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Peer Instruction as a path to integrate students in curriculum development: the case of a course in Engineering

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Abstract
The Bologna Process has provided the justification for restructuring Higher Education bringing about qualitative changes in pedagogical practice. The work to be undertaken by the students, both in the classroom and outside of it, is of the utmost importance as the need for other learning practices arises within this paradigm change. Peer Instruction has been recommended as a strategy to promote more significant and longer lasting learning for the students involved. In this case study, Peer Instruction was combined with synchronous assessment of the students' knowledge in order to establish the extent to which these two strategies could enhance students' theoretical learning. Findings validated the use of Peer Instruction but the methodology must be more systematic to become part of the strategies regularly used by students.

Keywords: Peer instruction; synchronous assessment; students' role in curriculum development; higher education.

Introduction

The Bologna Process has provided the justification for the restructuring of Higher Education bringing about qualitative changes to pedagogical practices (Brennan, Enders, Musselin, Teichler, & Välimaa, 2008). The work undertaken by the students, both in the classroom as well as outside, was stressed as the need for other learning practices arises from this paradigm change. This objective is still important in the way in which Higher Education prepares itself for the 2020 Horizon (European Commission, 2010). This requires working with students not only with respect to final assessment and certification but must be capable of developing and fitting its working methods into student training. In this context, Peer Instruction appears as a strategy able to promote more significant and lasting learning for the students involved.

A verbalisation and discussion of the concepts to be learned undergirds the interaction the model deems as crucial to the quality of learning. This method of

working is based on the literature which affirms that students develop improved reasoning capabilities when they are involved in the content they are being taught and the best way of holding their interest is through Peer Instruction work (Crouch & Mazur, 2001). Empirical evidence supports a relationship between Peer Instruction and improvement in the capacity for conceptual understanding among students (Cummings & Roberts, 2008).

The objective of this study was assessing the effects of models of Peer Instruction in supporting the appropriation of concepts essential to a structuring course by virtue of their transversal nature (included in various engineering courses) as well as being introductory (making the transition between the knowledge acquired by students during their secondary education and the demands placed upon them at this level of education). An underlying objective stemming from the circumstances behind this study was associating the process of Peer Instruction with synchronous assessment devices. These two combined strategies challenge the traditional interpretation of curriculum as a plan since experience is focused on appropriation of concepts. Therefore, the Peer Instruction strategy is argued as a way to integrate students into curriculum development.

This study first discusses the relevant literature on Peer Instruction informing the concept employed here followed by a brief introduction of the case and the reasons governing its choice. The instruments for the collection of data are explained together with the principal results obtained. Finally, the conclusions are drawn from the data as well as identifying which aspects of Peer Instruction were associated with the promotion of learning by students and the pedagogical configuration of the course.

Peer instruction

The adoption of the Bologna Process has produced a restructuring of Higher Education in which pedagogical practice and learning have undergone changes intended to increase their significance for students. Furthermore, it should be stated that one of the biggest challenges for teaching staff continues to be the lack of motivation amongst students when learning content (Pinto, Bueno, Silva, Sellmann, & Koehler, 2012). This lack of motivation may be explained by the organisation of teaching models linked to passive forms of transmission which at times provide a message disconnected from and without meaning for students. The promotion of meaningful learning above all requires a teaching methodology which leaves room for the students to become involved as protagonists in their own learning with an increasingly active role distanced from the concept of their being mere receptacles for the content (Dioso-Henson, 2012). From this concern, active learning methodologies have arisen that favour the realisation of this process of change.

The pedagogical method of Peer Instruction is one tool based on the understanding and the application of a conceptual type learning, itself based on the discussion between the students (between equals).

> Peer Instruction as described by Mazur (1997) is a teaching style that builds on the use of several cycles of interactive learning among students during the lecture. The method is found to result in a better learning outcome than are class-wide discussions (Schmidt, 2011, p. 413)

This teaching methodology seeks to distance itself from traditional teaching methods which have reduced the students to playing a passive role by introducing a greater degree of interaction in the classroom. With this method, interaction between the students hopefully provides mutual teaching and learning about the concepts to be studied which then are applied to conceptual matters and translated into greater active involvement in their own learning (Pinto et al., 2012).

