Chapter 2

Physics Teaching/Learning at Primary Level and Teacher education
Teaching About Energy Using Cooperative Learning: an Implementation and its Evaluation in a Teacher Training Degree

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Abstract
This research was performed within a 9 ECTS science course implemented in a Degree of Primary Education. The course was based on cooperative learning where, organised in groups of 3 to 5 people, the students had to design a lesson plan for the primary classroom, which could cover the concept of Energy from different angles. This task was presented as a “real-scenario” project. In this paper I present and discuss the starting point and learning outcomes of pre-service primary teachers regarding the understanding of Energy as a scientific concept, which was measured before and after a series of lectures and lab sessions devoted to study the concept of Energy and how it is learned in Primary School (10-12 years). The assessment tools were varied and included open-ended and multiple-choice questions. From a colloquial understanding of energy, primarily as an energy source, pre-service primary teachers learned about energy forms and its transformations, dissipation and the conservation of energy. As expected, some difficulties arose differentiating forces and energy or grasping the abstract but at the same time quantitative nature of Energy. The applied methodology received overwhelming support from the participants and received positive feedback and approval from an institutional program to promote active learning methodologies at the university level. A further cycle of implementation/evaluation of the proposal is under way.

Keywords
Energy, Nature of Science, cooperative learning, project-based learning, pre-service teachers, primary education, energy conservation.

1. Introduction

Cooperative Learning at Higher Education Institutions.
The European Higher Education Area (EHEA) has elicited a change of paradigm in this institution, calling for the education of flexible professionals that work in a knowledge society. In the Bergen Conference of 2005, a qualifications framework was established whose main goal was to educate future professionals that “can apply their knowledge and understanding in a manner that indicates a professional approach to their work or vocation, and have competences typically demonstrated through devising and sustaining arguments and solving problems within their field of study” (Bergen Communiqué, 2005). The use of active methodologies, such as cooperative learning (CL) and Project-based learning (PrBL) (Johnson et al., 1991) has proved to be an efficient tool to drive this change of paradigm. Cooperative learning is the instructional use of small groups so that students work together to maximize their own and each other’s learning, and proves an essential tool when students design and develop a project in groups (Johnson et al., 1991). Thus, I agree with Donnely and Fitzmaurice (2005) to understand PrBL as a group activity that goes on over a period of time, resulting in a product, in this case a science lesson for the primary classroom, which typically has a time line and milestones, and other aspects of formative evaluation as the project proceeds. This is the context in which an annual course of Natural Sciences for the Primary Classroom was designed, in which

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1. The author would like to thank the UPV/EHU for organising the ERAGIN faculty development program in Project Based Learning methodologies for university educators, in which this implementation was designed, evaluated and approved for publication as teaching material.
students used PrBL to learn about core concepts of science and produce a lesson plan for the primary classroom. One of the core concepts that was included in this annual course was the concept of Energy, which would be approached by some of the students when designing their lesson plan.

2. Learning and teaching about energy
Scientific concepts are acquired and developed through different stages of compulsory education (National Research Council, 2007). Energy is one of the core concepts in science, and it is essential to understand physical, biological, chemical and technological aspects of our world (Driver and Millar, 1986). In recent years, its relevance has increased in light of important social issues including climate change and energy production, use and conservation (Bueno, 2014; Mohan et al., 2009). Despite that energy and their related phenomena, such as light, sound, heat or electricity, are taught throughout the whole curriculum, including kindergarten (Hook and Huzziak-Clark, 2008), teaching and learning about energy is not trivial in any educational stage (Tobin et al., 2012). In fact, students' alternative ideas about energy and ways of using the term are very different from scientists' (Watts, 1983). Energy itself is an inherently abstract concept and quantitative at the same time (Herón et al., 2008; Tobin et al., 2012). In common language it is often not clearly distinguished from force, momentum, movement and power (Kruger et al., 1992; Solomon, 1985; Watts and Gilbert, 1983). In this sense Feynman's (Feynman et al., 1963) famous definition of energy as a conserved quantity is beyond grasp of elementary students or even pre-service primary teachers (Herón et al., 2008). Nevertheless, unlike children, pre-service teachers recognise a lack of rigour in their understanding of energy (Spirtou and Koumaras, 1993). Moreover, in primary school, teachers will still have to confront both their ideas about phenomena and their conceptions about the teaching process, which can be a complicated process since their ability to design innovative approaches seems to depend strongly on their scientific knowledge (Spirtou and Koumaras, 1993). As in other European countries, pre-service teachers are generalist teachers with a very limited amount of science education through an standard 4 year degree (15-20 ECTS at the UPV/EHU). Therefore, the teaching model presented here, takes into account constructivist approaches (CLIS, 1987; Heron et al., 2008; Tobin et al., 2012; Skamp and Preston, 2014), that future teachers could apply in their future professions, as well as addressing conceptual and persistent problems, such as defining Energy in scientific terms or understanding the principle of conservation of energy (PCE).

To that effect, the learning proposal discussed here took into account the following key ideas about energy: i) Energy is a property of a system and there are different forms; ii) Energy can be transformed from one form into another; iii) Whenever energy is transformed some of it is degraded or dissipated; iv) The overall amount of energy in the system remains conserved; v) Energy can be approached in a qualitative way at early stages without betraying its quantitative nature.

3. Context of the Instruction and characteristics of the Project-based science course
The Energy Concept module was implemented in an annual compulsory course called “Science for the Primary Classroom” (9 ECTS) following a Project-based methodology. The research was performed on 118 students. A total of 8 sessions comprising 100 minutes each were carried out, and four of these were performed in the lab. These sessions consisted on: a) assessing students' conceptions of energy using open ended questions and multiple choice exercises (CLIS, 1987; Varela et al., 1993), b) examining energy in food and its transformation into heat energy, c) examining energy in non-living things, by analysing processes or devices involving kinetic and potential energy d) describing energy transformations and identifying energy dissipation, e) identifying and differentiating forms and sources of energy g) understanding the PCE and h) assessing student's learning using a post-implementation questionnaire.

4. Research questions
In this report I will discuss the Primary Education Degree students' initial ideas on energy and its development after instruction through a hands-on enquiry-based module on Energy. The research questions are summarised here:

1. What is the initial knowledge of the Energy concept in Primary Education students?
2. Will the proposed teaching sequence help students identify young pupil's most common conceptual problems about energy?
3. Will the proposed teaching sequence help students apply the PCE in ideal conditions?
4. What is the level of satisfaction about the methodology?

5. Methodology
Assessment of the Energy Concept

Participants were asked at the start to perform two exercises to evaluate their initial ideas. The first exercise consisted on answering the following question: “What do you understand as Energy?, Write sentences with the word Energy on them”. Pupils were organised in informal groups of 4 and wrote five sentences each. Afterwards, they discussed their sentences and whether they agreed or not with their statements. These sentences provide insight into the students’ ideas and ways of thinking about energy. The terms and concepts used were counted and from these data categories were defined. Finally, frequencies for the defined categories were obtained.

The second question was extracted from the CLIS project (CLIS, 1987) and is called “Mickey's truck”. An image of a clockwork truck toy is shown, and students need to decide when it has more energy. The exercise aims to detect whether students exclusively relate energy with movement and correctly understand the principle of Energy conservation. This exercise was performed individually. Answers were classified in the categories proposed by the exercise: “A-The energy is at its highest before winding it up, B-the energy is at its highest just when it is wound up, C-The energy is at its highest when it is moving, D-The energy is highest when it stops, E-The energy is always the same”, and frequencies were calculated.

At the end of the Energy module, students were asked to answer two questions regarding primary pupils' ideas on energy and solve a problem of mechanical energy (ME) and application of the PCE. The two questions are shown here:

Q1. “Many students think that only moving objects have energy. What would you do to improve this idea?”
Q2. “Many students think that the higher an object is the bigger its force is. What would you do to improve this idea?”

Their answers provided insight on whether a conceptual and pedagogical understanding of energy had been achieved after the implementation. Regarding Q1, it was expected that the students would provide different examples of ME or everyday examples of energy transformations. Regarding Q2, it was expected to find definitions of force and energy or to establish differences between the weight and the Gravitational Potential Energy (GPE) of an object. Regarding the problem of application of the PCE, answers were classified following six formulation levels: L-1: A qualitative explanation of the problem along with a correct application of ME formula and the PCE was included; L-2: A qualitative explanation is included, formulae are used but the application of the PCE is wrong; L-3: A qualitative explanation is included but the application of the PCE is wrong or there are mathematical errors when applying the formula; L-4: There is not qualitative explanation nor mathematical reasoning; L-5: There is a correct mathematical reasoning of ME and PCE but not qualitative explanation.

Assessment about the methodology

The data presented in this report are part of a faculty program to implement PrBL at the University of the Basque Country UPV/EHU (Garmendia Mujika, Barragués Fuentes, Zuza Elosegi, & Guisasola Aranzabal, 2014). The students were asked to fill a survey about the methodology implemented during the science course that consisted of 17 questions to be answered on a four point Lickert scale and a yes/no question (data not shown). The questions analysed in this report correspond to Q1, 2, and 18 (Table 4).

6. Results

First Assessment of the Energy Concept (pre-implementation)

Table 1 shows the categories that emerged from the data from 164 sentences collected from 77 students. These students related energy mostly to sources (67 sentences) and particularly with renewable sources (40 sentences), followed by statements about saving or wasting energy (17 sentences; eg.: “saving energy is very important for our future”) and human functions (17 sentences). There were lesser instances where energy types (gravitational or elastic potential, kinetic, internal or light energy) and their transformations were mentioned (14 and 12 sentences, respectively). In contrast with other reports focused on detecting primary and secondary pupils' ideas on energy (CLIS, 1987; Watts, 1983) sentences related to sport activities, energy from food, etc., did not prevail (4 answers). Around a 4% of the answers showed confusing uses of the word Energy such as these shown here: “energy is a type of force”, “thanks to the force of the water in the reservoir, we get electrical energy”, there are two types of energy, natural and chemical”. In most groups, a few sentences were also found to relate to the colloquial use of the term energy, but when discussed, all
students agreed that those uses were non-scientific (“He woke up with lots of energy”, “She is full of positive energy”) as previously discussed by Spirtou and Koumaras (1993).

Table 1. Categories emerged from 164 sentences including the word Energy

<table>
<thead>
<tr>
<th>Categories</th>
<th>Number of answers (%)</th>
<th>Categories</th>
<th>Number of answers (%)</th>
<th>Categories</th>
<th>Number of answers (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sources of Energy</td>
<td>10 (6.10)</td>
<td>Mechanical Energy</td>
<td>14 (8.54)</td>
<td>Heat</td>
<td>2 (1.22)</td>
</tr>
<tr>
<td>Renewable Energy source</td>
<td>40 (24.39)</td>
<td>Essential for life</td>
<td>9 (5.49)</td>
<td>Work</td>
<td>1 (0.61)</td>
</tr>
<tr>
<td>Non-renewable Energy source</td>
<td>17 (10.37)</td>
<td>Electricity</td>
<td>8 (4.88)</td>
<td>Thermodynamics</td>
<td>1 (0.61)</td>
</tr>
<tr>
<td>Saving/wasting energy</td>
<td>17 (10.37)</td>
<td>Confusions</td>
<td>7 (4.27)</td>
<td>Light</td>
<td>1 (0.61)</td>
</tr>
<tr>
<td>Human functions</td>
<td>17 (10.37)</td>
<td>Food energy</td>
<td>4 (2.44)</td>
<td>Force</td>
<td>1 (0.61)</td>
</tr>
<tr>
<td>Transformations</td>
<td>12 (7.32)</td>
<td>Photosynthesis</td>
<td>3 (1.83)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Regarding “Micky's truck” question (CLIS, 1987), 63.2 % of the answers were correct (B category), around a 20% chose category C, which relates the maximum energy of the truck when it is moving, followed by a 13% answering E category, which stated that Energy was always the same. Categories A and D, which refer to the truck in an idle position (before and after being wound up) was answered by only a 5 and 1% of the respondents, respectively. When they were asked to justify their choice, their explanations fell into similar categories, which argued that the peak in energy would occur i) just when the truck was wound up (52.6%), ii) when the truck was moving (17%), or iii) that it did not change (16%) (showing a wrong application of the Principle of Conservation of Energy). It is also interesting to note that when arguing correctly that the peak of energy was just when the truck was wound (B category), the reason given in 40 % of the cases was that afterwards that energy would be “lost” (in movement). In fewer cases, the students argued that the accumulated energy would be transformed in movement (data not shown). Table 2 shows some examples illustrating this point.

Table 2. Examples of explanations to answers in categories B, C and E of Mickey's Truck exercise (CLIS, 1987).

<table>
<thead>
<tr>
<th>B</th>
<th>C</th>
<th>E</th>
</tr>
</thead>
<tbody>
<tr>
<td>“Because to make the truck move, you need to wind the key. In that moment it takes up speed, so it moves with more force. Therefore, it energy is transformed but it starts loosing energy”</td>
<td>“When the truck is moving, it uses more energy.”</td>
<td>“The energy that the truck has at the start is the same at the end. Energy has been transformed but not used. Before it is a source of energy but it has not transformed into energy yet.”</td>
</tr>
<tr>
<td>“When you wind it up, you fill it with energy and then while it moves it goes losing energy slowly until it stops”</td>
<td>“Because in this moment, it is using the energy and in the other situations the energy is not increased or decreased”</td>
<td>“All the energy is given to the truck and it has not spent any of it yet”</td>
</tr>
<tr>
<td>“All the energy is given to the truck and it has not spent any of it yet”</td>
<td>“Because when it is moving, it is producing energy”</td>
<td>“The truck always has the same energy. Another thing is its speed.”</td>
</tr>
</tbody>
</table>

Second assessment of the Energy Concept (post-implementation)

As stated previously, students performed a series of activities where they assessed different situations in which energy transformations were taking place. First, they assessed the energy stored in food and measured the heat released during combustion of different food sources. Afterwards, special emphasis was given to transformations of mechanical energy by working with springs, and balls falling freely and impacting on
trays full of sand. Half session was devoted to discuss Newton's Universal Gravitational Law to understand how Gravitational Potential Energy is stored in the object-Earth system (CLIS, 1987). Students also used computer simulations depicting a skater and a roller coaster that enabled them to identify those transformations and to visualise the PCE. The simulations were also run in non-ideal conditions in order to understand energy dissipation in the form of heat. Finally, basic arithmetic operations and application of the PCE were carried out using Gravitational Potential Energy (GPE) and Translational Kinetic Energy (KE) formulae. In order to improve their pedagogical content knowledge, the students were given extracts of scientific articles on evidence-based teaching and learning about Energy (CLIS, 1987; Varela et al., 1993) which were discussed in the classroom.

At the end of the implementation, an individual questionnaire was passed to the participants that covered most of the topics and concepts dealt in the module (data not shown). In this section I will discuss the results of two open-ended questions that aimed to evaluate their understanding of primary students' alternative ideas about Energy and the results of a mathematical problem on Conservation of ME.

