Learning About Safety, Prevention and Quality of Life Through PBL: Implications for Teacher Education

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ABSTRACT
In Problem-Based Learning (PBL) students learn 'new' knowledge by solving problems. Studies focusing on the efficacy of PBL for the learning science content knowledge are rare and their results are not fully consistent. This study aims at: comparing the effectiveness of a transdisciplinary PBL and traditional teaching with regard to students' learning of science knowledge within the scope of the theme Safety, Prevention and Quality of Life; finding out students' opinions on transdisciplinary PBL approach. The sample is made of two 9th grade classes of a school located in the north of Portugal. The experimental class (24 students) approached the theme through PBL in an integrated way that is, Natural Sciences and Physical Sciences teachers pooled together the concepts that they were supposed to teach and organized PBL oriented teaching as if those concepts belonged to a single school subject. The control class (25 students) studied the same theme through traditional teaching, with the concepts of each school subject addressed separately by each one of the teachers. Data relative to content learning were collected by means of a pre- and a post-test and data relative to PBL students' opinions on the new teaching approach were collected through an opinion questionnaire. Results indicate that transdisciplinary PBL led to a bit better results than traditional teaching and that students valued PBL.

CONTEXT OF THE RESEARCH

Problem-Based Learning (PBL) is a student-centred teaching approach that is consistent with the key principles of active learning as it is defined by Savery (2006) and Tan (2004). In a PBL learning environment, students are at the centre of the teaching and learning process (Barrows 1986; Barrows, 1996; Boud & Feletti, 1997; Lambros 2002; Hmelo-Silver, 2004) and they play an active role in it as they have to take the appropriate actions to learn (deeply) knowledge (that is new to them) by solving problems (Dahlgren, Castensson & Dahlgren, 1998).

In a PBL approach, problems are the starting point for learning (Barrows, 1986; Barrows, 1996; Dahlgren, Castensson & Dahlgren, 1998; Lambros, 2002; Hmelo-Silver, 2004). They determine what students learn, as this depends on the problem-solving process demands concerning knowledge and skills. Problems are qualitative or quantitative statements that offer an obstacle to problem-solvers who have to find strategies to overcome the obstacle and to reach a solution (Pozo, Postigo & Gómez-Crespo, 1995; Neto, 1998; Jonassen, 2004). To succeed in doing so, students need to use conceptual and procedural knowledge within the scope of the field(s) of the problem, as well as appropriate problem-solving strategies (Hmelo-Silver, 2004). Usually, problem-solvers do not possess all the necessary knowledge and skills and therefore they need to develop them (through study, inquiry, etc.) before being able to reach a good solution (if there is one for the problem that is at stake) or concluding that the problem has no solution.

In a PBL learning environment, teachers do not teach in the usual sense (Dahlgren, Castensson & Dahlgren, 1998; Chin & Chia, 2004). They are not there to *tell science* or to even to explain science concepts to students (Leite & Esteves, 2012). Thus, there is a risk that they feel that they are not playing their role as teachers (Li & Du, 2015). If it is the case, it may interfere negatively with the learning environment, as they may reduce students' learning freedom and responsibility. This is why teachers may need support (Goodnough & Nolan, 2008; Pepper, 2009; Morgado, 2016) before they are used to and become comfortable with PBL.

However, as it was discussed in another paper (Leite & Esteves, 2012), in a PBL context, teachers have a variety of important roles to play and many key things to organize and monitor. Above all, teachers *are there* to stimulate students' curiosity through scenarios or problems that interest to students and that make them feel willing to engage into a problem-solving process (Lambros, 2002). In doing so, teachers provide students with learning opportunities that these may feel as being relevant for school as well as for daily life purposes. Nevertheless, within school systems that acknowledge curricula which are not problem-based (as defined by Boud and Felleti, 1997) students' learning possibilities are often conditioned by the problems that are selected by the teacher. As a matter of fact, when making this selection, the teacher bears in mind a mandatory curriculum that requires certain concepts, laws and theories to be taught and learned at a given school level.

Besides, teachers have other key roles to play, namely to guide students' work towards learning goals achievement and to ascertain that learning takes place (Dahlgren, Castensson & Dahlgren, 1998; Hmelo-Silver, 2004). In the former case, teachers need to prevent the possibility of having students stuck before some difficulty, as this would cause demotivation and even frustration along with waste of time. The idea is not that the teacher gives direct answers to students' questions but rather that he/she 'answers them' by asking other questions (Hmelo-Silver, 2004) that make students think about relevant issues or rethink some procedures, or redistribute the group roles, etc. In the latter case, teacher needs to ascertain that learning takes place. To do so, he/she needs to use appropriate tools both during the problem-solving process (e.g., questioning the problem-solving teams about their achievements and the foundations of their actions) and afterwards. In fact, by the end of the process, teacher should promote a new knowledge synthesis (Hmelo-Silver, 2004) or revision (if necessary) and a retrospective analysis of the problem-solving process. On one hand, asking students to make the synthesis themselves can make evident the need for knowledge revision through appropriate remediation strategies, which should be student-centred, consistently with the PBL underlying philosophy. On the other hand, the retrospective analysis can help students to develop an awareness of the problem-solving strategies that showed to be more or less useful, as well as the team members' actions and behaviours that were more or less productive and consistent with the group's mission.