In this context, Peer Instruction becomes a strategy capable of promoting more meaningful and longer lasting learning for the students involved based on their interaction which in turn implies a verbalisation and discussion of the concepts acquired.

> Peer Instruction provides a structured environment for students to voice their ideas and resolve misunderstandings by talking with their peers. By working together to learn new concepts and skills in a discipline, students create a more cooperative learning environment that emphasizes learning as a community in the classroom Research suggests that this type of cooperative learning environment can help promote deeper learning, as well as greater interest and motivation (Gok, 2011, p. 418).

Simultaneously Peer Instruction also supports the students in the development of their meta-cognitive capacities as soon as they have managed to verify and recognise when they have failed to understand a concept or when they are unable to explain a topic or concept to their peers during the discussion period. In this way and through internal feedback the students are better able to assess their own conceptual understanding during the course of their own learning process.

The matters raised which promote discussion should also be carefully selected such that they provide students with the opportunity to discover and correct their errors:

> Appropriate concept tests are essential for success. They should be designed to give students a chance to explore important concepts, rather than testing cleverness or memory, and to expose common difficulties with the material. (…) Concept tests should be challenging but not excessively difficult (in order to maintain) the purpose of questions, participation with students, and norms of discussion (Crouch & Mazur, 2001, p. 974).

In an operational description of Peer Instruction, prior preparation of the students is an intrinsic requirement and must be assured (Pinto et al., 2012). In this case the student should assume responsibility for previously reading the texts recommended by the teaching staff while realising the need to follow the course, both in and out of the classroom environment. This requirement derives from the constructivist assumption that the student is not a blank page but rather they assimilate knowledge on the basis of previously acquired mental and knowledge structures. As a result ‘Peer Instruction requires students to be significantly more actively involved and independent in learning than does a conventional lecture class’ (Crouch & Mazur, 2001, p. 974). Prior reading is a boost to better comprehension of the texts as well as the content covered in the classroom resulting in students acquiring greater familiarity with the matters to be covered later by the teaching staff translating into a greater capacity for questioning and reflecting on the material with the learning becoming more

meaningful. This also contributes to the necessary assumption of responsibility from the students for their own learning process.

The role of the teaching staff is also distinct when using this methodology. As well as a disposition for overseeing the students, the teaching staff is responsible for ensuring the necessary mediation between the curricular content and discussion between peers in which providing guidance is a good example. As Turpen and Finkelstein (2007) concluded, the intention of the questions discussed together with the rules of the discussion comprise a guarantee of the effectiveness of the process which, at least for new students, needs to be verified by the teaching staff. The implementation of a culture of responsibility which is to be encouraged between the students begins as an assumption of responsibility also applying to the teaching staff.

The Peer Instruction pedagogical model also translates into a tool which can encourage greater capacities for reasoning on the part of the students involved (Turpen, Dancy, & Henderson 2010) given that they have the possibility of becoming more absorbed in the content being taught to them. Students able to discuss their responses among their peers provides a greater and more effective comprehension of the concepts as the language used during discussion with fellow students is simpler than that used by the teaching staff when explaining the content without prejudicing the discussion (De Backer, Van Keer, & Valcke, 2012).

It therefore appears possible to affirm the existence of a relationship between use of the Peer Instruction method and improvement in conceptual understanding on the part of the students as well as their more active participation in classes resulting from a significant increase in students' inter-personal interaction and motivation. This relationship provides the theoretical context for this study which seeks to assess the effect of Peer Instruction in learning theoretical concepts.