The first question (Q1, see Methods), asked students how, as teachers, they would help improving the idea that only moving objects have energy. It was expected that the students would use some of the examples seen during the Energy module. In this sense, nearly 80% of the students were able to give diverse examples of energy in the form of gravitational potential energy (17%), chemical energy as in stored in food (14%) or described transformation processes in where energy changes occur (45%). Interestingly, a very few examples of potential elastic energy (3.5%) were mentioned despite their previous lab session with springs.

Regarding Question 2 (Q2, see Methods), students were asked how, as teachers, they would help to overcome the idea that the higher an object is located, the bigger its force is. It was expected that the students would reflect on the experiments performed with falling balls and exercises on gravitation. As shown in Table 3, only a 39 % of the students were able to offer coherent explanations that differentiated between weight and gravitational potential energy, or gave correct definitions of both magnitudes.

The students were also asked to solve a problem addressing the application of GPE and KE formulae and the correct application of the PCE in ideal conditions. Along with those operations the students needed to provide written explanations. In order to evaluate the students' achievement, the responses were assessed regarding 5 formulation levels (see Methods). Taking the three groups of students together (118), approximately half of the students (50% ± 16.8) were able to gave satisfactory written explanations as well as correct applications of the ME formulae and the PCE (L-1) but nearly 20% failed to give neither written explanations nor correct mathematical operations. Levels of formulation that corresponded to satisfactory written explanations but failing to apply the PCE correctly (L-2) or contained mathematical errors (L-3) were found in 14% and 12% of the cases, respectively. Interestingly, very few cases in which only the mathematical formulae were applied correctly but failed to give written explanations (L-5, 4%) were found. This could be possibly due to the fact that it was insisted upon the students that a written explanation would contribute to the final mark of that particular exercise.

Table 3. What is the difference between energy and force? Categories and frequencies emerged from the data

<table>
<thead>
<tr>
<th>1-Gives both definitions</th>
<th>2-Discusses role of Weight in GPE</th>
<th>3-Compares both concepts</th>
<th>4-Incomplete/Incorrect</th>
</tr>
</thead>
<tbody>
<tr>
<td>11 %</td>
<td>18 %</td>
<td>11 %</td>
<td>61 %</td>
</tr>
</tbody>
</table>

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**Satisfaction survey about the methodology**

Upon ending the module, a satisfaction survey consisting of 18 items inquiring about different aspects of the employed methodology was passed to the participants. Table 4 shows the results regarding three general questions about the methodology and we can stress that an overwhelming majority were satisfied with the experience compared to other traditional methods (85%) and that they would like to repeat this instruction method in further courses (91%).

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2 PhET Interactive Simulations. University of Colorado. [http://phet.colorado.edu](http://phet.colorado.edu)
Table 4. Satisfaction survey about the instruction method

<table>
<thead>
<tr>
<th></th>
<th>Not satisfied</th>
<th>A little bit satisfied</th>
<th>Satisfied</th>
<th>Very Satisfied</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Taking into account all the methodological aspects, How would you appraise this experience?</td>
<td>1 (1%)</td>
<td>8 (8%)</td>
<td>47 (46%)</td>
<td>43 (42%)</td>
</tr>
<tr>
<td></td>
<td>Less</td>
<td>The same</td>
<td>More</td>
<td>Much more</td>
</tr>
<tr>
<td>2. To what extent do you think that this experience has helped you learning if you compare it with more traditional methods?</td>
<td>2 (2%)</td>
<td>5 (5%)</td>
<td>59 (58%)</td>
<td>28 (27%)</td>
</tr>
<tr>
<td></td>
<td>YES</td>
<td>NO</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Would you choose this methodology in future courses?</td>
<td>91 (89%)</td>
<td>7 (7%)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

7. Discussion

Effective science training for pre-service primary teachers is a matter of concern within the science education community, partly due to the limited formal background in science and mathematics of future primary school teachers, although some authors argue that this could prove to be an advantage if they are open to learning and aware of what they don't know (Tobin et al., 2012). The reality is that degrees on Primary Education (at least in the Basque Country and Spain) produce generalist teachers and devote a relatively small fraction of their curriculum to science, which implies that in general the science that is taught is extremely broad. Moreover, the majority of the students enrolled in Primary Education degrees normally left science subjects at the beginning of secondary school (approximately a 3-5 year gap until taking on a university science course). Enquiry-based methods and a special focus on core concepts of science, such as Energy, is relevant in this context because not only it helps learners make sense of natural phenomena but also provides the opportunity to develop scientific skills, such as formulating hypothesis, contrasting results and debating ideas (National Research Council, 2007). Within an annual course that focused on active methodologies and project-based learning, a series of eight sessions were designed to teach pre-service teachers about Energy.

The main goal of this research was to evaluate the starting and final point on understanding the Energy concept in pre-service teachers. A possible constraint of this research could be that no identical questions were performed at the start and end of the Energy module. It is possible, though, to use non-identical questions provided that the same content is addressed. In this research the development of the students' ideas about energy was assessed qualitatively by comparing their initial sentences about energy with their answers regarding specific conceptual problems about energy at the end of the implementation. This approach showed that an important change of ideas took place among the participants. At first, their ideas emerging from the sentences were mainly related to renewable sources of energy and could not associate them with particular forms of energy, as known scientifically, which were practically unknown. In this sense, the course had an impact on how students could identify different forms of energy and the transformations among them. They developed an improved understanding of kinetic and potential energy and in some situations they identified dissipation in form of thermal energy, giving examples that had arisen during the course.

The analysis of Micky's truck exercise at the start of the Energy module showed that even in those cases where the correct category was chosen, an incomplete understanding of the PCE was observed in nearly half of the cases. When analysing the mathematical problem about the PCE, one can state that the conceptual understanding of the PCE in ideal conditions was developed in most of the students. This problem however showed other conceptual problems, because some students jumped into mathematical operations without any conceptual reasoning and, in some cases, (around 20%), serious but common mathematical errors, which have been widely reported in the literature (Kuo et al., 2013), were found. Therefore, these mathematical
representations proved to be obscure and somehow intimidating to a reasonable proportion of the students and should be used sparingly and accompanied or complemented with qualitative explanations.

Another prevalent conceptual error was the confusion or equivalent use of the terms force and energy (Watts, 1983), even after the instruction (Kurnaz and Arslan, 2011).

As Tobin and collaborators (Tobin et al., 2012) discussed after a workshop with in-service primary teachers, it can prove a difficult task to help the students to gain a view of Energy as understood by scientists, for whom Conservation of Energy is a fundamental and universal law, while providing a context for understanding energy as is used in socio-economic or domestic uses. The role of dissipation should receive more emphasis in future editions, since it has been shown that this process, and not the identification of tangible forms of energy and its transformations is more challenging (Duit, 1986), and if that is not properly understood, it conflicts with the everyday observation that the energy has been “used up” (Solomon, 1985).

Another aspect that was looked at in this work was how PrBL could help on mobilising the students’ conceptual learning in situations related to their future profession, that is, developing professional knowledge (Bryan and Abell, 1999). The results of the survey and the students’ final products (not shown) show that this approach helped motivating the students, which found a connection between theoretical concepts and practical work. Despite the general scientific knowledge gap that most pre-service teachers have, the challenge lies into motivating them to keep learning and find inspiration from science so they can also inspire their future pupils.

References


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Early Childhood Science Education in an Informal Learning Environment

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Abstract
In this paper we present a learning/teaching experience about objects and materials performed with 5 years old children in Giocheria-Laboratori. This is an educational facility of Sesto San Giovanni, a municipality near Milan (Italy), designed for kindergarten and primary schools’ informal science education. Since many years, we are collaborating with its educators to improve their science education proposal. In particularly, in 2014 we collaborated to design and realize the “Unconventional matters” project, funded by the Italian Ministry of Education. The main aim of the project was to design and test some educational settings where many different types of scraps and unconventional materials are available to children of different ages (3-10 years old). The present learning/teaching experience was realized in the framework of that project, lasted one hour and a half and was focused on the young children’s ways to approach objects and materials in a specifically designed setting. Here we illustrate and analyse the experience from a physics education perspective through a visual narrative of selected episodes.

Keywords
Early childhood, informal education, unconventional matters.

1. Introduction
In the last years, early childhood science education has been receiving increasing attention by the scientific community (Science, 2011). Researches in different fields, from neurosciences to learning and teaching sciences, have shown that children are far more competent in their scientific reasoning than suspected before and have substantial knowledge of the natural world since very early childhood (NRC, 2007).

In Italy we have a long tradition about high quality early childhood education, worldwide well known: Reggio Children experience and Montessori method and schools (Lillard & Else-Quest, 2006). Although activities and contents assume different meanings in these two approaches (Pramling Samuelsson, Asplund Carlsson, 2008), both are characterized by the care of emotional, artistic and social dimensions.

Recently, the Reggio Children group put in their proposals more emphasis on scientific aspects. The Ray of light Atelier in Malaguzzi International Centre is an example of its increasing interest in promoting educational contexts supporting "explorations that inspire wonder and curiosity and stimulate creativity and deeper inquiry" (Reggio Children, 2014).

They proposed the Remida cultural project “that represents a new, optimistic, and proactive way of approaching environmentalism and building change through giving value to reject materials, imperfect products, and otherwise worthless objects, to foster new opportunities for communication and creativity in a perspective of respect for objects, the environment, and human beings.” (Remida, 2014).

In that perspective, they also created Remida centres to collect unconventional, alternative, waste, scrap materials with the aim to distribute them to schools and extra school educational contexts for specific educational projects.

In this paper, we present a learning/teaching experience about objects and materials performed in the informal environment of Giocheria-Laboratori. This is an educational facility of the municipality of Sesto San Giovanni (near Milan, Italy), offering informal science education to kindergarten and primary schools of the municipality since 1987.

Since many years, we are collaborating with the educators and the expert in childhood education of Giocheria-Laboratori. The collaboration aimed to improve their science education quality and to develop educational proposals linking the emotional, expressive, social and cognitive dimensions.
In 2014, we worked together to design and realize the “Unconventional matters” project, funded by the Italian Ministry of Education and aimed to design and test settings and laboratories about unconventional materials.

In particular, one of the main intents of the project was to transform the more spacious room of Giocheria-Laboratori, named the Pavilion, in a place where children could freely and safely explore many different types of materials and scraps recovered by Remida Centres and local industries.

Here, we illustrate and analyse a learning/teaching experience with 5 years old children from a physics education perspective, using a visual narrative of selected episodes from the entire experience.

2. Methodological details

The experience was performed in the “Unconventional matters” project’s framework, during an one hour and a half visit of a kindergarten school to Giocheria-Laboratori. In that context, the research question of our investigation was how children of 5 years old are able to distinguish between objects’ and materials’ properties.

3. Setting and investigation of children’s experience

The entire experience was made in the Pavilion, engaged 16 children of 5 years old, two educators of Giocheria-Laboratori and one of the author. The Pavilion’s setting was designed by the architect involved in the project with the aim to allow wide and deep explorations through many different types of unconventional materials and scarp.

Children were divided into two groups and were invited to make an investigation about materials present in the Pavilion. The two tasks were slightly different: the first group was invited to select some objects in a restricted area; the second one was invited to search for different objects made of the same material (plastic) all around the room. The groups worked separately for almost one hour, then they met each other to compare and discuss their findings.

According to the international early childhood education’s recommendations (NRC, 2001), the educators’ behaviour was intended to be responsive to children’s findings and questions. They had the role to be discrete guides trying to embrace what children caught during their explorations and support them in going further.

One of the author attended at the entire experience, following in particular one group. She had the role to be a participative observer. The approach she adopted was inspired by the observational “looking and listening-in” approach proposed by Sumision and Goodfellow (2012). She used “openness, sensitivity, deep awareness, interpretation, and simultaneously, a suspension of judgement” in the way she tried “to gain insight into the meaning that infants make of their experiences” and to make her interventions (pag. 316-317).

Based on diverse theoretical perspectives (phenomenological, socio-cultural and social cognitive ones), the “looking and listening-in” approach was suggested “as a methodological approach for helping us to edge closer to understanding the infant’s experience, and as a way of describing how the infant made meaning of his experience”. In this context, we mainly used it in the first perspective.

4. Data collection and analysis

We generated data via observational and reflective notes and a video footage of the entire experience. The video gave us the opportunity to analyse children’ actions, gestures and discourses with more detail than using only a written observational record.

We watched the video repeatedly and independently each other, searching for episodes that might be particularly meaningful from the physics education perspective about the difference between object and material.

We then transcribed the selected episodes using InqScribe video analysis software (InqScribe© 2005 – 2009) and, finally, we constructed the visual narrative to illustrate and analyse the experience (Table 1). The visual narrative was constructed following the example of Sumision and Goodfellow (2012) and the relative references.

The visual narrative and its reading

The visual narrative involves the first group of children, some objects of the Pavilion, the educator and the researcher. It illustrates an episodes’ sequence showing how the group investigates objects and materials with the support of experts in informal and physics education respectively.
Before the first episode represented in Table 1, children were sitting in a circle around the educator discussing with her about the objects they selected. After few minutes, a child introduced a jersey’s ball and all began to discuss about it and the material was made of.