Arguments for teaching science through a PBL approach (see, for example, Hmelo-Silver, 2004; Lambros, 2004; Azer 2008) assume that PBL may enable students to:

- learn science content knowledge, as problems focus on some science issue that is new or partly new for the students and that needs to be mastered before the problem solution is reached;
- learn procedural knowledge, including problem-solving skills and science process skill, as students need to find the most appropriate strategies to solving the problem. Reaching this goal may require the use of several process skills, some of which may be new to the students;
- develop interpersonal skills, as PBL is usually done in small groups or teams whose members need to cooperate so that they can reach their common goal that is to find one or more solutions for the problem, if it has a solution;
- develop communication competences, as they need to read, write, prepare materials, do presentations and discuss, at least, with colleagues and teacher.

These arguments are consistent with, for instance: Dewey's ideas of learning as a social process; Piaget's idea that learning depends on the learner's logic-mathematic reasoning abilities (Piaget, 1979); Vygotsky' idea that learning takes place in social contexts in which the teacher should scaffold the students (Palincsar, 1998; Tan, 2007); Bruner's idea that students learn better by doing (Palincsar, 1998); and Ausubel's idea that the type of learning that matters is meaningful learning which requires knowledge to be integrated into the cognitive structure of the learner (Ausubel, Novak & Hanesian, 1980).

Despite the convincing arguments for PBL, reviews of research focusing on the effects of PBL on science learning (e.g., Albanese, & Mitchell, 1993; Demirel & Dağyar, 2016; Dochy et al, 2003; Leite, Dourado & Morgado, 2016) do not provide unequivocal support for PBL as a teaching approach. In fact, PBL students' conceptual learning results are often similar to the ones attained through conventional methodologies and seldom overcome them. However, there are two aspects in favour of PBL that deserve being stressed: no PBL-based published research was found leading to lower results than the traditional approaches; PBL fosters the development of relevant learning components other than the conceptual one. However, it should be noted that some research studies have methodological limitations (Albanese & Mitchell, 1993; Hung, Jonassen & Liu, 2008; Leite, Dourado & Morgado, 2016) that reduce the credibility of the results attained.

Research on teachers' reactions towards PBL suggests that they fear (Goodnough, 2008; Leite et al, 2013; Morgado, 2016) but (after getting used) enjoy (Vernon, 1995; Dahlgren, Castesson & Dahlgren, 1998; Pepper, 2008; Ribeiro, 2010; Leite et al, 2013; Morgado, 2016) the challenge of trying a very different methodology but they feel unsecure about students' learning (Li & Du, 2015) in a PBL environment. They themselves ask for support from people experienced on PBL in order to get advice on how to deal with the challenge of putting PBL into practice in real classrooms. Besides, research indicates that according to teachers, students' reactions

towards science teaching through PBL depend on students' academic level, with the low achievers (according to teachers' criteria) showing better attitudes than top students (Leite et al, 2013; Morgado, 2016).
As it is well known, PBL started in medical schools (Barrows, 1996; Camp, 1996; Boud & Feletti, 1997; Barret & Moore, 2011; Hmelo-Silver, 2004; Savery, 2006) but it quickly spread to other areas and reached science education, namely in Portugal where the first known paper was written in 2001 (Leite & Afonso, 2001) and the first research was completed in 2001 by Gandra. At the time the research reported in this paper took place, the National Curriculum (DEB, 2001a) as well as the Physical and Natural Science Curriculum Guidelines (DEB, 2001b) did not explicitly mention the use of problems for science curriculum development but they suggested the use of problem-solving in the science classroom (Morgado & Leite, 2011). Nevertheless, they did not make any explicit reference to PBL. However, it seems possible to integrate PBL into science classes without contradicting the spirit of the national curriculum guidelines. This may happen because the guidelines argue for the use of student-centred teaching approaches that give students an active role and that acknowledge their previous knowledge as a starting point for the development of a diversity of competences, ranging from conceptual, to procedural, attitudinal and metacognitive.
Most science teaching in Portuguese schools is still teacher-centred and subject-based. There are a few experiments with PBL focusing on different science topics and school grade levels, organized on a school subject basis (e.g., Gandra, 2001; Carvalho, 2009; Torres, Preto & Vasconcelos, 2013). Despite the reduced sample size, they suggested that students might have benefited from PBL because they achieved better learning results or because they developed competences that their counterparts did not. In addition, a research study carried out by Morgado et al (2016) suggested that PBL organized into a transdisciplinary basis led to better results than the traditional approach when high demanding cognitive questions were at stake but not necessarily in the case of low demanding questions. If this can be confirmed, it would a strong argument in favour of PBL.
In summary, even though PBL seems to be a powerful approach, research results are not clear enough with regard to PBL effect on science learning, partly due to some research design weaknesses. Besides, some studies did not took into account the multidisciplinary nature of real problems, which requires PBL to be transdisciplinary rather than school subject-centred.