Methodology

This work utilised a case study approach evaluating the effect of Peer Instruction when used as the principal strategy in a Physics course to promote learning theoretical concepts. The course, of a theoretical nature, used a Peer Instruction model linked to the use of a system of synchronous questions and answers which comprised the starting point for peer discussion. This case was selected due to the difficulty students tend to have when learning the theoretical content; as a result examining which specific circumstances and the view points of the parties involved (teaching staff and students) were important for assessing the effectiveness of the methodology. This course was the only case studied.

A case study consists of a 'collection of formal data submitted as an interpretative opinion of a unique case and includes the analysis of the data collected during the field study and written up at the end of a cycle of action or participation in the investigation' (Morgado, 2012, p. 57). This is understood as being *instrumental* in nature given the need for greater overall comprehension on the matter in question when the main focus of attention falls not only on the teaching staff and the application of the pedagogical methodology in question but fundamentally on the patterns with which the latter administers it and the consequent repercussions for the students (Morgado, 2012). The objective of this

study was not the strategy, the teaching staff or the students themselves but rather the impact which the model had on the curricular practice of the teaching staff and the students' learning.

This way of working was complemented by a synchronous assessment mechanism which translated into a tool for monitoring conceptual learning. The objective for the students, in the first instance, was to undertake individual reflection and then discuss their responses with their peers before being informed of the correct response by the teaching staff.

The case

The object of analysis of this study was a theoretical course from the Porto University Engineering Faculty where the teaching methodology was Peer Instruction. The course was characterised by a theoretical approach which is both important as well as transversal to all aspects of engineering. A subsidiary aspect which weighed in the selection of this course was based on a transition period (from secondary to higher education) in which the majority of students were in their first year. The selection also resulted from the agreement of the teaching staff to use the Peer Instruction pedagogical model and the administration of questions with a synchronous response.

Instruments and procedures

Taking into account that this was a study focused on one course and in order to appreciate the diversity of the elements characterising the matter in question (synchronous assessment and Peer Instruction and their effect on the effective comprehension of the concepts), two data collection methods for both qualitative and quantitative data were used.

In the first stage, direct observation of the performance of the students in response to the conceptual questions was undertaken. The data collected were of a quantitative nature and comprised the responses obtained from the students in moments of synchronous response to multiple choice questions. The data collected corresponded to three observations undertaken in a classroom context. Observation permitted the quantification of the correct and incorrect responses which the students gave to multiple choice questions put forth by the teaching staff before and after peer discussion sessions which the students were invited to undertake on the question and the diversity of the responses was counted for the class. The teaching staff often encouraged the students to discuss possible solutions or contrary arguments which could help them to arrive at a more adequate response by themselves. Following these sessions the students were once more invited to respond to the same question and the number of correct and incorrect responses were counted.

Qualitative data was then collected characterising the students' understanding and the effectiveness of the method. Statements were taken from the students using six brief interviews with students taking the course in question. This method enabled placing the subject involved in the production of the information into relief. Understanding the significance that the interviewees gave to certain questions and/or situations was the main objective (Morgado, 2012) enabling access to a higher level of authenticity and depth regarding the

conceptions and the meanings attributed by the students using automatic and synchronous response devices, particularly in situations where Peer Instruction was used.

The interviews held were semi-directive in the sense that the questions were not entirely open nor were there many precise questions providing greater flexibility in respecting the tables of reference and interpretation of the statements. This would not have been possible if only direct observation had been used since, from the classroom observations, it was not possible to perceive the opinions and the specific effects on the students; thus the need for greater interaction and communication between them arose.

The data was treated in accordance with its nature: the quantitative data were subject to statistical analysis while the qualitative data – the content of the interviews – were analysed using the NVIVO 10 programme.

The quantitative data was counted according to the number and percentage of correct answers in relation to the total number of students in the class for each of the questions asked.