Table 1. Selected episodes’ sequence of the learning/teaching experience

<table>
<thead>
<tr>
<th>Photograph</th>
<th>Educator/Researcher</th>
<th>Children</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time 00:04:30.20</td>
<td>“What have you chosen? (E)”</td>
<td>“A ball”</td>
</tr>
<tr>
<td></td>
<td>“How is it made?” (E)</td>
<td>“Wool”,</td>
</tr>
<tr>
<td></td>
<td>“Do you agree that is made of wool? Try to touch it” (E)</td>
<td>“Yes”</td>
</tr>
<tr>
<td></td>
<td>“Someone says twine and not wool” (E)</td>
<td>“Twine”</td>
</tr>
<tr>
<td></td>
<td>“What happens if you push the ball?” (E)</td>
<td>“If I push, it seems that it is hard”</td>
</tr>
<tr>
<td></td>
<td>“Is the ball made of the same thing as these threads?” (E)</td>
<td>“I think there is a stone inside here. It is impossible to destroy!”</td>
</tr>
<tr>
<td></td>
<td>“Why the threads are soft and the ball is hard?” (R)</td>
<td>“Yes”</td>
</tr>
<tr>
<td></td>
<td>“It would be nice unrolling the ball and looking what there is inside” (E)</td>
<td>“Because inside there is something on which you can roll up the twine”</td>
</tr>
<tr>
<td></td>
<td>“Maybe, it is better rolling the ball from the other end than unrolling it” (R)</td>
<td></td>
</tr>
<tr>
<td>Photograph</td>
<td>Educator/Researcher</td>
<td>Children</td>
</tr>
<tr>
<td>------------</td>
<td>---------------------</td>
<td>----------</td>
</tr>
<tr>
<td>Time 00:11:46.12</td>
<td>“Look at me. I don’t put anything inside, I just start to roll the thread” (E)</td>
<td>“It is hard”</td>
</tr>
<tr>
<td></td>
<td>“Can you try to touch the ball now?” (R)</td>
<td>“It is hard”</td>
</tr>
<tr>
<td></td>
<td>“Can you try to touch the one I’m rolling up?” (E)</td>
<td>“It is decreasing more and more”</td>
</tr>
<tr>
<td></td>
<td></td>
<td>“There is only a knot!”</td>
</tr>
<tr>
<td>Time 00:15:05.21</td>
<td>“So, what makes the ball hard? (E)</td>
<td>“Because it becomes very very big and it hardens”</td>
</tr>
<tr>
<td></td>
<td>“I can make a very very big bunch of threads, is it hard? (E)</td>
<td>“No, it is soft”</td>
</tr>
<tr>
<td></td>
<td>“Do you think there is more thread in the ball or in the bunch?” (R)</td>
<td>“In the bunch”</td>
</tr>
<tr>
<td>Time 00:17:04.14</td>
<td>“How could we know that?”</td>
<td>“Because they are so many!”</td>
</tr>
<tr>
<td></td>
<td>“Look, she attached two threads and she made a longer one” (R)</td>
<td>“Wow, I made it long”</td>
</tr>
<tr>
<td></td>
<td>“So what could we do?” (R)</td>
<td>“We have to tie all of them”</td>
</tr>
</tbody>
</table>
The pathway begins with a question “How is it *(the ball)* made?”. Children immediately say that it is made of wool, but touching the ball they change their minds (“it is made of twine”, photograph #1). Pushing the ball, children feel that it is hard. Touching some threads, they realize that are made of the ball’s material even though the threads are soft (photograph #2). The researcher asks the reason why this happen (“Why the threads are soft and the ball is hard?”, photograph #3) and some children suggest the idea of a stone inside the ball.

This idea is explored unrolling the ball and simultaneously making another ball with the same thread. In this way, children verify that there is no stone inside the old ball and, at the same time, that the new one is still hard (photograph #4).

### Table 1. (Continued)

<table>
<thead>
<tr>
<th>Photograph</th>
<th>Educator/Researcher</th>
<th>Children</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1" alt="Photograph" /></td>
<td>“So, can we make a very long thread using these pieces and then roll it to make a ball?” (E)</td>
<td>“Yes, we make knots and then we tie the threads”</td>
</tr>
<tr>
<td>Time 00:22:23.10</td>
<td>“Do you think the thread made by small pieces will make a hard ball or a soft one?” (E)</td>
<td>“A ball very hard!”</td>
</tr>
<tr>
<td><img src="image2" alt="Photograph" /></td>
<td>“If everyone ties two or three pieces, the thread will be long enough” (R)</td>
<td>“It is very hard!”</td>
</tr>
<tr>
<td>Time 00:34:43.23</td>
<td>“We had to find if the ball made by small soft pieces is hard or soft. Try to touch it” (E)</td>
<td>“Three ways to attack things without glue!” (E)</td>
</tr>
<tr>
<td><img src="image3" alt="Photograph" /></td>
<td>“We still have to understand why many pieces tied together and rolled up make a hard ball. We have to think about it” (E)</td>
<td>The child shows how to attack two magnets. One child wedges a wire into a box and another wedges two cylinders.</td>
</tr>
<tr>
<td>Time 01:02:08.13</td>
<td></td>
<td>“Three ways to attack things without glue!” (E)</td>
</tr>
<tr>
<td><img src="image4" alt="Photograph" /></td>
<td>“They tried to tie the threads making knots, here she was able to tie two things in a different way. Do you show in which way to us?” (R)</td>
<td>Children go all around the Pavilion and try to tie things together using glue, magnets, press studs, Velcro and even water. They also explore the possibilities to build stable structures and move tying things.</td>
</tr>
<tr>
<td>Time 01:05:28.29</td>
<td>“Are there other ways to tie/attack things?” (R)</td>
<td></td>
</tr>
</tbody>
</table>
A child tries to explain the ball’s hardens introducing the volume (“Because it becomes very very big and it hardens”, photograph #5). The educator gets a lot of threads making a big bunch: it looks bigger than the ball but still soft. It is not a matter of volume.

The researcher then asks if there is more thread in the ball or in the bunch and how we could know that. A child realizes that two threads can be tie to make a thread longer than before (“Wow, I made it long”, photograph #6).

Her finding suggests the idea to make a long thread joining together the small pieces (photograph #7). Rolling it, the educator makes another ball and children feel that it is still hard. No matter if the pieces are soft. Children realize that pieces and ball have different properties, even though they are not yet able to explain why this happen (photograph #8).

The learning/teaching pathway seems to be arrived at its end when the other group arrives to share findings. However, two children of that group show two other ways to take things together without glue (photograph #9).

Children go around in the Pavilion trying to tie things together with many different types of materials and exploring the possibilities to build stable structures and move binding things (photograph #10).

### 5. Conclusions

The research we presented in this paper explored the possibilities to introduce young children to first ideas about objects’ properties as depending on material and/or on structure of the small pieces they are made of. The opportunity offered by the Pavilion and by the large amount of objects available allowed children to explore objects’ properties through senses (appearance, elasticity, softness, shine, texture, colour, etc.) and to look for similarities and differences among them. Moreover, its particular setting gave them the opportunity to investigate objects and materials following not stereotyped questions and finding their own answers.

The Pavilion’ setting was an opportunity also for the adults involved in the experience. Scraps and cuttings without a conventional name or a recognizable function aided them to abstract from the idea of object to the material from which it is made and to make their interventions as much as possible from the children’s perspective.

In the analysed experience, the educator let the children free to explore the environment using body and senses and to express emotion and creativity. She paid a lot of attention to children's questions and actions, trying to recognize hooks to the theme that children wanted to treat and dealing with the issue in a comprehensive way. She also supported the collaboration and the communication among children and the researcher.

As the visual narrative shown, the researcher was able to guide children to recognise that a jersey ball can be made of small pieces and that their properties can be different from the ball’s one.

Although it was not possible to introduce more advanced interpretations in the available time, children were introduced to the basic physics idea the object’ properties depend on the properties of the single constituents, the kind of links among them and the arrangement of the entire structure.

### 6. Perspectives

Beside the experiences with kindergarten school, we are now working to introduce in the Pavilion workspaces with instruments and tools where primary school children can investigate objects and materials in interaction with water, light and heat sources.

Even though we are designing more structured experiences, it is our opinion that also primary school children need to recover the joy and the taste of exploring by senses before to be guided toward a more formalized knowledge.

For the next years, we hope to continue the collaboration with Giocheria-Laboratori and the schools of the municipality to design and test learning contexts and pedagogical progressions for formal and informal science education at different ages.

### Acknowledgements

We thank the educators of Giocheria-Laboratori: Daniela Calò, Anna Cuccu, Laura Plebani, Simona Vimercati; Alessandro Porcheddu, the coordinator of Giocheria-Laboratori; Arch. Maurizio Fusina-Re Mida; all the children, teachers and parents participating to the labs and school experiences.

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Remida (2014) http://www.reggiochildren.it/atelier/remida/

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Using Videos and Video Editing Software with Pre-Service Teachers for our Modern Primary Science Classrooms.

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Abstract  
International priorities and policies for improving teacher quality and teacher education place an emphasis on improving teacher competencies in the use of ICT and linking knowledge and information about ICT to curriculum delivery. Therefore colleges of Initial Teacher Education (ITE) need to ensure that all newly qualified teachers enter the teaching profession with the ICT knowledge and skills to be able to teach effectively, incorporating ICT into their teaching and learning strategies.  
The aims of this research were to investigate the technologies being used by pre-service primary teachers during their teaching practice experiences in their first year of their undergraduate programme and to use an integrated approach to Science Education Modules where technology was used to further develop the students Subject Matter Knowledge (SMK), Pedagogical Content Knowledge (PCK) and their Technological Pedagogical Content Knowledge (TPACK) to prepare teachers to teach where technology significantly impacts and changes teaching and learning methodologies in primary science classrooms.  
Questionnaires were distributed at the middle of the semester when the pre-service teachers had several experiences of teaching different subject areas, to investigate their use of technology in the classroom and again at the end of the semester to evaluate the integrated approach to the Science Education Modules (N=254). The results indicated that ICT was being used in a very limited manner during their school placement experiences. Digital videos were then designed and edited by the lecturer to deliver the science content using specific, effective and appropriate teaching and learning approaches to acquire understanding of a topic. Feedback from the pre-service teachers in the post-module questionnaire showed that the use of videos in lectures were successful in developing their knowledge and understanding in science. Their comments also indicated that the use of videos developed their PCK and TPACK, providing the pre-service teachers with ideas for future lessons, how to structure a lesson and how to use videos in the primary science classroom. Their end of the semester assignment involved the recording and editing of videos that the pre-service teachers could use in their teaching of science. Their experiences of and opinions on the assignment further highlighted that this module contributed in developing their SMK, PCK and TPACK.  
The lecturer introduced the use of videos to the pre-service teachers and modelled this teaching methodology in her own teaching. This integration of the technology was time consuming and required a high level of commitment. The development of future teachers’ TPACK in methods courses requires that teacher educators learn to integrate technology into their own practice. For teacher educators to integrate technology effectively into classes, they must receive appropriate training and support.

Keywords:  
Teacher Education, Primary, ICT, SMK, PCK, TPACK

1. Introduction  
The 21st Century has been characterised by the introduction of a wide range of modern technologies, with a vast selection of communication technologies to choose from and thus leading to the acceleration in the use of ICT in education (OECD 2001, 2005). In the past several decades there has been a considerable level of investment from governments with the aim of improving the amount of technology available, resulting in an increase in the access to and the use of ICT in primary schools across Europe (BECTA 2006; DiES 2005; EACEA 2007; DES 2001; NCTE 2004). However increasing access to computers in educational settings and
computer usage at home does not translate into the increasing use of technology in the classroom (European Schoolnet 2012; Eurydice 2004). It also does not translate into the productive use of and integration of technology into classroom activities (Cuban 2001; DiSessa 2001).

Integration of ICT requires training and support for teachers, innovation, and a change in teaching and learning strategies (BECTA 2006; Ofsted 2004). The ‘Impact of Technology in Primary Schools (STEPS)’ study found that National ICT Policies across Europe usually aimed at improving infrastructure and teachers’ digital competence but were less frequently focused on the supply of digital learning resources and pedagogical reform (EACEA 2007). Studies have highlighted that there can be an overemphasis on developing an awareness of the actual technology in many of the pre-service and in-service professional development courses for teachers rather than on models or frameworks for effective technological integration (Carr et al. 1998; Cox et al. 1999; Crompton and Mann 1996; Hargreaves and Fullan 1998; Mishra and Koehler 2006).

2. ICT and Science Education

Internationally, standards in Science Education place an emphasis on curricula where technology is an essential component of the learning environment, in both content and instruction (National Council of Teachers of Mathematics (NCTM 2000; National Research Council 1996; ISTE 2000). As far back as the 70’s computer literacy was ranked as one of the ten key basic skills needed in mathematics and science education in the US (National Council of Supervisors of Mathematics, 1978). In the US the National Research Council states that a central component of scientific literacy is the appropriate use of technology to support learning goals (NRC 1996). However a gap exists between technology for doing science and technology for learning science (Songer 2007). Studies have shown that teachers often move away from the integration of ICT to focusing on teaching ICT skills in isolation to the curriculum subject areas (Tondeur, Braak and Valcke 2007). Tondeur, Braak and Valcke (2007) advocate that ‘the educational use of ICT should be embedded within subject-orientated competencies’.

European priorities for improving teacher quality and teacher education, state there is a need to improve teacher competencies in the use of ICT, linking knowledge and information about ICT to curriculum delivery (BECTA 2006). Colleges of Initial Teacher Education (ITE) need to ensure that all newly qualified teachers enter the teaching profession with the ICT knowledge and skills to be able to teach effectively incorporating ICT into their teaching and learning strategies (NPADC 2001; Lim, Chai, and Churchill 2010; The Teaching Council 2011), placing an emphasis on the pedagogy of technology rather than focusing on the technical aspects of technology (EACEA 2007; Pelgrum and Plomp 1993). While pre-service teachers today are more skilled ICT users than their predecessors (Richards 2004; Albion 2003), it is often incorrectly assumed that they have developed sufficient skills outside their teacher education courses. The first exploratory phase of this research investigated the technologies being used by pre-service primary teachers when teaching during micro-teaching and school placement experiences.

3. Subject Matter Knowledge (SMK), Pedagogical Content Knowledge (PCK) and Technological pedagogical content knowledge (TPACK)

Effective science teaching incorporates pedagogical content knowledge (PCK) and Subject Matter Knowledge (SMK) (Shulman 1986; Cox and Carpenter 1989; Hollingsworth 1989; Appleton 1995). There is the consensus that in order to be a good teacher you not only need a strong scientific background knowledge (Shulman, 1986; Veal and MaKinster, 1999) but also a coherent understanding and a strong PCK (Cox and Carpenter 1989; Appleton 1995; Johnston and Ahtee 2006; Parker 2004). Science education programmes in ITE need to directly link SMK, PCK and Contextual Knowledge (CK) (The Teaching Council 2011).

Technological pedagogical content knowledge (TPACK) is emerging as an important area for research and development (Angeli and Valanides 2005; Lundeberg, Bergland, Klyczek, and Hoffman 2003; Mishra and Koehler 2006; Niess 2005). TPACK is the integration of the development of knowledge of subject matter with the development of technology and of knowledge of teaching and learning (technological knowledge, pedagogical knowledge and content knowledge). Integrating these different domains supports teachers in teaching their subject matter with technology (Hewitt 2008; Wright 2010). Mishra and Koehler’s framework for teacher knowledge emphasizes the connections and interactions, between content, pedagogy, and technology (Fig. 1). In this model, knowledge about content (C), pedagogy (P), and technology (T) is central for developing good teaching.
4. Pre-service teachers and Technological Pedagogical Content Knowledge (TPACK)

For technology to become an integral component or tool for teaching and learning, science pre-service teachers must also develop an overarching conception of their subject matter with respect to technology and what it means to teach with technology (TPACK). Traditionally, teacher preparation programs have depended on one course focusing on learning about technology. Most teacher education institutes currently offer at least one if not a number of courses that address the need to scaffold pre-service teachers’ development of expertise for ICT integrated teaching. However, many of these courses in the past focused on technological skills increasing the likelihood of pre-service teachers’ using ICT in the classrooms when they became teachers (Hammond et al. 2009; Mishra, Koehler, and Kereluik 2009; Polly et al. 2010). Studies have reported that pre-service teachers are inadequately prepared for ICT integrated teaching even after the study of the above mentioned courses (Kay 2006; Mims et al. 2010).