RESEARCH QUESTION

Bearing in mind the disciplinary teacher-centred characteristics of most Portuguese science teaching and the multidisciplinary nature of real life problems, this study aims at comparing a transdisciplinary PBL approach with traditional teaching of the theme 'Safety, Prevention and Quality of Life' , with regard to students' learning of science content knowledge; finding out students' opinions on the transdisciplinary PBL approach. According to the official curriculum, this 9th grade theme is supposed to be approached within both Natural Sciences and Physical Sciences school subjects and therefore the two of them were involved in this study.

RESEARCH METHODOLOGY

In Portugal, science education for all children goes up to 9th grade that is to 14/15 years old. Afterwards, students must continue at school but they can choose to study science or not. Thus, this research is centred on the last school grade in which science is taught to all children, which is a relevant stage from a citizen's education point of view. It took place in a secondary school that volunteered to participate in a research project which encompassed the research reported in this paper.
As mentioned above, the science theme chosen for the purpose of this research was 'Safety, Prevention and Quality of Life', which belongs to the syllabuses of two school subjects: Physical Sciences (includes Physics and Chemistry) and Natural Sciences (includes Biology and Geology). Physical Sciences are supposed to cover topics like Basic motion concepts, Collisions, Airbags, Helmets and seat belts, Traffic accidents prevention. Natural sciences are supposed to address issues like Traffic accidents, Effects of alcohol and drugs on the driver's abilities, Driver's food behaviour and psychological characteristics.
A quasi-experimental, pre-/post-test design with control group (see McMillan & Schumacher, 2010) was adopted. Two 9th grade classes and their four teachers were involved in the study even though with different degrees of engagement. Thus, from the experimental group (EG) side, a Physical and a Natural Sciences teacher were involved together with their 24 students. From the control group (CG) side, a Physical and a Natural Sciences teacher were also involved together with their 25 students.
The EG followed an active student-centred transdisciplinary PBL approach. Teachers were invited to work together to approach the topics referred to above, with no differentiation between what used to be the class time periods of each one of the two school subjects. Teaching materials were prepared or selected by the EG teachers and the researchers. To start the PBL sequence, a scenario like a press news focusing on 'Reducing traffic accidents: a matter of safety, prevention and quality of life', was adapted by the two schoolteachers and the researchers. It worked as a context for students to raise problems that would require concepts within the scope of the whole theme if they were to be solved by the students. Both teachers monitored the students, which were asked to work in small groups, each at a time or together, according to their availability and the anticipated students' needs of guidance. One of the researchers observed all the EG classes to give support to teachers.

However, at the end, both teachers assisted to students' presentations and conducted the solution analysis and the process evaluation. Figure 1 gives a synopsis of the process followed in the EG.

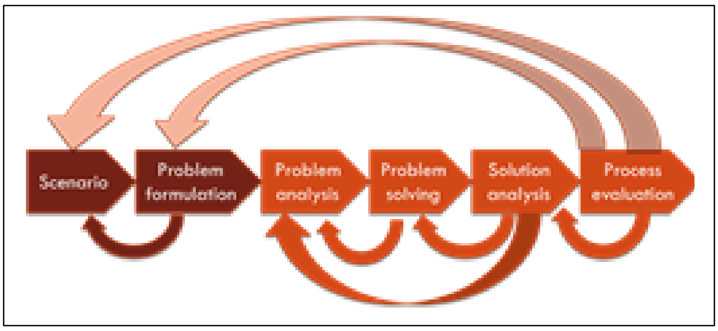

Fig. 1: Synopsis of the PBL approach followed in the EG

The CG followed a disciplinary teacher-centred approach with teachers working separately and with a well-marked differentiation of the two subjects. They followed the assigned textbooks approach, namely with regard to the sequence of the topics and the activities performed in each subject.

Both interventions lasted for about a month. However, in the CG part of the time was devoted to solving exercises after addressing the content.