Fragments of the statements from the analysis process using the NVIVO 10 programme were assigned to three central categories: *Selection of Engineering Programme*; *Methodology* and *Course Features.* In the *Selection of Engineering Programme* category, the reasons behind choosing this area of study were sought and whether or not they were related to personal or extrinsic concerns. In *Methodology* the form of pedagogical work used by the course in question was sought, also covering the Peer Instruction pedagogical tool concerning the students' view of this method, particularly their assessment of constraints and advantages. In the third category, entitled *Course Features,* the objective was to take account of the features of the course, namely the transversal nature of its theoretical concepts, its importance to the students' curriculum development and to understand at what point students were aware of the strength of this theoretical basis for their academic career.

The first category, *Selection of Engineering Programme,* was broken down into sub-categories – *personal features* and *employment*. The category *Methodology* was separated into three: *texts*, a*ssessment*; and *contextualisation*. The main idea was to assess the relationship between the use of Peer Instruction and the advantages and disadvantages attributed by the students during higher education learning. With *texts,* we sought to establish at what point the students used this study and classroom support materials and in what way they were essential for overseeing the methodology adopted. With the sub-category *contextualisation,* we sought to understand at what point the students felt there was a need for their different academic courses, in particular physics concepts, to be related to their daily routine. We also sought to understand whether this relationship was beneficial or not to conceptual learning and whether the knowledge acquired was transferred to concrete situations. For the *assessment* sub-category, we sought to find out whether the methodology used by the teaching staff had positive effects on the students' results as well as whether the structure of the test was seen as pertinent from the point of view of the latter.

Finally, within the *Course Features* category, we intended to organise information regarding the course that was important to its development. Features like: class composition, degree of difficulty, importance of the course and

previous preparation were of the utmost importance to characterise the course and judge the impact of the Peer Instruction method.

Lay-out of results

The lay-out of the results follows the stated order of planning for the study: first the data relating to the results of the Peer Instruction sessions assessed with a synchronous system of responses to multiple choice questions before and after said sessions were described. Next, the data for the qualitative analysis focusing on the statements collected from the students were described.

The assessment of the Peer Instruction sessions was undertaken by calculating the correct responses given by the students during the in-person sessions to the multiple choice questions chosen to fit in with and motivate discussion between the students permitting the data to be organised into two groups as depicted in the following tables. The first focuses on the diversity of the in-person subjects (Table 1) while the second concerns the different experimental circumstances (Table 2).

Table 1: Average percentage of responses to multiple choice questions before and after the Peer Instruction sessions and questions in the final exam consonant with the scientific subject taught.

Subject		R First assessment	R second assessment	R exam
kinematics	Average % correct	80%	88%	57%
	N of questions	7	2	1
Newton´s Laws	Average % correct	64%	89%	67%
	N of questions	3	2	3
Work and energy	Average % correct	57%	92%	57%
	N of questions	7	5	4
Dynamic of	Average % correct	68%	49%	67%
particle systems	N of questions	6	1	5
Rotation dynamic	Average % correct	84%	71%	53%
of a rigid body	N of questions	10	2	5
Total	Average % correct	73%	84%	61%
	N of questions	33	12	18

For questions related with kinematics, the first assessment had a total of 80% correct responses for a total of 7 questions. In the second assessment 88% of students correctly responded to the 2 questions while for exam questions the total was 57% correct responses for 1 question.

For questions relating to Newton's laws, of a total of 3 questions garnered 64% of correct responses during the first assessment; at the second assessment 89% of students responded correctly to the 2 questions while for exam questions there were a total of 67% correct responses for 3 questions.

For work and energy, 57% of students responded correctly to the 7 questions in the first assessment; during the second assessment there were a total of 92% correct responses for 5 questions while for 4 exam questions, 57% of the students responded correctly.

For particle systems dynamics there were a total of 68% correct responses for 6 questions in the first assessment; at the second assessment 49% of the

students responded correctly to 1 question and 66% responded correctly to the 5 exam questions.

Finally, for the subject of dynamic rotation of a rigid body, at first assessment 84% of students responded correctly to the 10 questions; for the second assessment there were 70% correct responses to the 10 questions; at the second assessment with a total of 2 questions, there were 70% correct responses and in the exam with 5 questions, 53% responded correctly.