Recommendations have been proposed to integrate technology in all courses in the teacher preparation program and to develop the pre-service teachers’ skills in designing ICT integrated lessons (Angeli and Valanides 2005, 2009; Chai et al. 2010; Jimoyiannis 2010; Koehler, Mishra, and Yahya 2007; Niess 2005; O'Neill 2000). The overall aim of this research is to use an integrated approach to Science Education Modules where technology (videos) is used to enhance teaching and learning of science and strengthening pre-service teachers’ SMK, PCK and Technological Pedagogical Content Knowledge (TPACK) for the modern world.

5. Aims of the research

To investigate the technologies being used by pre-service primary teachers during their teaching practice experiences.

To use an integrated approach to Science Education Modules where technology is used to further develop the students SMK, PCK and their TPACK to prepare teachers to teach where technology significantly impacts and changes teaching and learning methodologies in primary science classrooms.

6. Research Framework - Technological Pedagogical Content Knowledge (TPACK)

The science modules concentrated on the development of the students’ knowledge and thinking in a manner that considers the development of an overarching conception of teaching with technology. The lectures firstly challenged the pre-service teachers to reconsider their subject matter content and the impact of technology on the development of that subject matter as well as on the teaching and learning that subject i.e. learning subject matter with technology in contrast to learning to teach that subject matter with technology (Niess 2005). Secondly the focus on technology was to use it as enrichment not as a replacement in science teaching, exploring how a technology tool could be used to foster meaningful learning i.e. combining...
pedagogy and technology, developing the pre-service teachers’ Technological pedagogical content knowledge (TPACK) (Tasar and Timur 2011).

7. Pre-service Teachers’ Prior Experiences
This research was carried out with first year Bachelor of Education (Primary Teaching) students during their second semester of third level education in one of the largest college of initial teacher education in Ireland for elementary teachers.
When deciding on an Integrated Approach to Science Education Modules, Sandholtz, Ringstaff, and Dwyer’s (1997), conceptual framework of technology integration was considered. They state that technology integration should be gradual and a slow careful approach should be taken. This framework includes five stages: entry, adoption, adaptation, appropriation, and invention. At the entry phase, teachers use technologies such as Interactive White Boards and overhead projectors. The pre-service teachers on entering third level education in their first semester would have experience of this in most modules they were taking, where the academic staff used technology in their lecture presentations. At the adoption phase, teachers begin to show more concern about how technology can be integrated into daily lesson plans to teach children how to use technology. The pre-service teachers would have experienced this in their pedagogy modules, where the integration of ICT would be referred to and modelled (Pedagogy of Irish, Mathematics and Educational Methodology Modules). In their first semester within the module ‘Becoming a Student Teacher’ they developed word processing skills, learned how to use the Interactive White Board (IWB) and screens, became familiar with presentation software and developed internet literacy. The adaptation phase involves the integration of new technologies into classroom practice. In their first and second semesters the students gained first-hand experience of teaching and had the opportunity to teach during their microteaching tutorials and while on school placement in primary schools using the IWB and Presentation software. In all science education lectures in semester two the Entry, Adopt and Adapt phase were considered and applied to the lecturers teaching and student learning, using technologies they were familiar with from the previous modules taken.

8. Methodology
Questionnaires were distributed at the middle of the semester when the pre-service teachers had several experiences of teaching different subject areas to investigate their use of technology in the classroom and again at the end of the semester to evaluate the integrated approach to the Science Education Modules to investigate the effect of videos on the pre-service teachers’ SMK, PCK and Technological Pedagogical Content Knowledge (TPACK). 254 pre-service teachers completed the questionnaires of which 22% were male and 78% female.

9. Design and development of the videos
The pre-service teachers were then introduced to videos as a teaching and learning methodology in science. Using recording equipment and video editing software videos were designed to use in face-to-face lectures and as part of their on-line learning component of the module. The videos were designed to develop the pre-service teachers’ scientific background knowledge (Shulman 1986; Veal and MaKinster 1999). The videos were used to engage students with a topic being covered, to get their ideas and prior knowledge about a scientific concept, to develop their problem solving skills by leading them to investigate a problem that appeared in the videos, to consolidate learning that occurred in the science education workshops and to promote further reflective and critical engagement with such tasks. For example they included recordings and images of science demonstrations and ‘mysteries’, where by the students was asked could they explain the science behind the demonstration. One such video included the use of a ‘hand boiler’ where by the heat from our bodies cause a liquid in the hand boiler to expand and rise upwards. Other videos had a scenario or problem posed in the video for the students to think about for example ‘if you leave an ice cube on a table for 20 minutes and wrap another ice cube with cotton wool and leave it on the table also for 20 minutes, which ice cube will be the first to melt?’. The videos were also designed to develop a coherent understanding and a strong pedagogical content knowledge (PCK) incorporate PCK i.e. the delivery of science content using specific, effective and appropriate teaching and learning approaches to acquire understanding of a topic (Shulman 1986; Cox and Carpenter 1989; Appleton 1995; Johnston and Ahtee 2006; Parker 2004). For example the videos incorporated Concept Cartoons, Concept Maps, demonstrations, pictures of activities and experiments etc. that can be carried out in the classroom. The use of videos by the lecturer and the assessment component in the science education module were used as the appropriation phase and invention
The appropriation phase is where teachers understand technology’s usefulness, and they integrate it to teach science effectively in a meaningful way (Sandholtz, Ringstaff, and Dwyer’s 1997). The invention phase involves teachers experimenting with new instructional patterns and reflect on teaching and question old patterns of instruction (Sandholtz, Ringstaff, and Dwyer’s 1997). Drawing on the principles of constructivism, the pre-service teachers recorded and edited video to use in their teaching of science and designed complete lessons plans to accompany the videos focusing on the development of the children’s scientific knowledge and scientific process skills (Willis and Sujo de Montes 2002; Brown 2002; Zhiting and Hanbing 2002; Delargey 2003; McNair and Galanouli 2002).

10. Results

Use of ICT in the primary classroom

Before this module 93% had never recorded and edited a video for teaching in the primary classroom (N=254). Their use of technologies in the classroom was also limited. They were asked to list any technologies they had previously used when teaching. 39% used data projectors with the majority (22%) stating they used it for powerpoint presentations, 3% used it to watch videos from youtube, 1 person used a visualiser and camera. 61% stated that they used the IWB but they did not state clearly if they used it interactively or just solely for presentations.

Experience of videos in the Science Education Module

There were then asked their opinions on the use of videos in developing their SMK and PCK. Overall the majority pre-service teachers felt that the videos helped to develop their SMK and PCK (Table 1). 71% felt the videos challenged their thinking, helping them gain knowledge and understanding in science (81%). 73% felt it also helped them to understand how to structure a lesson, providing different ideas and activities for teaching science (92%).

Table 1. Pre-service teachers’ opinions of the use of videos in developing their SMK and PCK (results indicate % of 254).

<table>
<thead>
<tr>
<th>Did you find the use of Videos</th>
<th>Yes</th>
<th>No</th>
<th>I don’t know</th>
</tr>
</thead>
<tbody>
<tr>
<td>Challenged your thinking and prior ideas on different topics in science?</td>
<td>71</td>
<td>17</td>
<td>12</td>
</tr>
<tr>
<td>Helped you to gain knowledge and understanding of science?</td>
<td>81</td>
<td>12</td>
<td>7</td>
</tr>
<tr>
<td>Helped you to understand how to structure a science lesson?</td>
<td>73</td>
<td>18</td>
<td>9</td>
</tr>
<tr>
<td>Provided you with ideas for teaching science?</td>
<td>92</td>
<td>6</td>
<td>2</td>
</tr>
</tbody>
</table>

Their comments also indicated that the videos engaged them in their learning, developing their knowledge and understanding in science and helped them in the planning of future lessons. Their comments included:

Engagement

They were very interesting and engaging.
They provided stimulation for students at the beginning of lessons.
The videos acted as a stimulus and engaged us in wanting to learn more.

Knowledge and Understanding

Very helpful in my learning
They were interesting and put the concept being taught into perspective.
Made the lectures easier to understand and more interesting.
I found it fun and interesting to learn on a different platform.

Lesson planning

The videos helped me to plan better science.
I thought they were very helpful as they gave great ideas for lessons and made topics interesting and engaging.
Experience of recording and editing videos for the Primary Science Classroom

Iphones were used by 81% of the pre-service teachers to record their videos, 8% used IPODs, 4% Digital camera and Video recorders and 3% IPADs.

A variety of video editing software and applications were used by the pre-service teachers: Powerpoint, Moviemaker, Spark, Splice, Video editor, Videditor, Perfect video, Video shop and Pausebutton.

They were asked to rank the effectiveness of using videos as part of their assignment (Table 2, 1: Very Effective - 5: Not Effective).

Table 2. Pre-service teachers’ opinions of the use of videos in developing their TPACK (results indicate % of 254).

<table>
<thead>
<tr>
<th>Rank the effectiveness of using videos in contributing to the following:</th>
<th>1</th>
<th>2</th>
<th>3</th>
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<tr>
<td>Developing your understanding how videos can engage children in a topic</td>
<td>55</td>
<td>33</td>
<td>7</td>
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<tr>
<td>Developing of your own teaching strategies</td>
<td>29</td>
<td>43</td>
<td>20</td>
<td>7</td>
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<tr>
<td>Using ICT to facilitate Pupil’s teaching and learning in science</td>
<td>36</td>
<td>40</td>
<td>18</td>
<td>5</td>
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</tr>
<tr>
<td>Developing your ability to structure a science lesson</td>
<td>34</td>
<td>35</td>
<td>24</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Helped in developing your ability to engage children in a science lesson</td>
<td>51</td>
<td>33</td>
<td>11</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Developing your understanding of how to integrate videos into the a Science Lesson</td>
<td>42</td>
<td>38</td>
<td>13</td>
<td>3</td>
<td>4</td>
</tr>
</tbody>
</table>

Their comments included:
Videos are useful overall for all aspects of teaching as well as learning.
I think the use of an engaging video immediately captures the attention and interest of the student.
I feel that using a video to prompt the children at the beginning of the lesson is a beneficial way of elicting prior knowledge.
Helped to engage students and structure lesson.
The video was a different method of engaging the class.
It made it easier to plan a science lesson.
Using videos at the start of lessons I now find to be a great way to engage the class.
I feel videos are effective engaging children and relating them to a real life context.
Posing a problem with a video is a great way to engage children. The children became more motivated to participate in the class.
Videos overall are useful in science.
Provided a new approach.
I became aware of how to integrate videos into the classroom in an effective manner.
ICT is the way forward, children connect better with it.
I had not considered creating videos to engage children but I will in the future.
Its modern and interesting with a personal spark.
I think a video is the best way to engage pupils and this module taught me how to do it.
It gave me a good overview of ICT in the classroom.
The video was a new experience for the class and so they were engaged and interested.

Future use of videos in science lessons
65.4% stated they would now use their own videos in the primary science classroom. 6.9% stating they would not and 27.6% stating maybe.
They were then asked how they would use them in future lessons.

Table 3. Future use of videos in their primary science lessons (results indicate % of 254).

| % |
|----------------------|---|
| Beginning of the lesson to engage and elicit discussion | 97.7 |
| To test the pupils prior knowledge | 67.1 |
| The starting point for investigations | 85.5 |
| As a form of assessment | 26.1 |
| End of the lesson to elicit discussion | 56.4 |
As can be seen from Table 3 above the majority of students highlighted they would use videos at the beginning of a lesson to engage and elicit discussions. They also felt they would be most useful as a starting point for investigations.

11. Discussion and conclusions
This research was carried out to investigate the technologies being used by pre-service primary teachers during their teaching practice experiences and to use an integrated approach to Science Education Modules where technology is used to further develop the students SMK, PCK and their TPACK to prepare teachers to teach where technology significantly impacts and changes teaching and learning methodologies in primary science classrooms. The results from the pre-questionnaire showed that the pre-service teachers were using ICT in a very limited manner i.e. using the interactive white board to present power point presentations. The students were introduced to the use of videos for the primary science classroom by the lecturer that designed and developed a wide variety of videos using them in lectures with the aim of developing the students’ knowledge and understanding of science. Feedback from the pre-service teachers showed that the videos were successful in developing their knowledge and understanding in science. The videos were also designed to develop a coherent understanding and a strong pedagogical content knowledge (PCK) incorporate PCK i.e. the delivery of science content using specific, effective and appropriate teaching and learning approaches to acquire understanding of a topic. It can also be seen from the results that the videos provided them with ideas for future lessons, how to structure a lesson and how to use videos in the primary science classroom. Their experiences of and opinions on the assignment which required them to record and edit videos for the use in a primary science lesson further highlighted that this module contributed in developing their SMK, PCK and TPACK.

The entry, adoption and adaptation phases were very important in this research where the lecturer introduced the use of videos to the pre-service teachers and modelled this teaching methodology in her own teaching (The Teaching Council 2011). However it should be noted that the integration of technology in a method courses is not an easy task and required a high commitment from the researcher (lecturer) (Angeli 2005). Using technology in science education lectures required that the lecturer developed competences in editing digital videos. The development of future teachers’ TPACK in methods courses requires that teacher educators learn to integrate technology into their own practice (Hadley, Eisenwine, Hakes, and Hines 2002). For teacher educators to integrate technology effectively into classes, they must receive appropriate training and support (Groves and Zemel, 2000). The results indicate that the task of preparing pre-service teachers to become technology competent is difficult and requires many efforts for providing them with ample of opportunities during their education to develop the competencies needed to be able to teach with technology (Angeli 2005). In future science education modules it would be important to infuse technology allow student teachers develop a sound pedagogical rationale of how to teach with technology (Mullen 2001).

12. Summary
This research shows that technology can be effectively integrated into a science education module for pre-service primary teachers however it highlights that becoming technology competent requires time and effort on both the part of the educator and student. Pre-service teachers will be able to effectively develop the competencies needed to teach with technology only when teacher educators systematically infuse technology throughout the teacher education curriculum (Angeli 2005). Programs of Initial Teacher Education need to develop a college-wide plan for technology preparation that spans both the technology and methods courses (Strudler and Wetzel 1999).

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Funding acknowledgement: The Blended Learning Unit, Mary Immaculate College, Limerick.
Methods Based on Non-Formal-Learning and Emotion-Based Learning for Teaching Physics in Primary and Lower Secondary Schools.

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Abstract
Teaching Physics in primary and lower secondary schools involves the choice of particular strategies and methodologies, as often the students of these educational stages lack the mathematical tools needed to formalize concepts. Furthermore, in many cases they lack the basic knowledge of many phenomena, the interest in direct observation and experimentation, the participation in the laboratory activity. Very often they have an intuitive and misleading interpretation of some concepts, which causes distortions in the learning process difficult to get rid of [Besson, 2004]. A relevant example is the physical concept of “density” (or specific weight), which is regularly confused with the mass (weight). In the case under consideration (the school-laboratory project ‘From Archimedes to submarines: the concept of density’) the concept of specific weight of a body is not introduced as an a priori definition, but as the culmination of a journey rich in discoveries and surprises: a series of experiments designed with the aim of generating an alternation of fun, emotions and moments of reflection. The choice of a non-formal didactic approach, developed in a learning user-friendly environment, and characterized by involving interfaces, gives the opportunity to create a connection between everyday experience and scholastic knowledge. In our design we have always kept in mind the results of recent research on informal/non-formal learning and emotion-based learning, which highlight how the emotional involvement of the learner is able to remove mental blocks and to activate deep structures that generate a stable knowledge [Michelini, 2006; Bachara et. al., 2000; Damasio et. al., 1994].