Inquiry through questionnaire was the data collection technique adopted. Then, to avoid contamination, the researchers alone designed a paper and pencil test to be used as pre- and post-test in the two research groups. The test covers the contents addressed and includes open-ended questions so that students could explain their ideas without being influenced by a given set of predetermined possible answers.

Students answered the test individually, two days before initiating the theme (pre-test) and eight days after concluding it (post-test). Both groups have done it in a Physical Sciences class time, supervised by their own Physical Sciences teacher.

Data analysis included content analysis based on a set of predetermined categories, as follows:

- *Correct answer*: scientifically accepted and complete answer, according to what is expected for this grade level, based on what is prescribed in the syllabus;
- *Incomplete answer*: answer that misses one or more elements required to be considered complete but does not include any incorrect idea;
- *Answer including alternative conceptions*: answer that includes ideas which are not consistent with the scientifically accepted ones;
- *Don't answer*: comprises no answer, incomprehensible answers and answers that simply repeat the question.

Pre-/post-test gains were also computed. They have to do with the difference between the post-test and the pre-test percentages obtained for each category of answer. They indicate a variation that can be either positive or negative and that is good or bad depending on the category that is at stake. A positive gain is desirable for the correct answer category and a negative gain is desirable for the Don't answer category. For the other categories, the interpretation of the gain in a category depends on the gains in the other categories. Finally, to attain the objective of the study, control group *versus* experimental group comparisons were made.

Afterwards, a more detailed analysis was performed in order to get more information on the incomplete answers and the ideas that were more and less hard for students to acquire.

In a physical sciences class after the post-test, the EG students were asked to answer to an opinion questionnaire on the PBL approach. The questionnaire, composed of 15 directional Likert type items, had been developed previously by Leite, Dourado & Esteves (2011). The scale used was a five degrees scale ranging from *Nothing* to *A lot*. Frequencies per item and scale grade were computed in order to get information on issues that deserved more and less positive reactions from the EG students.

RESEARCH RESULTS

Students' learning

Table 1 shows the results relative to students' science content knowledge learning which were collected through a test used as pre- and post-test in both research groups (EG and EC). In the pre-test, no research group reached a correct answer in any question. In the post-test, correct answers were obtained in one question (question 3) only.

Table 1: Control/experimental gains comparison for questions asking for an explanation (%)
(N=49)

Question	Group	Correct		Incomplete		Including AC		Don’t answer	
		Pre	Post	Pre	Post	Pre	Post	Pre	Post
1 - Driving under alcohol	CG	0,0	0,0	96,0	92,0	4,0	4,0	0,0	4,0
	EG	0,0	0,0	75,0	91,6	25,0	8,3	0,0	0,0
2 - Driving under drugs	CG	0,0	0,0	84,0	96,0	16,0	0,0	0,0	4,0
	EG	0,0	0,0	83,3	87,5	12,5	0,0	4,2	12,5
3 - Slow down motion	CG	0,0	4,0	24,0	44,0	4,0	20,0	72,0	24,0
	EG	0,0	29,2	20,8	16,7	12,5	20,8	66,7	33,3
4 - Speed and velocity	CG	0,0	0,0	0,0	4,0	36,0	44,0	64,0	52,0
	EG	0,0	0,0	0,0	70,8	33,3	4,2	66,7	25,0
5 - Asleep driver after lunch	CG	0,0	0,0	28,0	44,0	72,0	44,0	0,0	12,0
	EG	0,0	0,0	45,8	62,5	50,0	37,5	4,2	0,0
6 - Instantaneous velocity *versus* mean speed	CG	0,0	0,0	12,0	24,0	8,0	0,0	20,0	60,0
	EG	0,0	0,0	20,8	58,3	8,3	0,0	70,8	41,7
7 - Collisions on a road	CG	0,0	0,0	28,0	40,0	8,0	8,0	64,0	52,0
	EG	0,0	0,0	42,2	54,2	4,2	0,0	53,6	45,8

Note: n_{EG} = 25; n_{CG} = 24

Table 2 shows the gains (positive, null or negative) for the seven questions used to assess students’ learning in this research study. An analysis of the gains obtained for the correct answers shows that non-null gains were obtained for question 3, the only got correct answers. Those gains are positive for the two research groups. However, the gains obtained for the EG (29,2%) are much larger than those obtained for the CG (4,0%) which is a result in favour of the EG.