As a whole, the students improved significantly in their responses following the peer instruction session with the exception of the set of questions relating to the subject of dynamics: particle system dynamics and rotation dynamics for a rigid body. There was also a difference between these good results and the subsequent final exam where the students' performance worsened relative to the post-experimental situation (that is after peer discussion).

Table 2: Average percentage of correct multiple choice responses before and after Peer Instruction sessions and the questions in the final exam consonant with the experimental circumstances.

Experimental situation		R first assessment	R second assessment	R exam
Assessed well without subsequent control	Average % correct	97%		
	N of questions	9		
Object of peer instruction without control in exam.	Average % correct	43%	86%	
	N of questions	6	6	
Object of peer without control	Average % correct	43%	82%	59%
	N of questions	6	6	6
without peer, with control in exam	Average % correct	85%		61%
	N of questions	12		12
Total	Average % correct	73%	84%	61%
	N of questions	33	12	18

When the questions were well assessed in the first assessment situation, it can be seen that these were not subject to Peer Instruction nor was there subsequent control by examination. In these instances, a total of 9 questions, 97% of the responses obtained were correct.

As for the questions which were subject to Peer Instruction but were not subject to control by examination, the results were as follows: with a total of 6 questions, at the first assessment the percentage of correct responses was 42% while in the second assessment this value rose to 85%.

The questions which were assessed by Peer Instruction and final examination had the following results: for the 6 questions, at the first assessment the total correct responses was 42% while in the second assessment this rose to 82% and in the assessment by examination the value was 59%.

For the questions which were not subject to Peer Instruction but rather assessed by final examination, the results were the following: of a total of 12 questions, in the first assessment 82% of correct responses were achieved while in the assessment by examination this fell to 61%.

In all, a total of 33 questions for the first assessment reached 73% for correct responses; at the second assessment for a total of 12 questions, 84% of responses were correct; finally, in assessments by examination, 60% of responses were correct for a total of 18 questions.

As a whole, the students were found to significantly improve their responses after discussion sessions with peers but achieved lower results in the final examination circumstances.

Analysis of students' statements

When the procedure for the choice of course was raised, there were two trends in relation to this subject. One concerned the question of personal character where the students identified themselves with the characteristics of the course. The second tendency related to the choice of the scope of the course translating into a greater range of possibilities in the labour market.

The composition of the class was a pertinent factor for the functioning of the course. It was possible to identify that the composition of the class could be a negative factor for the functioning of the class with a lack of concentration on the part of some students. A further negative factor indicated by the functioning of the class derived from the small amount of time given for students to reflect on and discuss the responses to the questions by the teaching staff; 'yes – at times there's a lot of pressure. The teaching staff asks something and then everyone is responding and there's no time to think'.

The results obtained from the statements showed that the concepts covered in the classroom were important on two fronts. Firstly, there was unanimity about the importance given to understanding the concepts to obtain the best study results and subsequently obtaining satisfactory results. Secondly, there was agreement on the utility of the concepts covered for the learning experience of the students also translating into concepts which are fundamental for other areas of the curriculum; 'Yes I think it's very important. This course is also a basis for other units (....) yes, understanding of the concepts is very useful for future application'.

A further aspect worthy of mention was demonstration of the need on the part of the students for there to be a contextualisation of the concepts using specific examples which permit the establishment of relations between the curricular concepts and conceptual learning with the specific and family situations in their day-to-day life.

> Well there isn't. Due to attrition which is a bit confusing because we can never imagine things without wear. A hammer – if there were no wear, resistance from the air drops to the level of the speed of a leaf and it's a bit hard to imagine this because it doesn't happen here. That's why it can't be demonstrated. But I think that if it were more practical it would be easier (Student A).

In general it can be seen that the course studied was seen by the students as being transversal and pertinent since its curricular concepts permitted a greater understanding of other scientific fields.