1. Introduction
The idea at the base of our work originates from the observation that the daily experience often leads pupils to “see” what they have around without really to “observe” the reality with careful and critical look, an attitude which would lead them to develop personal reflections, often wrong. This behaviour leads, in a later age, to misconceptions, which generate prejudiced attitudes towards scientific disciplines. Pupils often feel themselves inadequate in front of the observation of a phenomenon, inhibited to formulate explanatory hypotheses and conjectures, just because they are not familiar with the formulation of interpretative models. The subject of the educational path "From Archimedes to submarines" is the buoyancy, or better the difficult concept of "density" or "specific weight" of a body. The path is designed to deepen concepts which are often misinterpreted by children and young students (and not only by them!) because based on a misleading common sense, like: “the more heavy the object is, much better it will sink”.

2. Main objectives of the path
The path that we designed was initially thought to be proposed during events devoted to science popularization, such as Scientific Festivals, or occasional workshops, also performed in classroom settings, but characterized by a short duration (maximum two meetings of two hours each one). This is why we have chosen to pay particular attention to the preparation of the experiments to be presented: they had to be the most catchy and amazing, to be able to capture the interest of young people in the shortest possible time; at the same time, they should lead to acquire correctly physics concepts little known or, in many cases, wrongly acquired by students (as the concept of the specific weight, often confused with that of the weight, which is, in turn, confused with that of the mass).
Recent theories on emotion-based learning argue that the emotional involvement of children and young people during the phases of the study and learning of concepts is able to remove mental blocks and to activate deep structures that generate a stable knowledge [Michelini, 2006; Bachara et. al., 2000; Damasio et. al., 1994]. An attractive and engaging didactic path, where the playful side is structured to act as a support
to the teaching, has therefore the double advantage to attract and intrigue the learner and, moreover, to act as an activator of emotions, and thus facilitate the assimilation and the consolidation of the presented concepts.

In designing our didactic path, the original idea was therefore to introduce the fundamental concepts that we wanted to present through what we have termed "trick experiments", which somehow produce wonder and bewilderment in the pupils. The experiments have been realized using material easily available, in order to allow interested teachers and didactic operators to reproduce them. Some of them have been originally designed by the authors, while others are didactic experiments available in literature (the cartesian diver, the glass bottle with balloon placed in hot water, the underwater volcano and so on); in both cases, particular attention was given to enhance and emphasize their more spectacular aspects, and they have been inserted into a single path that introduces the different aspects of the proposed topic (the buoyancy).

An example is the experiment of the double-weighing with hydrostatic balance, a classic experiment that we try to make more interesting through the use of samples-weights of particular materials (such as nylon, aluminum, polyethylene, various types of wood etc.), whose behavior in water lends itself very well to cause misunderstandings and induce doubts in students.

This fact, which acts on an emotional level, produces a revival of interest and an increased desire to understand, and helps the child to overcome the momentary confusion of thinking, stimulating his wish for testing himself. The subsequent overcoming of the obstacle produces an effective consolidation of the concept acquired, thanks also to the increased self-esteem [Tagliagambe2011].

A further confirmation of the validity of this approach was provided to us by recent research in neurology that, like those of Damasio on emotion-based learning, are offering a scientific basis for this type of teaching strategies based on the overcoming of mistake [Roediger and Finn 2009]. In particular, results of these study suggest that the use of challenging tests - not finalized to avoid errors in the student answers - may be one key to effective learning [Kornel et.al 2009].

The idea of "trick experiments" is not new. The authors have already experienced it on previous occasions (Genova Science Festival 2009, Parmascienza 2010 Parmascienza Lab 2012, Museoland-La Spezia 2013, etc.), by means of workshops ranging from the origin of fossil fuels to the physical, chemical and optical properties of the glass [Merlino et al. 2013a, Merlino and Evangelista 2013b]. From conversation with teachers and didactic operators, we realized that the approach semi-playful and the choice of presenting more difficult concepts through trick experiments that lead students to experiment mental confusion and so to commit errors in reasoning, has proved particularly effective in increasing the subsequent scientific performance of the pupils involved in these events. But this kind of events does not facilitate the acquisition of data and documents suitable for the evaluation of the didactic effectiveness of the course. For this reason we are not able, at the moment, to produce quantitative data to validate this approach, in terms of improving the school performance of students in the treated argument.

Nevertheless, in this paper we would like to illustrate, at a qualitative level, the principal choices we made in designing this laboratory: choices and teaching strategies that, according to our experience in this area, are able to promote better learning of scientific concepts. The qualitative results that we shall describe later (in paragraph “discussion”) are based mainly on our observations, made during the many laboratory implemented, on discussions with teachers and didactic operator intervened, and on output material produced by students (during the laboratory and in the evaluation phase described in next paragraph).

3. Structure of the path

Basing our choices on the IBSE/IBL methodology [Report Rocard 2007] we tried to design the structure of our path in 5 steps (following the 5E model), to promote the emergence and enhancement of the research skills:

**Phase 1- Engagement(or qualitative observation of the phenomenon)**

The senses play a major role in the construction of a spontaneous model. Students can freely express their opinions and observations. This phase has the aim of attracting attention, stimulate curiosity, encourage the student's feeling of "wanting to know more."

In our specific case, we give to kids everyday objects, different in shape, material and weight, and they are asked to express their a priori assumptions about their behaviour in water. After that, in order to analyze one by one the different factors that affect the buoyancy of a body in the water, we restrict initially the quantitative analysis to the "weight" (or mass): we give students a set of sample-weights, all equal in shape and volume (a cylinder of 5 cm of diameter and 5 cm of height) but different in weight and materials. As in
the previous case, students are asked to divide the objects in two categories: those that they suppose to sink, and those they suppose to float. They can handle and so estimate weight. Their suppositions are reported in a “workbook”. Materials we chose to build the sample–weights were such to cause doubt and induce the children in errors due to erroneous interpretations typical of common sense, and this is reflected in their choices. In fact, during this procedure they often find, as in the previous step, themselves in conflict with their incorrect prior knowledge: an example is the nylon sample, which in their opinion undoubtedly floats (because associated to nylon socks), and the aluminum one, which makes them in troubles because it is associated both to metal ("heavy" in common sense) and aluminum foil ("light" in common sense). From the analysis of their responses, there is indeed a predominance in assigning the full floating to the three types of wood presented (one of them instead sinks), and to have serious doubts about the behavior of aluminum, nylon and rubber.

**Phase 2 - Exploration (or experimentation phase)**

We ask students to perform an experiment and to verify if their previous hypotheses were correct or not. The most simple experiment, of course, is to experiment the buoyancy of the sample-weights in water. Students realize that they have made numerous errors of interpretation, and we note that they are often astonished by this fact. Many of them repeat the experiment several times, and check the sample to detect something strange in it. They appear very curious after this demonstration, and their interest to understand where their interpretation failed encourages them to continue the investigation. Often, in fact, the common sense and the inability to identify the roles of the various intervening factors induce a spontaneous model which fails in the interpretation of what is observed.

**Phase 3 –Explanation (explication of the individual observation)**

The purpose of this phase is to introduce and highlight, through correct scientific terms, the involved parameters and physical quantities, so that the student may be able to distinguish between those which are influential on the evolution of the event and those which are not, thus stimulating autonomous investigation of the studied context and leading him to explain the results of his investigation.

In our path, students approach this phase with the desire and curiosity to understand their previous mistakes and, in our opinion, they deal this problems with a renewed interest; in the course of our experiences we have in fact seen, at this stage, an increase of interventions, questions, suggestions by pupils, compared to the previous steps. This is especially important as it is here that are introduced to new concepts (new in particular for children of primary and early secondary school), as the concept of force, also visualized through a vector representation, and the concept of balance of forces, displayed through a real play of "tug of war": this ludic experiment with the rope is important not only to attract the attention of students, but also to visualize and consolidate the concepts just exposed.

Moreover, we designed the steps of the path in order to propose simple experiences (as the different behaviour of the samples-weights inside and out of the water) in form of trick-experiments, playing with the concept of "force of gravity that acts on all bodies" and "push of Archimedes that acts on all bodies immersed in water", and with their role and efficacy inside or outside water. Here, the ability of the tutor is important: posing the right questions at the right time during a simple experiment like this, it is possible to lead most children into error about the behaviour of some sample (example in Figure 1); the reaction, in front of the evidence that contrasts with their expectations, triggers a process of reworking of the error in the light of what was experienced, and produces the actual understanding of the concept of "balance of forces". Later, if finding themselves in similar situations during the course of the laboratory, those mistakes do no more occur!

During this phase we introduce, also, the concepts of mass, weight and volume, stressing the difference between mass and weight, and calling the attention to the role that the volume has in determining the behavior of objects immersed in water (so, not only their weight is important!).
Figure 1. Even a simple experience of buoyancy can be presented to students in form of trick experiment: many students are in difficult in putting together what they just heard from teacher/expert voice (i.e. that the push of Archimedes acts on all the bodies immersed in water) with what they see during the experiment. In fact, the polyethylene-sample, in the empty jug, falls due to gravity (Fig.1.a), while in the jug full of water initially it sinks, but quickly moves upward, showing with evidence the presence of an upward force (Fig.1.b). On the contrary, nylon or aluminum go deep also in a full jug (Fig.1.c), and for many of the students this is unequivocally a demonstration of the absence of the push of Archimedes! Thanks to the experiments they will do after this (i.e. , during phase 4), they will be able to understand their initial error, and to interpret the phenomena in terms of balance of forces (Fig.1.d).

Phase 4 – Elaboration (or critical review)
This phase, based, as the previous, on the methodology "hands - on, mind - on" , consists of a second series of experiments aimed to disprove perceptions or erroneous interpretations, to break prejudices and to validate positive conjectures.
Here children are invited to validate concepts encountered during previous phases through quantitative experience, as the double-weight experiment with hydrostatic balance, using sample-weights of different material and equal volume, and also with samples of the same material but different volume. Taking into account that it is not only the weight of an object to be relevant for understanding its buoyancy, but also the volume has an important role, the didactic path leads, in a logic way, to the definition of a new quantity (specific weight), necessary to understand the behaviour of bodies in water. The concept it is not given a priori, but emerges as a result of the experimental path and, once acquired, enable students to understand many natural phenomena often erroneously explained by common sense (see the next phase for details). The next step is to speak about buoyancy in liquids, not only in water. Some trick-experiments help in this task, through the use of common liquids (oil, glycerin, alcohols etc.) with different specific weight. (Fig. 2)

Phase 5- Evaluation (or Formal organization of thought/ transformation of knowledge in competence)
At this time a real problem is submitted to the kids, in the form of an investigative question. In order to solve the problem they have to put in place all the acquired knowledge, consistently correlated. Students are asked to explain, in the light of what they saw and learned in the previous phase, some natural phenomena: from floating pumice stones and stratification of liquids with different density to the aerostatic balloons.
The correct acquisition of concepts introduced during previous phases is absolutely necessary and preliminary to this part of the laboratory, as the concept of density (or specific weight) is crucial in these cases in which weight and volume of the fluids we compare are not defined (Fig 2). And again: for the third state of the matter, can we apply the same rules? Can we still speak of "buoyancy" for gas in liquids, or gas inside other gases? These are the questions that students are asked to answer, using concepts and terminology acquired in the previous phase.
This is perhaps the most surprising and amusing part of the path, particularly reach in experiments that often appear as small "magic tricks" or "sleight of hand" to the eyes of the students. It is an important phase for them: they realize to be able to give a logical explanation to phenomena not previously understood or incorrectly explained, or to experiments that initially seem magic tricks but that, when analyzed, are instead easily understood.

The laboratory ends by posing two open questions at students: the first is: "what determines the density (or the "specific weight") of an object? Some of the last trick-experiments concern stratification of liquids with different temperature and salinity, and also the different behavior (and specific weight) of materials in their different states (example. ice, liquid water or vapor) (Fig 2). We let the students give us an explanation of that and arrive to the correct conclusion: it depends not only on the constituting material, but also on its chemical structure and its temperature. The second question is: “can we change the density of a body (solid, liquid or gas)? Which could be the consequences? Showing examples taken from nature and human artifacts, in which these principles are exploited, and building small exhibits with cheap material, we shows that it is possible to answer to this question and moreover we suggest to the students an investigative method to read the scientific principles hidden in natural phenomena that appear incomprehensible.

The concept of density deals, in fact, with many of the apparently mysterious phenomena we see every day: how do fishes and submarines move upward and downward inside water? How do balloons and hot-air-balloons float in the air? The children learn that they are able to coordinate their knowledge and insights to address and solve problems, not necessarily related to schoolwork but also questions and issues resulting from their personal curiosity (Guile and Griffiths 2001). And, we believe, this is a very appropriate definition of "skills acquisition".

Moreover, according with the non-formal learning environment in which we operate, we decided to propose, to students, particular evaluation methods, like the setup of theatrical representations; here students propose the path of the laboratory to the general public, emphasizing the more entertaining and funny aspect of the experiments. For the children it was a special time of consolidation of the acquired concepts, since the presentation to the public had to be made by themselves. The experiment has involved one class of secondary school in Parma (Emilia Romagna) and two classes of primary school in Sarzana-La Spezia (Liguria) in 2012, and we think it can be a validation instrument of undoubted value for education and training, perhaps not always easy to use.

4. Discussion
Basing on the analysis of what is reported in students workbooks, on questions and discussions that inevitably follows the trick experiments performed (sometime we have registered the student conversations), on teacher reports and especially on the experience of the set up of theatrical representations (during the "evaluation phase"), we were able to elaborate some preliminary considerations about our didactic approach.

Figure 2. Some of the experiments, looking like “magic tricks”, introduce the behavior of liquid mixtures with different densities, gases inside liquids and gases inside other gases.
As regard to methodology and teaching strategy that we applied, two important results emerge:

- Stimulus based on surprise, wonder and bewilderment is a powerful activator of interest and inevitably leads to the will to overcome the (eventual) initial error of interpretation of a phenomenon: the misconception have to be removed in order to understand where is the trick. This step is a fundamental cornerstone in the cognitive process and ends with the understanding of the phenomenon.
- The former achievement is essential for correct acquisition and consolidation of knowledge, and for this reason it is important to project didactic paths that allow students to reach independently (i.e. without a superimposition of the teacher) the understanding of the concepts and strengthen self-esteem.