Table 2: Control/experimental gains comparison for questions asking for an explanation (%)
(N=49)

Question	Correct		Incomplete		Including AC		Don’t answer	
	CG	EG	CG	EG	CG	EG	CG	EG
1 - Driving under alcohol	0,0	0,0	-4,0	16,6	0,0	-16,7	4,0	0,0
2 - Driving under drugs	0,0	0,0	12,0	4,2	-16,0	-12,5	4,0	8,3
3 - Slow down motion	4,0	29,2	20,0	-4,1	16,0	8,3	-40,0	-33,4
4 - Speed and velocity	0,0	0,0	4,0	70,8	8,0	-29,1	-12,0	-41,7
5 - Asleep driver after lunch	0,0	0,0	16,0	16,7	-28,0	-12,5	12,0	-4,2
6 - Instantaneous velocity *versus* mean speed	0,0	0,0	12,0	37,5	-8,0	-8,3	-4,0	-29,1
7 - Collisions on a road	0,0	0,0	12,0	12,5	0,0	-4,2	-12,0	-7,8

Note: n_{EG} = 25; n_{CG} = 24

Then, an analysis of the gains for the incorrect answers shows that: no null gains were obtained; larger positive gains were obtained for the experimental group in three questions (question 1, 4 and 6); similar positive gains were obtained for questions 5 and 7; lower gains were obtained for the EG in question 2 and 3. However, if in the case of question 3 we sum up the gains obtained for the correct and incomplete answers, for each group, 24,0% and 25,1% will be obtained for the CG and the EG, respectively. Even though these two percentages are similar, the 25,1% of the EG are better because they come mainly from complete answers while the 24% of the CG come mainly from incomplete answers. Data given in table 2 also show that positive gains in the complete and incomplete answers are associated with negative gains in the Don’t answer and/or Including Alternative Conceptions (AC) answer. Thus, it can be stated that the EG achieved better results than their counterparts in the CG.

As far as the incomplete answers are concerned, table 3 shows that in question 1 the CG incomplete answers were more incomplete than those of the EG as the percentage of incomplete answers mentioning 2 or 3 effects that alcohol can have on a driver’s organism is much larger in the EG (40,9%) than it is in the CG (26,1%). Being the numbers of students similar in both groups (22 and 23, respectively), this result is also in favour of the EG.

Table 3: Driving under the effect of alcohol - # of effects in Incomplete Answers (%)

# effects mentioned	Pre-test		Post-test		Gains	
	CG (n=24)	EG (N=18)	CG (n=23)	EG (n=22)	CG	EG
1	87,5	83,3	73,9	59,1	-13,6	-24,2
2 or 3	12,5	16,7	26,1	40,9	13,6	24,2
4 or 5	0,0	0,0	0,0	0,0	0,0	0,0

Table 4 shows that the two research groups mentioned the same effects of the alcohol, in the pre- and the post-test, the only exception being the EG that did not mention sleepiness, in the pre-test. 'Difficulty of risk assessment' was the effect mentioned by larger percentages in the pre-test probably because it has to do with every day (including mass media) arguments against drink ingestion before driving.

Table 4: Driving under the effect of alcohol - Effects mentioned in Incomplete answers (%)

Effects	Pre-test		Post-test	
	CG (n=24)	EG (n=18)	CG (n=23)	EG (n=22)
Reduction on the reaction capacity	25,0	27,8	65,2	63,6
Difficulty of risk assessment	50,0	61,1	34,8	54,5
Sleepiness	20,8	0,0	8,7	9,1
Vision limitations	20,8	27,8	17,4	22,7
Motor coordination limitations	0,0	0,0	4,3	9,1

Percentages relative to 'Reduction on the reaction capacity' and to 'Motor coordination limitations', increased from the pre- to the post-test, being a bit favourable to the CG in the former case and to the EG in the latter case. These effects have to do with human physiology (Ogden & Moskowitz, 2004; Carson-DeWitt, 2003) and the increase in the percentages from pre- to post-test may mean that learning took place in both groups.
Table 5 shows that in question 2 the CG incomplete answers were quite as incomplete as those of the EG, as the percentage of incomplete answers mentioning 2 or 3 effects of drugs on a driver's organism is quite as large in the EG (28,6%) as it is in the CG (29,2%). It should be emphasised the CG students that had mentioned 4 or 5 effects in the pre-test did not mention the same number of effects in the post-test. Therefore, these results are not clearly in favour on any of the groups.

Table 5: Driving under the effect of drugs - # of effects in Incomplete Answers (%)

# effects mentioned	Pre-test		Post-test	
	CG (n=21)	EG (n=20)	CG (n=24)	EG (n=21)
1	85,7	95,0	70,8	71,4
2 or 3	9,5	5,0	29,2	28,6
4 or 5	4,8	0,0	0,0	0,0

Data given in table 6 show that the most mentioned effects in Incomplete answers relative to the effects of drugs on the driver compare to those most mentioned for the alcohol question (see table 4). However, the control group added a new effect in the pre-test that is hallucinations, which is also mentioned by authors like Ogden and Moskowitz (2004) and Carson-DeWitt (2003). In the EG, from pre- to post-test, percentages increased for all effects except for 'Difficulty of risk assessment'. In the control group, the percentages obtained for several effects decreased a little bit. The 'Reduction on the reaction capacity' was again the effect whose percentages suffered a larger increase as it happened in the case of alcohol (see table 3). This increase was larger for the EG.