> It's the basis for lots of things. So now, in the second year, all of the subjects are linked with physics. (....) Of course they're very important. Physics is the basis for engineering along with math. So if you have a good grasp of physics other subjects can be passed more easily which would not happen without this knowledge. For example, in the case of fluid mechanics, without basic physics, it is impossible to pass the subject (Student B).

The question of previous preparation led to an understanding that the students experienced an inadequate secondary education. This translated into a

lack of the basics in central subjects such as math and physics making it difficult to follow the course in question. In addition the lack of the practical component in the study of these subjects was mentioned.

> The 11th year content doesn't have much to do with this subject. It's a bit more difficult. I think the subject is very abstract and very detailed (....) In secondary I don't think that we were properly prepared because the subject is taught very differently to the way it's taught in the university. The practical side wasn't shown to us at all – it was all very abstract. In first year, in terms of preparation for this subject, it's a year aimed more towards chemistry. So this is the first time that we've had contact with physics (Student A).

From the data, the difficulty of this course arose from its abstract content. 'Yes – I think it's difficult. It's very abstract. (....) I think this subject is a bit abstract so I try to make it more concrete' (Student C). That this course required the students to break with common sense was another aspect underlining the difficulty. 'Someone might think that they'll find basic ideas which we have in physics and which defy our culture in general. It is often the contrary of what we think and so people find it difficult to believe in physics' (Student B).

The results showed that the students did not blame these difficulties on inadequate preparation or excessive protection on the part of the teaching staff in secondary school. They believed however, that they were due to a greater degree of responsibility at university compared with their secondary school experience.

> No – I don't think so. I think that the teaching staff in secondary school are like the ones here but the level required is very different. Now we're also preparing to go out into the labour market while in secondary school it wasn't really like that so much (Student D).

This attempt to understand the pertinence of the texts led to the conclusion that they were seen by the students as instruments for supporting studies. On the one hand, they managed to provide an improved oversight of the class and on the other allowed the students to put themselves in a more secure position when responding to the questions and to obtain better results; 'it's good to have a basis for study. So if we have any questions it's all explained (....) because it helps to prepare before coming into class (....) they are useful for responding to the class responses' (Student E). It can be seen that these study support materials provided for the course were tools which aided comprehension of their concepts as well as for other areas of the curriculum 'and do they end up serving for other subjects? Yes'.

The main conclusion for the category from *Contextualisation* of the curricular content was that for the students they were important for comprehension of the concepts by using concrete examples 'because if we didn't have an example, even if it's quite banal, which we see day-to-day, is a way of simplifying things, not having so many names and symbols makes things easier to understand' (Student C).

We can see that the results obtained were dependent on the structure of the test using multiple choice answers. From the students' comments, there was either a predisposition to adapt to this test structure or the final result was conditioned:

> The test had lots of multiple choices which are a help to many people but are prejudicial to others because besides being a means of assessment which is very 'dry': it's either right or wrong it doesn't tell you anything about the process (Student F).

Another conditioning factor was the duration of the tests which seemed brief for the activities to be undertaken.

For the central assessment mechanism, in general students regarded Peer Instruction as something functional and motivating learning. The extrapolation of this mechanism went beyond the classroom such that students had recourse to this as a way of structuring their study. This motivated discussion between peers including outside of the classroom providing an incentive to discussion and exchange knowledge. 'Do you use this example when studying for the tests? Yes. Who with? I never study alone. First of all I read on the subject and then the exercises but never alone. I think it's 100%' (Student D). The use of this assessment tool was still seen by students as a way for teaching staff to select the most important content. 'Yes because the teaching staff make this into a "study aid" and the main focus so then I can study and orient myself by the points which I know are essentially the most important' (Student A).