"People can be convinced more easily by reasons that they discovered by themselves than by those arising from the mind of others. "Blaise Pascal"

In fact, the observation of the phenomena always induces interpretation of them, even when the individual is not aware of it. This interpretation is affected by complex factors of personal experience, sometimes incorrect, that have proved to be very difficult to remove if they are not put in crisis due to conflict situations: only in this case, in fact, the student experiences the need to overcome them, with the result to change his/her mental attitude. Moreover, for students it is important the “social dimension” of the spontaneous interpretative hypothesis, and the comparison between their ideas and those of their fellows, in a sort of peer discussion that should lead to the construction of shared logical models. This fundamental phase leads to understand the difference between “to state” and “to argue” and, in our experience, generates the mental attitude of acceptance of an idea, not through its imposition, but through motivated criticism.

This phase is also crucial in the structuring of a learning model, because it persuades the kids to understand that a mistake is not a definitive failure, as it may induce useful discussion for the construction of a proper knowledge, highlighting the epistemological obstacles or misconceptions that come from their own personal experience. The mistake is then considered under a different light: as one of the steps of the cognitive process [Tagliagambe 2011]. For this reason it is important to enhance and to address this method, without transgressing it through the imposition of predefined concepts. Such approach has been proved to be effective especially for the implementation of the labs for primary school children, where the discussion of the phenomena and the verification on the field of different interpretative models are very important. This has proved to be of particular interest to us, as we had the opportunity to test the students understanding level on these concepts, without the contamination of a superimposed scholastic knowledge, due to the fact that they are not inserted in scholastic programs for this age range. In particular, it appears that some fundamental concepts, concerning the argument that we have treated, have been badly acquired or misinterpreted - following an erroneous common sense - by most students. Especially:

A- The concepts of "light" and "heavy" often may be misinterpreted. They should be gradually replaced, in the children vocabulary, with those of "less dense" and "more dense" respectively.

B- The buoyancy of a solid body inside water is often put in relationship only with its weight or with the material that is made of, without considering other factors, like its volume or shape.

C- Among all fluids, water is assumed to be the only one to be considered for the evaluation and comparison of the solid bodies density.

D- The behaviour of liquids inside other liquids is considered a totally different phenomenon respect to the behaviour of solid bodies inside liquids, therefore in the former case the principles and concepts applicable to the latter case are not recognized as valid.

E- Even after understanding the Archimedes principle and therefore the buoyancy of bodies in terms of balance of forces, this concept is rarely considered to be valid in situations different from those with which children are familiar (solid and liquid): the physical medium "gas" is not perceived as a possible replacement of a "liquid."
5. Conclusions and future improvements

The described laboratory, thought to be carried out during educational or popular-science events, have been proposed, since 2009, in different contexts, (not just non-formal but also informal, as Festival della Scienza di Genova 2009, Parmascienza 2010, ParmascienzaLab 2012, Museoland-Spezia 2011, Festa della Marineria 2013-La Spezia), in order to build up the best strategies “for activating experiences to understand phenomena in playful contexts” (Michelini 2006). In these contexts the laboratory has been much appreciated from the students, as well as from the involved teachers/operators (private communication, and report of ParmascienzaLab results, in Bianucci et al. 2013).

During the many of the laboratory we realized the validity of the learning strategies adopted, especially the set up of trick-experiments, that intrigue and attract students, help to overcome the errors arising from erroneous common-sense explanations and, through this process, lead to the consolidation of the learned concept. Moreover, we have been able to detect the most common mistakes due to common sense misinterpretation (reported in the “discussion” paragraph), so to identify which are the more sensible parts to deal with for an effective introduction of the concepts of buoyancy and specific weight.

We think that this approach, experimented in non-formal and informal environment, could be valid also in a formal-learning environment, as scholastic path, and it could be useful to introduce and consolidate concepts of physics, often not included in the school programs of students of that age (primary schools), or otherwise treated only marginally, but (in our opinion) very important in order to understand many of the natural phenomena that are experienced in everyday life.

However, to use our laboratory path in a formal-learning environment, it should be essential to have an appropriately designed validation protocol, which could consent to check whether the use of such a laboratory actually afford an understanding of the concepts better than that afforded by traditional methods (lectures or even use of educational standard workshops). Unfortunately, at the moment we have not elaborated a similar instrument. It is our intention to do that, basing the elaboration of such tool also on the results of our experience.

For example, our experience has led us to confirm that the children of primary school age don’t want to passively accept what they are told, but they ask for a demonstration of what is asserted by the teacher. In contrast, secondary school students (11-14 years), despite having a greater acquaintance with complex scientific concepts, show lower interest in the experimental activity and greater tendency to assume concept passively, often avoiding the discussion and comparison. A recent research on science perception performed by the Working Group for Science and Education of La Spezia - established by the 5 Research Centres and the technological public/private cluster settled in the city of La Spezia - confirm this trend [Locritani et al. 2015].

Moreover, this kind of approach can be useful to stimulate interest in those children/young people who generally demonstrate, in class, poor motivation or will to learn. According to private conversations with many of the involved teachers, we found that this type of educational approach awakens interest in those children who work with great difficulty during classroom lessons. In this regard, our laboratory has been included, for scholastic year 2014/2015, in the project “Crescere in armonia/Grow with armony”, funded by MIUR (Ministry of Public Education) and devoted to combat early school leaving, which was recognized by the EXPO 2015 [Crescere in armonia 2015].

These considerations led us to interact with Working Group for Science and Education of La Spezia, in order to evaluate, with their methodology [a recent inquiring protocol, based on specific questionnaires and statistical validation methodologies, in Locritani et al. 2015], the validity of our non-formal teaching strategies, especially for stimulating a change, in a positive sense, of science perception in secondary school students; the first results will be available, to be processed and analysed, at the end of scholastic year 2014/2015.

Moreover, with the aim of investigating also the effective validity of this approach to favour the skill acquisition by students, we are elaborating quantitative methods aiming to compare our strategy with the standard teaching methodology (lectures), through special questionnaires to be used during the next scholastic year (2015/2016) in primary and secondary school of La Spezia province and Parma province.

The hope is to quantify, by means of well-defined indicators, the impact that these didactic methods have in different educational settings, in line with what has already been carried on for other disciplines (Stroobant et al. 2014, Merlino et al. 2014).

All the images of this paper have been printed with the approval of the student parents, through a special consent form signed by them.
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The Persistence of the Alternative Conceptions: the Case of the Unipolar Model

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Abstract
This article identifies the alternative conceptions of 88 students in teacher training for primary school with regard to the notions of open and closed circuits. For this purpose, we constructed a questionnaire with two choices (true or false). In order to identify their conceptions, we asked them to justify their choice of answers. The analysis of the data demonstrates that for most of them, the electric current can circulate in an open circuit. This conception belongs to the unipolar model and according to several researches, the pupils abandon this conception in the case of a simple circuit composed of a bulb, a battery and electric wires for operative reasons. Thus, we observed the persistence of this model when one questions students on the working of more complex circuits.

Keywords
Primary, student teachers, alternative conceptions, persistence, unipolar model

1. Introduction
Several studies achieved among others in France, in England, in Italy, in Finland, in Australia, in Canada and in the United States demonstrate that the conceptions of the teachers of the primary schools, as well as their pupils, on the basic notions in fields of physics, chemistry and biology are erroneous, compared to those commonly accepted by the scientists (Métioui and Baulu Mac Willie, 2014; Métioui and Baulu MacWillie, 2013; Métioui and Trudel, 2012; Pilatou and Stavridou, 2004; Furió, Guisasola and Almudi, 2004; Henriques, 2002; Valanides, 2000; Canãl, 1999; Sharp, 1996; Webb, 1992) For example, in the case of the working of an electric circuit constituted of a battery, a bulb and two electric wires, several of these works demonstrate that majority of pupils explains its working while referring to the following models: (3) the unipolar model (the current leaves from the battery (either positive or negative) and arrive to the bulb; thus, the wire back toward the battery is considered as superfluous or passive), (2) the attenuating (or dissipative) model (in which the currents leaves one terminal of the battery and is partially consumed in the bulb, so that a lesser current returns to the battery), (3) the model of clashing currents (both a positive as well as a negative current meet at the bulb and “clash” causing the bulb to light, and (4) the sharing model (each of several components receives its share of the current; identical components receive and consume identical currents. These spontaneous models are relatively erroneous to the scientific model postulated that every portion of a closed circuit is crossed by the same current. Other works led this time on high school students having followed scientific teaching with regard to the working of electric circuits demonstrated that the unipolar model continues to nourish the speech of these students (Closset, 1983, Shipstone, 1988; Jabot and Henry, 2007; Stanton, 1990). It seems that this model lasts among some students frequenting the first academic year (Fredette and Lochhead, 1980; Arons, 1982) and secondary school (Mackay and Hobden, 2012).

About the persistence of this model, Tiberghien (1983), Tasker and Osborne (1985) and McDermott and Shaffer, (1992) underlined that the majority of the pupils abandons this erroneous model during the training of the electric circuits and that the one that persists the more to the teaching is the model of the current that is attenuated. Let's note to this topic that very few research have been done in order to insure that in fact, the pupils abandon this model more easily. The present research, of qualitative type, appears in this view and serves to identify the alternative conceptions of Quebec (in Canada) future teachers on this unipolar representation. Besides, the survey of electric circuits been part of the curriculum in the primary school of Quebec, as in several countries.
2. Sample, context
Research has been achieved in the setting of a formation carrying on the didactics of the sciences. The sample was constituted of 88 students; their majority are female and registered in second year of the program in elementary education. The middle age was of 22 years and the majority followed a course on the electric circuits during their secondary studies. They are all possessors of a diploma of collegiate studies in liberal arts.

3. Methodology
To identify the conceptions of the students with regard to the unipolar model, we distributed them a questionnaire of a length of 60 minutes including five questions. For each, they had to answer by true or false, while justifying their choice of answer, what was indispensable to identify their conception. Thus, in a first time, we compiled the answers, a question at a time, each taken separately. Then, we conducted their regrouping in distinct categories, the number of which being variable from one question to the other, according to the different advanced answers. Let's note that the answers found to reoccur have been grouped into the same category, following Gilbert ans Watts (1983):

“To generalize beyond the individual is to construct groupings of responses that are construed as having similar intended meanings. This is to construct a category of responses commonly in the context of single, or specific, sets of questions.” (p. 69).

So, the analysis of the answers started by the distinction between those that are correct, partially correct or incorrect and those that are indecipherable. To qualify the answers of correct, partially correct or incorrect, we compared them to those presented to the section bellow.

4. Construction of the questionnaire
The questionnaire included five questions (see annex 1) carrying on the notions of open circuit and closed circuit. Several of these questions have been presented in other research and we rephrased them slightly. The first served to know if there is an electric current that circulates in the electric wires leading to a lamp, knowing that its filament is broken and that the switch is in position "on". In these conditions, no current circulates in the filament since the circuit is open. The second was about a circuit composed in series of two bulbs in series of which a bulb that normally illuminates and another one that doesn't illuminate. One wanted to know if, the bulb that doesn't illuminate is burnt. This situation concerns two bulbs that don't have the same characteristics, what explains that one functions and the other no. This last "cannot be burnt" since the circuit is closed. The third question was about a circuit composed of two branching of which one is closed and contains a bulb and the other is open and contains two bulbs. The question was to know if the three bulbs could shine with the same intensity if they were identical. Evidently, it is not possible since in the open branch, the bulbs will be extinguished. In the circuit of the fourth question, the bulb is connected to the positive pole of a battery and to the negative pole of another and so, the circuit is not closed. Therefore, it won't work.
Finally, with regard to question 5, the B bulb of the circuit 2 won't work, as in the case of the fourth question, because the circuit is not closed. However, with this question we wanted to know, for the students for whom a bulb will light if it is plugged between the positive terminal and the negative terminal of two batteries that are not joined together, if the electric potential difference of every battery will influence the lighting of the bulb and if yes, how.

5. Analysis of the questionnaire
The analysis of the results allowed us to demonstrate the persistence of the unipolar model of the majority of the participants. Bellow, we present the analysis of each question.

Analysis of question #1
In the case of this question, 18% (16/88) of the students advanced a correct answer: no current flows in the wires, because the circuit is open since the filament of the lamp is burned. Bellow, some students' justifications:

“The current won't flow, because the circuit is open.” (e40)

“The current must leave from one point and come back to the same point. In this case, the current cannot complete the circuit because the filament of the lamp is burned.” (e49)
“In order to say that there is a current flowing in a circuit, the current should flow throughout the circuit from one point and come back to it. However, since the circuit is open there is no flow of current.” (e69)

For the majority (82%), there is a current in the wire leading to the bulb, even though its filament is grilled. For several, the current is present in the wires since the switch is open. Thus, the analysis of data has permitted us to identify 2 erroneous conceptions. Bellow, percentages of each conception, as well as some justifications:

Conception 1 (52/88 - 59%): The switch is "on", therefore the current flows in the wires leading to the lamp (unipolar model)

“If the switch is "on", it means that there is flow of current in the electric wires, even though the bulb is burned.” (e3)

“The current is always there as far as the switch is "on". The lamp is just a breakage. So, if you touch the connecting wires, you will feel the electricity.” (e10)

“The connecting wires carry current up to the bulb. If there is over flow of current, the filament of the bulb will burn.” (e20)

“I believe that the electric current flows in the wires but can’t flow through the bulb, because it stops right before it.” (e21)

“Of course, this is why you should turn off the switch before changing the bulb.” (e36)

“If you replace the bulb with a new one, the new bulb will light without changing the position of the switch.” (e79)

“The filament is burned, but the current continues to flow when the switch is "On". (e87)

For these students, the current flows through the cables and stops at the beginning of the bulb because the filament is burned. Thus, the current moves from the current outlet to a point of the circuit. It is the unipolar model.

To justify the presence of this current, it is sufficient to remove the bulb, to put our fingers there and one will feel its effect. For other students if the lamp is replaced by another one without touching the switch, the new lamp would light automatically. These students don't know that one connecting a new bulb, it illuminates because one has just closed the circuit and no because the current was in the wire since the switch is in position "On".

Conception 2 (20/88 - 23%): The lamp does not light because its filament is burned. Despite this fact, the current continues flowing through the lamp.

