn (Q): Yes.
I: What is a force?
Q: A force is an interaction.
I: Between two objects. When the ball hits the baseball bat, describe the interaction.
Q: The bat is going to push on the ball and the ball is going to push on the bat.
I: Okay, equal and opposite. When the ball is speeding away, does it possess a force?
Q: Well, I suppose it doesn't.

I: You're not very sure. It doesn't? What would you have said? It has a mass and it has acceleration so it has a force. Is force an object?
Q: No, it's not.
I: What is it?
Q: It's an interaction.
I: Between two objects. Okay, what does the baseball have?
Q: Oh yeah okay. So the force is applying. The way I was thinking was the baseball is going to be hit. It's going to be falling at some point, it's going to be decelerating.

Discussion

The Peer Leaders (N = 11) stated that becoming a Peer Leader improved their physics knowledge. They reported that they enjoyed being a Peer Leader and that they had a positive experience. They felt that the students also benefited from the Peer Learning programme. However they felt that preparation time took longer than they anticipated but they would 'definitely' take part in the programme again.
There was a significant difference ($P < 0.05$) in the Peer Leaders test scores. There was no significant difference ($P > 0.05$) in the number of misconceptions from pre to post to post-delayed. For the Peer Leaders, simply doing the course work tutorials sheets did not seem to have an impact on their misconceptions. The results indicate that getting the Peer Leaders to reflect on their pre, post and post-delayed responses to the conceptual test is an effective method of confronting and altering their misconceptions about Newton's laws, specifically Newton's third law. Studying the Peer Leaders physics understanding and concepts is not the only factor which can affect their conceptual change. Affective and social aspects such as their approaches to teaching and learning physics can have an impact.

Does becoming an undergraduate Peer Leader provide the necessary motivation for overcoming misconceptions in introductory physics? Yes, the process of providing the Peer Leaders with feedback but also challenging them about their understanding was the final step in the Peer Leader process. The semi-structured interview showed evidence of conceptual change.

Do Peer Leaders experience similar misconceptions after they have reviewed, organised, and taught the physics material? Yes, even after taking part in the study similar misconceptions were reported by the Peer Leaders. However during the semi-structured feedback interviews the Leaders demonstrated instance of a positive increase in their conceptual understanding of physics.

Conclusion

Preliminary findings suggest that the Peer Learning method employed is effective in providing beneficial teaching and learning opportunities to Peer Leaders. Initial investigations suggest the Peer Leaders did experience a change in their conceptual understanding of physics. The author felt the process of providing the Peer Leaders with feedback but also challenging them about their understanding was the final step in the Peer Leader process.

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