Table 6: Driving under the effect of drugs - Effects mentioned in Incomplete answers (%)

Effects	Pre-test		Post-test	
	CG (n=21)	EG (n=20)	CG (n=24)	EG (n=21)
Reduction on the reaction capacity	28,6	10,0	50,0	61,9
Difficulty of risk assessment	47,6	85,0	41,7	57,1
Sleepiness	9,5	0,0	4,2	4,8
Vision limitations	14,3	5,0	8,3	14,3
Motor coordination limitations	0,0	5,0	0,0	9,5
Hallucinations	28,6	0,0	25,0	4,8

Question 3 asked students to explain why a child (Rui) traveling without the car seat belt fasten was project forwards and hit the head when his father slowed the car down due to meeting a red traffic light, in a raining day. Table 7 shows that each incomplete answer for this question includes one of two explanations. The first explanation is a synthetic statement that does not provide fully evidence that their holders really understand what they are saying. This interpretation is supported by answers like the following one: "His seat belt was not fasten and a body that is moving tends to keep on motion" (post-test, CG11). The first part of this answer is a repetition from the question (the seat belt was not fasten) which is not explicitly related to the second part of the answer, which is a general statement (on the inertia law), not explained.

Table 7: Motion when slowing down - Explanations in Incomplete answers (%)

Explanation	Pre-test		Post-test	
	CG (n=6)	EG (n=5)	CG (n=11)	EG (n=4)
Rui's body tends to continue in motion	0,0	20,0	63,6	0,0
As Rui's seat belt was not fasten, there was nothing to prevent him from keeping moving with the car speed at the slow down instant	100,0	80,0	36,4	100,0

The second one is much more explicit in terms of why Rui was projected. In fact, it implicitly mentions the role of the seat belt (it would prevent Rui from keeping moving with the car speed), as shown by the following answer: "As a force was exerted on the car, it stopped; as no force was exerted on Rui, he kept on moving" (post-test, EG18). In the post-test, all the incomplete EG answers fell into this category, while the same happened with only about one third of the CG incomplete answers.

Question 4 focused on Rui's conversation with his father; Rui was talking about the car speed and his father talking about the car velocity. Table 8 shows that incomplete answers relative to a possible difference between the meanings of the two words were registered in the post-test only and that they fell into three categories.

While the CG incomplete answer fell into the most incomplete group of answers, the EG incomplete answers are distributed by the three categories, being some of them (11,8%) quite complete, which is an indicator of deeper learning. An example of this is the following answer, which combines type of magnitude and trajectory: "Velocity is the distance (straight line) between points A and B (displacement) over a certain time; speed is the path travelled between points A and B over a certain time." (post-test, EG18). Bearing in mind table 1, the incomplete answers are a result of a reduction in Including Alternative Conceptions and/or Don't know answers. Therefore, data in table 8 reinforce the idea of a better performance of the EG.

Table 8: Speed and velocity - Explanations in Incomplete answers (%)

Explanations	Pre-test		Post-test	
	CG (n=0)	EG (n=0)	CG (n=1)	EG (n=17)
Velocity is a vector magnitude and speed is a scalar magnitude	0,0	0,0	100,0	52,9
Velocity is a ratio between the displacement and the time spent to make it; speed is a ratio between the path covered and the time used to cover it.	0,0	0,0	0,0	35,3
Velocity is a ratio between the displacement and the time spent to make it; speed is a ratio between the path covered and the time used to cover it. Then, opposite to speed, velocity does not depend on the trajectory.	0,0	0,0	0,0	11,8

When explaining why a truck driver fell asleep after lunch, having slept well the night before (question 5), students mentioned only one of the two issues that would be demanded to them according to the syllabus. Thus, they based their explanation either on 'Digestion energy requirements' or on 'Blood concentration on stomach and intestine' (table 9), which are effects that are mentioned in the literature (Barr & Wright, 2010; Eldelstone & Holzman, 1981). The former was the most popular in both research groups, in the pre- as well as in the post-test. Surprisingly, a few students of the EG abandoned the explanations based on the idea of 'Blood concentration on stomach and intestine'. In the whole, these results are consistent with those given in table 1, as they are not in favour of none of the research groups.