“The current flows because the switch is "On". The current passes through the bulb, but the lamp doesn't light because the filament is burned.” (e13)

“Although the filament of the lamp is burned, the current still flows through the lamp.” (e18)

“Since the filament is burned, the bulb wont light but the current will still pass through.” (e50)

“Yes, the current flows in the wires but the bulb cannot light because the filament is burned. This doesn't change the fact that the current flows in the wires.” (e52)

“The fact that the bulb doesn't work is referred solely to the burned filament. The switch is "On", and the current continues to flow.” (e54)

“Even though the lamp is burned, the electric current flows in the wires, it is just that the bulb doesn't have to light.” (e65)

“When the filament is burned, the current will flow in the shell casing the bulb.” (e74)

These students, don't seem to make the difference between a conductor and an insulator since, according to them, the current continues to move through the bulb. On the other hand, they didn't refer to the unipolar model since, according to their reasoning, the current continues to circulate, even though the filament is burnt. Their confusion is probably related to the fact that they don't know the principle of the mode of the construction of the bulb (e74).
Analysis of question #2

As for the second question, 23% refer implicitly or explicitly to the bipolar model to justify their answers. For 17%, their answer is correct (the bulb cannot be burnt otherwise the circuit would be open):

“To claim that the circuit is functioning, electricity must flow throughout the circuit, therefore bulb B cannot be burned.” (e19)

“Perhaps the battery is down because it has used all of its energy to light bulb A. Therefore, the battery could not supply bulb B with enough energy. If bulb B is burned, the whole circuit would not work.” (e40)

Some students justified their answer while indicating that in the case of a parallel circuit, one could have a bulb which works and another burnt and no in the case of a circuit in series:

“In this case, if bulb B is burned, bulb A would not light. However, if the two bulbs are connected in parallel and bulb B is burned, bulb A would not be effected and remain light.” (e64)

The other students (6%) advanced erroneous justifications in referring to the model of the current that is attenuated. For them, the bulb B doesn't illuminated because the bulb A take a big part of current (attenuating model).

“Bulb A has consumed most of the total current, and therefore there is insufficient current to light bulb B.” (e5)

“It is just that the bulb A consumes the whole current coming from the battery and that there is not some unfortunately enough to light the B bulb.” (e18).

“Maybe the power of the battery doesn't match with that of bulb B. If bulb B is connected to a battery of low power, the bulb will not light.” (e15)

“Not necessarily, it is possible that the value of the electric current is not enough to lighten bulb B.” (e88)

For the majority (77%), the B bulb doesn't light because (1) it is burnt, (2) it is connected improperly, (3) the connecting wire that joins bulb A and bulb B is disconnected or (4) the current is not enough to flow in the whole circuit:

“The current should flow, therefore if it doesn't illuminate that is that it is burnt.” (e1)

“Maybe bulb B is burned, and maybe that it is the reason for the deficient thread.” (e2)

“Bulb B is going to receive less current than bulb A. This current will allow bulb B to light, but with less brightness. If bulb B doesn't light, it should be burned or the current is not strong enough.” (e24)

“Either bulb B is burned, or bulb A has used the whole current to remain light.” (e35)

“It is uncertain whether bulb A demands all energy from the battery to light.” (e52)

“Perhaps bulb A used up the total current, and there is no current left to light bulb B.” (e62)

“Maybe bulb B is burned, or the wire between the two bulbs does not allow flow of current.” (e65)

“Because the negative side of the battery has as much current as the positive side.” (e68)

“Bulb B is not necessarily burned. It might have a poor connection.” (e86)

These justifications demonstrate the persistence of the unipolar model that stipulates that a current circulates from the positive terminal of the battery to the bulb and stops there. As for the B bulb, it doesn't function: because either it is burnt, badly connected or that the whole current has been used (consumed) by the bulb (attenuating model).

Analysis of question #3

Only 20% advanced a correct answer. The bulbs B and C won't work, because it is an open circuit.

“Only bulb A will shine, because the short circuit makes no current reaches bulb B or bulb C.” (e40)

“Only bulb A will shine because it is the only that makes closed circuit.” (e48)

“Only A will shine because it is the only one that is part of a complete electric circuit.” (e63)

“Bulbs B and C won't light because they are not in a closed circuit.” (e69)
For 80% of the students, the current produced by the battery will cross the bulbs A, B and C and so they will illuminate. On the other hand, with regard to the intensity of their brightness, we identified four categories of answers:

1. A illuminates more than B and C,
2. A illuminates less than B and C,
3. C illuminates less than A and B,
4. A, B and C will have the same lighting.

The conceptions that underlie each category as well as their percentages and some examples of students’ answers are presented below:

Conception 1 (13/88 - 15%): Bulb A will shine with more brightness compared to bulbs B and C because it is joined to two places of the battery.

“Bulb A will light brighter because bulbs B and C don't have a connecting wire on one end.” (e67)

Conception 2 (6/88 - 7%): Bulb A will shine less than bulbs B and C because it is far away from the battery.

“Bulbs B and C are going to light brighter because they are closer to the battery. Therefore, bulb A will receive less power.” (e11)

Conception 3 (15/88 - 17%): Bulb C will light less than bulbs A and B because the current leaving the battery is divided between bulbs A and B, and then the current passes through bulb A will cross bulb C (unipolar model).

“If you imagine the positive pole of the battery to the left. The current will split equally at a junction between bulbs A and B. However, bulb C that is far away from the positive pole will be dimmer.” (e21)

Conception 4 (e82).
“Bulb C will shine probably stronger than the other two because the current will first pass through bulbs A and B. On the other hand, I believe that bulbs A and B will shine similarly because they share identical currents.” (e30)

Conception 4 (25/88 - 28%): Bulbs A, B and C will shine with the same brightness because the current will be equally distributed between them.

“They receive the same current. They are plugged to the same battery and they are identical bulbs.” (e3)

“As they all are connected to the same circuit, they will have the same brightness. If wires B and C were very long, bulb A would have shined more strongly.” (e50)

“Even though the two wires of bulbs B and C aren’t in contact, the currents + and - of the battery flow to the bulbs. Then the bulbs will shine with similar brightness.” (e79)

For 7%, the brightness of the bulbs depends on (1) the charges of the battery, (2) the length of the connecting wires, or (3) how far the bulbs are from the battery:

“All depends on the electric charges received and the length of the trajectory.” (e31)

“It goes depends on the strength of the electric current that passes in every bulb.” (e33)

“It depends on the current and the distance between the battery and every bulb.” (e35)

Finally, 6% of the students advanced incomplete or indecipherable justifications while affirming that the B and C bulbs lights up.

“There will be a power loss due to the path of electricity. The 3 bulbs won't shine with the same intensity.” (e25)

“According to me, the site of light on the electric circuit plays a role. The current may not be the same everywhere.” (e51)

“Bulb A will receive less current because the current returns from bulbs B and C intersection will divide in to two.” (e59)

Closset (1983) asked the same question to students in a group (16-19 years old) and noted that for 18% among them, the three bulbs are equally lit, because electrical current flows through every wire. These students, refers simultaneously to the unipolar and sharing model in the circuit.

Analysis of question #4

Only 33% of the students affirm correctly that it is about an open circuit and that it would be necessary to join the two other poles of the two batteries by a wire so that the current circulates:

“There is a gap between the two batteries. If the wires would have been in the (-) pole of the battery, the circuit would work.” (e19)

“It is necessary to connect the 2 batteries with a wire to form a complete circuit.” (e7)

“The electric current flows from (+) to (-) when it reaches only one battery.” (e10)

Thus, according to 67% of the students, the bulb will light since it is joined to the positive pole of a battery and the negative pole of another, no matter if the two batteries are not joined together. This false conception probably ensues from their experience when they place a battery after another in a pocket-size lamp, for example. These students know the relative convention with respect to the circulation of the simple electric current in a circuit, namely that the current moves from the positive boundary-mark to the negative boundary-mark. Since the bulb is joined to a positive boundary-mark and to the other negative, therefore the current circulates. It is about the unipolar model that ensues implicitly from the teaching, contrary to the unipolar model that ensues from first intuition, according to which the current circulates from the battery toward the bulb, as underlined in the introduction. As an illustration, the justifications advanced by the students are:

“It will normally shine because it is plugged in to the positive and negative terminals.” (e47)

“Indeed, I believe that a lamp can be plugged in to 2 batteries as far as the current flows from (+) of one battery towards the (-) of the other.” (e21)
“The electric current should flow between the positive and the negative.” (e65)

“If the wire is in contact with the two positive boundary marks, it would have flown in the circuit.” (e66)

This question has been asked to students of the secondary school in the setting of a research carrying on the transition between electrocinetics and electrostatics of which several, to justify the lighting of the bulb, referred to the law of attraction between the electric charges of opposite signs (Bensghir and Closset, 1996).

**Analysis of question #5**

One observes a weak reduction of students having advanced a correct answer, namely that the circuit 2 is open compared to the circuit of the question 4 (31%) that is similar, but where one had modified the formulation of the question. Thus, for this question, 31% refer to the bipolar model to justify their answer:

“Bulb A will light, whereas bulb B will be extinguished because the current does not flow beyond the positive terminal of the second battery.” (e1)

“So that the bulb lights, the energy must come out of (+) and (–) terminals of the same battery, otherwise the bulb won't light because there will no energy dissipation.” (e8)

“Only bulb A will light because the circuit is closed. While there is no current in the other circuit because it is open circuit.” (e48)

“In circuit 2, bulb B won't shine. Because both batteries should be connected.” (e52)

For the students according to whom the B bulb will work (69%), the justifications given allowed us to identify two erroneous conceptions presented below with the percentages of each, followed by the presentation of some answers as an illustration:

**Conception 1 (40/88 - 45%):** Bulbs A and B will light similar because (1) identical currents will pass through the bulbs, (2) the batteries have equal voltage (1.5 v), (3) the currents pass through the (+) and the (–) terminals of two identical batteries (each of 1.5 V), (4) the places where start the currents (the pole +) belong to identical batteries (1, 5 V), etc. (Unipolar model).

“The B bulb shines as the bulb A, because it leaves nevertheless of the positive in 1.5 V and it arrives to the negative in 1,5 V.” (e9)

“Considering that the two batteries are identical, I think bulbs A and B will shine similar.” (e11)

“Bulbs A and B should shine the same way since they each one has a positive and negative terminals.” (e12)

“I don't believe that it has a tie. The important it is that the 2 leave from the (+) to the (–). They will shine with the same intensity.” (e21)

“The current that flows from the battery to the bulb is the same (1,5 V) the bulbs will shine with the same intensity. The two batteries of circuit 2 don't combine themselves.” (e24)

“I think they receive the same amount of voltage. I don't think if they are connected in this way, the voltage will multiply.” (e47)

**Conception 2 (21/88 - 24%):** Bulb B will light more than bulb A because it (1) receives more current (two batteries), (2) more voltage (3 V) therefore more of current, (3) more energy or (4) the wires shorter.

“It is true, because bulb B will receive more energy than bulb A. Bulb B has two batteries while bulb A has only one.” (e3)

“Bulb B will shine more strongly, since it is connected to 3 V rather than 1,5 V.” (e26)

“Bulb B will light more, because the connecting wire between the 2 batteries is shorter than the first circuit.” (e65)

“In circuit 1, there is only a + to provide the current. In the circuit 2, there are 2 + to provide the current, therefore this circuit offers more electric current.” (e70)

“The current is the same, but the charges stored are different. B won't shine more than A; it will shine longer.” (e74)

“If the two bulbs are identical, lit once, they will remain identical. Only the bulb B will light more.” (e81)
“The source of the batteries is the same, which is 1.5 V. Circuit 2 will take more time to release the charges. This is the only difference.” (e86)

6. Summary of the results
A very small percentage of students answered correctly, based on coherent reasoning. Others have provided incorrect answers. A comparison between the conceptions identified and those developed in the context of circuit theory is presented in Table 1.

Table 1. Summary of students’ conceptions and of their corresponding scientifically accepted counterpart.

<table>
<thead>
<tr>
<th>Students’ conception</th>
<th>Scientific conception</th>
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<tbody>
<tr>
<td>When one makes a switch on position “On” to light a bulb whose filament is broken, the electric current passes until the bulb.</td>
<td>No current circulates in a branch containing a bulb whose filament is broken, because this last opens the branch.</td>
</tr>
<tr>
<td>A break anywhere in the path don’t mean that the electric current stops passing. For example, if the filament of the lamp break, the current pass through the lamp even though it won’t light.</td>
<td>A break anywhere in the path results in an open circuit, and the flow of electrons ceases.</td>
</tr>
<tr>
<td>A bulb connected between the positive terminal of a battery (1.5-V) and the negative terminal of another battery (1.5-V) has the same light intensity that if it was plugged between the two poles of a battery (1.5-V) since, in the two cases, we have a current that circulate from the positive terminal toward the negative terminal.</td>
<td>A bulb connected between the positive terminal of a battery (1.5-V) and the negative terminal of another battery (1.5-V) is not moved by any flow of electrons since the circuit is open.</td>
</tr>
<tr>
<td>A bulb connected between the positive terminal of a battery (1.5-V) and the negative terminal of another battery (1.5-V) receives two times more current than if it was connected to the positive terminal and negative terminal of a battery 1.5-V.</td>
<td></td>
</tr>
<tr>
<td>If two bulbs are connected in series with a battery and that one of the two bulbs illuminate and the other no, then the one that doesn't illuminate is burnt.</td>
<td>The bulb that doesn't function cannot be burnt, otherwise the circuit would be open. If the two bulbs were plugged in parallel, it can happen that the one that doesn't function is burnt.</td>
</tr>
<tr>
<td>If two bulbs are connected in series with a battery and that one of the two bulbs illuminate and the other no, then the one that illuminate received the whole current of the battery and it didn't remain any anymore for the one that doesn't illuminate.</td>
<td>If two bulbs are connected in series with a battery, the current is the same through the bulbs in the circuit. If the two bulbs they don’t have the same brightness it means that the two bulbs don't have the same characteristics (are not identical).</td>
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7. Conclusion
The results of this research demonstrate the necessity to conceive non canonical situation-problems to identify the alternative conceptions of the students in order to verify if they indeed have understood the basic notions associated to the field of the electric circuits. To attain this objective, it would be necessary to interrogate them on several related situations, as presented in this research, in the case of the notions of open and closed circuits. The results of the researches achieved throughout the world prove the recourse to the unipolar model by children to interpret the working of a simple circuit composed of a battery, a bulb and two connecting wires is very early abandoned and they rather refer to other erroneous models more evolved (clashing currents, attenuating and sharing in a series circuit). However, while interrogating the students on the working of more complex circuits, we showed that they refer simultaneously to the unipolar model and non-unipolar model. This last result can be explained by the complex phenomenon of the juxtaposition in learner’s conceptual structure of several contradictory explanatory systems with respect to the same phenomenon, dependently of the context one gives to it (Mackay and Hobden, 2012; Métioui and Trudel, 2012):
“In the same way, the overlap between context and cognitive factors in conceptual situations such as the wiring of a dolls house is a fertile avenue for further research. Whether or not the transitional thinking found in developing wiring diagrams from circuit diagrams is evidence of the influence of context and the failure of students to transfer conceptual knowledge from one context to another or of the development of intermediate concepts within a conceptual development process needs further investigation, as does the high prevalence of unipolar thinking amongst students.” (Mackay and Hobden, 2012, page 142)

To help students to give up the unipolar model, a didactic intervention would be necessary, one that would be able to produce conceptual conflicts while putting them in situations in which this model will be proved to be inadequate (Vosniadou, Vamvakoussi and Skopeliti, 2008; Treagust, 2006; Posner, Strike, Hewson and Gertzog, 1982). The situations presented to the students should take into account their alternative conceptions, as identified in this research and others done in the same perspective.