According to the data, the space for reflection provided by this assessment mechanism was shown to be essential to the construction of concepts on the part of the students and for its absorption 'because in the same way in which we absorb the response is important for creating our point of view' (Student A). Otherwise the students stated that this individual moment became pertinent to reflect on the questions and consider different hypotheses. When the response was made the group can have an influence on the individual response where there were no certainties: 'when I'm not sure how to respond I am guided by how the majority responds' (Student D). Giving the wrong response in relation to the group had major implications for the motivation of the student in seeking to effectively understand why it was wrong and to fully absorb the explanation: 'suppose that the teaching staff set a question and mine is the only incorrect response I guarantee that I'm not going to forget the correct response' (Student D).

The space for peer discussion was seen as something valued by the students and which stimulated the prior preparation of arguments and an organisation of the reasoning. It permitted the construction and explanation of opinions even when they were not wholly correct. On the part of the students there was an awareness that this attempt to express an opinion, even when not correct was something more complex in the presence of the authority of teaching staff where the student tends to be more passive and observe a hierarchy.

> When it is teaching staff we have to accept what they say because they are above us and when it's with a colleague we can have a more amicable discussion (....) we can usually talk to each other more easily and the explanations from our colleagues and so at times it helps more and it turns out to be easier (....) it's good with colleagues too because the teaching staff use a language for everybody but with the colleague it's like they explain things, they're on the same side and clear up our questions (Student B).

The disadvantages go back to the fact that due to the number of students and as a consequence of the variety of questions there was a concern that not all

concepts were completely cleared up. This was also due to the lack of time for peer discussion and the clarification of doubts.

> At times it was not completely clear (....) at times there's a lot of pressure. The teaching staff set questions and then everybody responds then there's no time to think (....) we don't have much time to think about the exercise set (Student D).

In relation to the areas for discussion, this can be created by its very existence or success due to the existence of a close relationship between the persons involved:

> If there are 80 people then it's quite likely that there will be some that I don't know and many people only talk and discuss their ideas around friends or otherwise it must be because of this because I think that everybody should follow (Student B).

The disadvantages found by the students with this method of working were seen as an instrument for the application and self-assessment of the learning. In other words, through the exercises the students were able to conclude which questions they were unsure about and opened up a space for talking about their doubts. Some students felt that at these times the teaching staff were more predisposed to respond to their doubts:

> (...) Then the questions serve for us to understand where we are unclear and what we are or aren't understanding about the subject (...) for example, the teaching staff give the class and then through their questions whether we understand means that the class given wasn't understood (Student A).

Discussion of the results and conclusion

From the data, it can be seen that the students significantly improved their responses after a peer discussion session but then obtained worse results in the final examination. This result was in line with the conclusions of earlier studies reported in the review of the literature (Crouch & Mazur, 2001; Cummings & Roberts, 2008). Similarly, peer discussion was a strategy appreciated by the students, developing other competencies such as the production of arguments and the organisation of reasoning associated with verbalisation and discussion of the concepts acquired which systematises and extends the conceptual comprehension of the science to be learned. Also, students' role in curriculum development was increased. This result was also reported in the review of the literature (Pinto et al., 2012).

Comparing the immediate results of Peer Instruction with the results of the final examinations of the same students, they obtained worse results than those resulting from the peer discussions although they were consistently better than those from the initial assessment. The time factor can be put forward as the logical explanation for this difference. Similarly, the results of the examinations were for all the students while participation in Peer Instruction was not compulsory which could explain this difference. Furthermore, the structure of the multiple choice tests implies a linguistic and logical domination of the reasoning which – according to some students – makes a course more difficult in the sense that it is frequently contrary to common sense. It is therefore plausible to consider that these lower results are explained by the epistemological rupture in relation to common sense which some students have still not understood.

In conclusion it can be confirmed that the study of this course validated the use of Peer Instruction but the methodology needs to be more systematic to

become part of the strategies regularly used by students and improve their curriculum role. If curricular study which demands a more active and inter-active attitude from the students were not required by the university it is difficult to understand how these same students will rise to the expectations of society: university students who think like everyone else are not able to think for themselves; they should say what others are unable to say and make what others are unable to make (Nóvoa, 2011).

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