Table 9: Driving when feeling asleep after lunch - Explanations in Incomplete answers (%)

Explanation	Pre-test		Post-test	
	CG (n=7)	EG (n=11)	CG (n=11)	EG (n=15)
Digestion energy requirements – needs energy and originates a deficit in the rest of the body	85,7	45,5	100,0	86,7
Blood concentration on stomach and intestine – brain has not enough blood to react	14,3	54,5	0,0	13,3

Question 6 focuses on who was right: a driver, arguing that he made calculations (with time and km) and was moving at 100km/h, and a police officer, accusing the driver of having exceeded the maximum velocity (or instantaneous speed, that is equal to instantaneous velocity magnitude) limit of 120km/h. Table 10 shows that three types of incomplete explanations were obtained, being the first one a statement that does not make explicit the difference between the two concepts that are at stake: instantaneous velocity and mean speed.

Table 10: Instantaneous velocity vs mean speed - Explanations in Incomplete answers (%)

Explanation	Pre-test		Post-test	
	CG (n=3)	EG (n=5)	CG (n=6)	EG (n=14)
Mean speed is different from instantaneous velocity	0,0	0,0	16,7	0
The value shown by the policy radar has to do with instantaneous velocity	33,3	0,0	16,7	0
The driver's argumentation is wrong because it is based on the computation of the speed and this is not what the radar shows.	66,7	100,0	66,6	100,0

Even though many incomplete answers were got in the post-test for the EG, they not only resulted from a decrease in the Alternative conceptions and Don't know answers but also fell into the most complete group of incomplete explanations. This group shows disagreement with the driver's reasoning, uses the concept of mean speed and implicitly or explicitly suggests that the radar does not shows that magnitude. This can be illustrated by the following answer: "The car driver calculated the mean speed [100km/h] but he may have exceeded the velocity limit [120km/h] even though the mean was that one." (post-test, CG25).

Table 11 shows that the number of Incomplete answers increased in both research groups form pre- to post-test, for question 7. This question focuses on the effects of two cars colliding with the road protection rails. In one of the collisions, the rails were damaged but not broken; in the other collision, the rails were broken. The two explanations obtained for incomplete answers suggest that students seem to focus on the observable effects rather than on the interaction between the cars and the protection rails. Nevertheless, it seems that the second explanation given in table 11, shown by lees students in both groups, is a bit more complete than the first one. In fact, the second explanation relates force, speed and collision effects, as illustrated by the following answer: "To break the protecting rails a large force is needed; this means that it was travelling with a larger speed." (Post-test, EG15). These results suggest that the numbers of students showing the most complete answer did not change from pre- and to post-test.

Table 11: Collision on a road - Explanations in Incomplete answers (%)

Explanation	Pre-test		Post-test	
	CG (n=7)	EG (n=10)	CG (n=10)	EG (n=13)
The larger the magnitude of the impact force, the more violent is the collision	85,7	80,0	80,0	92,3
The larger the speed, the larger the magnitude of the impact force and the strongest is the effects of the collision	14,3	20,0	20,0	7,3

EG students' opinions on PBL

The EG students' opinions on PBL were collected through an opinion questionnaire, after the post-test. Table 12 shows the questionnaire 15 items, clustered according to the skills that underlie them, and the frequencies obtained for each grade of the scale.

Table 12: EG students' opinions on the PBL approach (f)

(N=24)

Skills	Items	Nothing	A little bit	Modera-tely	Quite a lot	A lot
Learning	13. Deepen knowledge/ideas	0	0	7	9	8
	14. Understand content	0	5	4	10	5
	12. Learn about issues that interest to me	0	3	7	8	6
Problem-solving	10. Learn how to solve problems	0	1	4	15	4
	8. Learn how to plan tasks	0	2	4	14	4
Thinking	11. Learn how to synthesize	0	2	5	13	4
	7. Learn to think	0	2	2	12	8
	5. Learn how to interpret information	0	0	9	11	4
Communication	3. Learn how to communicate ideas	0	3	3	14	4
	4. Learn how to present own ideas	0	2	6	14	2
	1.Lean how to argue and counter-argue	0	2	9	11	2
Social interaction	6. Learn how to share tasks	0	1	7	15	1
	2. Learn how to cooperate with colleagues	0	0	4	14	6
	9. Learn how to respect the others' opinions	0	0	7	12	5
Welfare	15. Feel comfortable	2	5	8	4	5

An analysis of the frequencies given in this table shows that at least two thirds (that is 16) of the 24 students choose the Quite a lot or A lot degrees for 10 (out of 15) items. Item 15 was the only item that got non-null frequencies for the Nothing degree and about one-third only for Quite a lot plus A lot, meaning that some students did not feel comfortable with PBL classes. This sensation may be due to students' initial lack of experience with not only PBL but also with teamwork and with enquiry like tasks, as well as with their high level of anxiety regarding the non-distinction between the two disciplines and the nonexistence of exercises to be solved by (and after) the end of the classes. Thus, it seems that the novelties introduced may have really caused initial discomfort to students. Nevertheless, for what researchers and teachers could observe, most of them overcame those difficulties and anxiety quite fast. An additional evidence of this is that the discomfort felt did not impair them from recognising the positive things they got from the PBL approach. Excluding item 15, items 1 and 12 are the ones that got less Quite a lot and A lot. In the former case, on one hand, it should be noted that argumentation is not an easy competence to develop (Belland, Glazewski & Richardson, 2008) and, in the other hand, it may happen that students were not familiar with the words, especially with counter-argumentation. It may be that argumentation and counter-argumentation competences development may need more assistance from the teacher than the PBL context provided. In the latter case (item 12), it should be emphasized that what students learned was limited by the problems that emerged from the scenario. During the classes, teacher(s) were used to monitor the small groups' activities in order to check whether they were on the task or whether they were doing other things. It was necessary to settle strict rules for internet access in order to prevent waste of time with issues that were not relevant for the task students had at hands. In fact, undue internet use was an expected issue (see Dogruer, Eyyam & Menevis, 2011) as it was students' unhappiness with limitations on this. On the other hand, as argued above, the fact that the Portuguese curriculum is not a problem-based one, obliged teachers and researchers to find problems to be solved that were consistent with the curriculum demands, as the use of a new methodology and the undertaking of a research experience could not prevent the compulsory curriculum to be followed.

CONCLUSIONS AND IMPLICATIONS

The global results together with the incomplete answer analysis suggest that students in the EG performed better than their CG counterparts, which is a result consistent with studies that compared PBL with traditional teaching (ex. Gandra, 2001, Carvalho, 2009; Khoshnevisasl et al, 2014; Zahid et al, 2016; Strobel & van Barneveld, 2009; Morgado et al, 2016). However, both groups rarely reached complete answers, which may be partly due to strict correction criteria adopted in this research and partly due to language issues. The latter may be especially true for physics questions that deal with the speed and velocity concepts, as the words that give names to these two physics concepts are usually used undistinguishably in Portuguese everyday language. Besides, even though the EG students may have felt an initial discomfort (as it happened in other studies – see, for example, Gandra, 2001; Selçuk, 2010; Alessio, 2004; Larin, Buccieri & Wessel, 2010), they seem to have valued PBL as they recognized that they have developed several types of competences.

Thus, the use of a transdisciplinary approach neither impaired students from learning nor made them feel confused and unhappy. However, the fact that some students (not only but also in the EG) used a sort of slogan-like explanations when trying to explain their reasoning on issues related to daily life situations should deserve

attention. On one hand, pedagogic attention is needed in order to find better ways of promoting deep learning. Hence, results obtained through the present study should be combined with those obtained by Morgado et al (2016) in order to find ways of making PBL more useful for the learning of students' complex and familiar issues. On the other hand, research attention is needed in order to find out whether slogan-like answers just happened or whether this is a result consistent with what Silva, Leite and Pereira (2013) found with seven graders, which were asked to solve familiar problems.
This concern raises a few questions that are worth considering. Were students happy with their previous common sense knowledge about the effect of drugs and alcohol on the organism so that they did not feel the need to learn more about it? Should the teaching context have been able to deal with such knowledge to show that it is not enough to fully explain the situation? Was inertia law too much emphasized so that students memorized it and, maybe, based on previous experiences, felt that it would be enough to restate the law without explicitly relating it to the problem-situation that was at stake? Of course it may also have happened that the information sources used by the students were reinforcing the slogan-like answers or that they were unable to propel students to go deeper into the issue. Answering to these questions would be useful for organizing learning situations more able to foster students' deep learning through PBL.
Finally, bearing in mind that EG students managed well with transdisciplinary PBL, it should be investigated how disciplinary and transdisciplinary PBL convey students the ability to deal with real problems which are transdisciplinary in nature. Transdisciplinary PBL is more demanding for teachers and school organization. From the authors' experience, teachers need to get not only training but also support from researchers or colleagues used to PBL as well as from the school director. PBL requires flexible classroom organization and school resources use which need to be acknowledged by the whole school. Effort to get such support may be worthwhile as PBL seems to be one of the best teaching approaches for XXIst century students, which need to be prepared for solving real problems. As it was argued elsewhere (Leite et al, 2017; p.159).), PBL can "show students that science […] is all around them and that the knowledge it encompasses may help them not only to better understand, fully appreciate and respect more the natural world but also to take more advantage from what the natural world can offer without putting it at risk.".

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