References


ANNEX

Questionnaire on electrical circuit

Question 1:
In the circuit shown, the switch is “On”, but the filament of the lamp is burned. There is electric current flowing through the wires leading to the lamp.

True □ False □

Justify your choice:

Question 2:
In the circuit shown one observes that bulb A lights normally whereas bulb B doesn't. This tells that bulb B is burned.

True □ False □

Justify your choice:

Question 3:
In the circuit shown, if bulbs A, B and C are identical, they will shine with the same brightness.

True □ False □

Justify your choice:

Question 4:
In the circuit shown, the lamp will light normally since the electric current flows across its pole + and pole – terminals.

True □ False □

Justify your choice:

Question 5:
In circuits 1 and 2, if bulbs A and B are identical, bulb B must shine two times as much as bulb A because it is connected to the (+) and (-) terminals of the batteries, each of 1.5V.

True □ False □

Justify your choice:
The Role of Scientific Museums in Physics Education Courses for Pre-Service Primary School Teachers

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Abstract
Within the 2013-14 Physics Education Course for pre-service primary school teachers, we have developed an educational project involving the Museum of the History of Physics of Padua University and the Museum of Astronomy of Padua Astronomical Observatory. The main goals of the project were: (a) to stimulate in pre-service teachers a reflection on how scientific museums could be used for proposing effective and motivating scientific experiences within primary school curricula, (b) make them experience and recognize the advantages of an historical and narrative approach in the learning of a new subject. The presentations in the Museums focused on the relation between instruments and the evolution of scientific knowledge. Cosmological models from the ancient times up to eighteenth century were presented through instruments, paintings and significant narratives related to astronomers and physicists of the past. The effectiveness of the experience was evaluated through a written essay that students were asked to write at the end of both visits.

Keywords
Pre-service teacher education, astronomy education, museums.

1. Introduction and context of the project
In Padua, the physics education course for pre-service primary school teachers is organized so that most of the physics concepts are introduced through practical experiences. The course includes 60 hours of classroom lectures and 16 hours of laboratory activities. About 180 students attend the course every year and during the laboratory activities they are subdivided in groups of 30 people. The classroom lectures present and discuss basic physics concepts, together with an illustration of possible school activities that future teachers could organize at school to develop scientific knowledge and attitude in children, from kindergarten to the end of primary school.

Every year a particular topic is selected and several activities, including the laboratory on physics education, are dedicated to a deeper analysis of this special topic. The idea is to illustrate through a particular example how each topic needs to be explored at various levels along the whole school period. Particular emphasis is put on everyday experiences of the phenomena under study and on interdisciplinary connections, in order to help future school teachers to develop scientific educational projects meaningful for young students.

From 2014, the course was reorganised according to the National Indications of the reformed university curriculum for the graduation of primary school teachers. One of the main changes introduced by the new Indications was the requirement to include some basic astronomical topics in the physics education course.

For this reason, in the academic year 2013-14, the special topic of the course was “Astronomy”, which was explored through various activities in classroom and outdoors, in laboratory and at museums.

In the classroom, one of the activities was the construction of a quadrant with cardboard, string and a small weight; this activity was done in collaboration with the teacher of mathematics education. The quadrant is an instrument used to measure angles up to 90°: it can be used for measuring the position of sky objects, like stars, the Sun and the Moon, but it can also be used for measuring the height of buildings. It is worth mentioning that quadrants were widely used in Europe during the Renaissance and the sixteenth century in astronomy, time measuring and surveying. In figure 1, we see students outdoors learning how to use a quadrant for measuring the height of a building.
In the laboratory, students first explored the properties of light, in particular the characteristics of the shadow produced on a screen behind an object in relation with the position and extension of the light source. These experiences helped them to construct the straight-lines model of light, useful for interpreting astronomical observations, like day and night alternation. The straight-lines model was then used for interpreting reflection and refraction phenomena. The second part of the laboratory was dedicated to the analysis of astronomical phenomena, like the length of day and night at different latitudes, the characteristics of lunar phases in relation to the Earth, Moon and Sun’s relative positions. For these explorations students used light sources and spheres as physical models for representing the Earth and the Moon (see figure 2).

Finally, in tight connection with the activities just mentioned, a project was developed in order to plan and organize specific visits and activities at the Museum of the History of Physics of Padua University and at the Museum La Specola of Padua Astronomical Observatory. The project was the fruit of the collaboration of the three authors of the present paper, Ornella Pantano, who is in charge of the Physics Education course, Sofia Talas, the Curator of the Museum of History of Physics, and Valeria Zanini, the Curator of the Museum La Specola.

The advantages of a historical approach in the learning of a specific subject is well documented in the literature [see e.g., Monk & Osborne, 1997; Rudge & Howe, 2009], but the actual state of implementation of this approach in schools is still poor due to the difficulty of finding and adapting history-based teaching material and the lack of pedagogical content knowledge necessary for confident and effective teaching [Henke & Hôtecke, 2014]. We think that one of the ways to deal with these problems could consist in...
exposing future teachers to a personal experience of learning paths in historical scientific museums. Two of the authors have a wide experience in developing thematic paths in physics for secondary school students with laboratory activities and visits to the Museum of the History of Physics [Pantano & Talas, 2010]. This was the first experience with undergraduate students doing a primary school teacher degree.

After an outline of the two Museums involved in the project, the paper will describe the main goals of the project, its content and some final considerations on its outcomes.

2. The two Museums involved, a short presentation

Both the Museum of the History of Physics and La Specola keep important collections of physics and astronomical instruments, heritage of the fruitful scientific activity at Padua University throughout the centuries. Historical instruments, working places and paintings constitute windows to examine and understand the way cosmological models evolved throughout the centuries.

The Museum of the History of Physics houses the instruments that were invented, made or used at the University of Padua to carry out physics research and teaching [Talas, 2012; Talas, 2013]. A first nucleus of instruments was collected for the lecture courses on Experimental Philosphy – Experimental Physics in modern terms that were introduced at the University of Padua in 1738. Giovanni Poleni, who was assigned the new chair, gathered a first group of machines within a couple of years and he continued to enrich the collection until his death, in 1761. His successors went on acquiring new instruments both for teaching and research, including objects that already had an historical value. The Museum thus has some sixteenth- and seventeenth-century devices, but the main part of its collection is made of instruments of the eighteenth, nineteenth and twentieth century.

The other museum involved in the project was La Specola, which preserves the instruments and historical heritage of the Astronomical Observatory of Padua, one of the main structures of the National Institute of Astrophysics (INAF) [Pigatto, 2007]. The Astronomical Observatory of Padua was founded in 1761, within a complex program of reform that the University of Padua developed in order to instruct the students in the practice of experimentation. The high tower of the old city castle was chosen as the best place where to build the Observatory, which was made of two parts: a lower observatory, flanking the east wall of the tower at a height of 16 meters from the ground, and a higher one, at 35 meters, on the battlements. The lower observatory was later called the Meridian Room. Here, the local time at midday was measured along the meridian line carved in the floor, and stars were observed in their transit across the celestial meridian. The upper observatory was dedicated to observations with telescopes of various types, which could be pointed in different directions and also moved outside, on the terrace surrounding the tower. The museum collection includes telescopes, globes and quadrants of the eighteenth and nineteenth century. All the instruments are placed in the rooms where the astronomers used to work in the past.

3. The main goals of the Museums Educational Project

The project has been developed within a course in which prospective primary school teachers learn both some basic physics and astronomy topics and how to teach those subjects to young children. For this reason the goals of the project concerned both the discipline and its teaching.

From the point of view of the discipline, the aims of the project were to present to the students the principal steps in the evolution of cosmological models across centuries and, at the same time, outline some important features of scientific methodology. Cosmological models from the ancient times up to the eighteenth century were presented using instruments, paintings and narratives related to astronomers and physicists of the past. The important features of scientific methodology were discussed through the storytelling of some of the events that led to the development of new models and theories. The description of some historical instruments and the story of their role in scientific discoveries was very effective in showing the relationship between instruments and the evolution of scientific knowledge. This relation between the advance of technology and the growth of scientific knowledge is a theme very important also today.

From the point of view of physics and astronomy education, the main goals of the project were (a) to stimulate in pre-service teachers a reflection on how scientific museums could be used for scientific education in primary schools and (b) make future teachers experience and recognize the advantages of a historical and narrative approach in learning a new scientific subject. In order to attain those goals, we exposed pre-service teachers to the same kind of experience that they could propose in the future to their students.

4. The Museums Educational Project
The Museum Educational Project proposed to the students one visit of about 1.5 hour at each Museum. The students could participate on a voluntary basis but, as the Physics Education Course is attended by around 180 students and as there were many requests for participation, it was decided that groups of 30 students would be created. These groups were then divided in two sub-groups of 15 people, so to facilitate the interaction between the students and the Museums’ staff. The idea was to start from the objects and from the buildings, in order to extract from them information and details.

In tight connection with the topics treated at the Physics Education Course, the visit at the Museum of the History of Physics focused on two groups of instruments: a couple of astronomical Renaissance instruments – an astrolabe and an armillary sphere –, and the optical instruments of the Museum, with a particular focus on telescopes and microscopes.

We started from the observation of the astrolabe and the armillary sphere and, at first, we discussed the stories of the people around these objects. Who made them? Who used them, and so on? The astrolabe for instance, is signed “Renerus Arsenius Nepos Gemme Frisy Faciebat Louany 1566” and it is worth reminding that Arsenius worked in Louvain with Gemma Frisius, mathematician, cartographer and inventor of scientific instruments (figure 3).

![Figure 3. Astrolabe by Renerus Arsenius, Museum of the History of Physics, University of Padua](image)

We examined the way these instruments were used and, as for the astrolabe, this was made easier because the students had already made and used a quadrant during the Physics Education Course. But there is much more information lying within these objects. They tell about the theories and models of their time, in this case about the Ptolemaic-Aristotelian model of the universe, with the Earth unmoving and located at the center of the Universe. They also tell about the role of scientific instruments in the Renaissance. At that time, mathematics was applied not only to transform the art of painting through the introduction of perspective, but it was also applied to the needs of the other arts through the invention or the improvement of instruments. Gnomonic, astronomy, the art of topography, the art of navigation and the military art were thus transformed by the so-called “practical mathematics”. Several Renaissance engravings, showing the use of astrolabes and other instruments for surveying or even military uses, were presented to the students in this sense. However, it was also crucial to underline to the students that these instruments, used as models and/or for measurements and calculations, were not regarded at that time as possible conveyers of new knowledge about Nature. The latter was only the matter of philosophers and it was based on Ancient texts. Observations and measurements could not significantly change the accepted models of the World.

Renaissance instruments nevertheless started to be regarded as symbols of power, as they were crucial for navigation and surveying of the newly discovered countries. It is not by chance that Manoel I of Portugal included in his flag an armillary sphere at the end of the fifteenth century, and that armillary spheres became part of the Manueline architectural style. Instruments were also regarded as symbols of knowledge, and lots of them were included in paintings by Renaissance artists like Giorgione, Vittore Carpaccio, or Hans Holbein the Young. Scientific instruments became in those years symbols of social status as well, so that astrolabes, armillary spheres and quadrants were included as part of the Wunderkammer, the Renaissance noble collections. In this sense, instruments thus also tell us about the connections between science and the society of their time.

The second part of the visit to the Museum of the History of Physics then dealt with telescopes, microscopes and other optical instruments. Here again, details were given about the single instruments, their inventors, makers and users. However, as in the case of the astrolabe and armillary sphere, there is much more
information to be extracted from telescopes and microscopes. They are among the main instruments that marked the Scientific Revolution. Telescopes, in particular, were crucial to observe the sky and look for confirmations of the Copernican Model, the newly proposed model of the Universe, in which the Earth and other celestial bodies move around the Sun. Moreover, they marked the introduction of a totally new way of studying Nature. Galileo refused to base himself on the authority of the Ancient scholars and on what he called a “mondo di carta”. He wanted to read “the book of Nature” and used instruments to do so. Instruments thus became the essential media between Man and Nature: this was a totally new role for instruments, which became crucial for scientific research, thus marking the birth of the so-called Scientific Method. Moreover, a new link between Science and Technology was established, a link which is still one of the main features of Modern Science.

At the Museum La Specola the aim of the visit was not only to see the ancient instruments, but also to observe the whole building, which represents itself a scientific instrument.

The visit began with the video “Ancient Heavens”, which illustrated the special relationship that humanity always had with the sky. Since ancient times, in fact, an eternal and perfect order was felt in the great sky, conflicting with the transience of everyday life. A geocentric picture of the Cosmos consolidated in the Greek era and survived until the mid-sixteenth century, when the Polish astronomer Nicolaus Copernicus proposed his new model of the Universe. The video thus reminded the evolution of cosmological models, already discussed at the Museum of the History of Physics. It also emphasized the crucial role of the habit to observe the sky, which was typical of ancient men, an habit which is today very rare not only in students, but in teachers as well.

The visit continued in the Meridian Room and focused especially on the meridian line and the mural quadrant. The meridian line was carved in 1776 and, on this line, the true midday of Padua Observatory was measured by the Sun’s luminous image projected on the floor through the gnomonic hole placed in the south wall of the room. This was the first important device used by astronomers to measure the time and to set clocks; but we also showed to the students its usefulness today for understanding the movement of the Sun on the celestial sphere throughout the year. The students’ attention was then focused on the mural quadrant, made by the famous instrument-maker Jesse Ramsden and installed in the Meridian Room in 1779. The mural quadrant was used to measure the height of stars above the horizon at their transit at the celestial meridian. It was an extremely precise instrument for that epoch and students were explained that, in order to ensure the maximum exactness in hand-made graduations and avoid errors in divisions, mural quadrants were built very large: in this case the quadrant radius is 244 cm. Future teachers could thus appreciate the close link between scientific knowledge (mathematics and astronomy in particular) and the technical skills of manufacturers.

Reinforcing what had been shown at the Museum of the History of Physics, the Meridian Room provided the students with another practical example on how the Scientific Revolution implemented the new methodology of knowledge both through observation and experimentation, and through the central role of instruments.

Figure 4. The fresco in the Meridian Room showing the Solar system before 1781, Museum La Specola.

Highly instructive was also the large fresco painted on the east wall of the Meridian Room (figure 4). This fresco shows with considerable accuracy the geometrical configuration of the model of the solar system before 1781 and it was for students an efficient visual summary of the astronomical knowledge at the end of the XVIII century.
The visit ended in the Figures Room (figure 5), where eight life-size full-length portraits of famous personages in the field of astronomy are painted all around the walls. They are, in chronological order: Ptolemy, Nicolaus Copernicus, Tycho Brahe, Galileo Galilei, Johann Kepler, Isaac Newton, Geminiano Montanari and Giovanni Poleni. The students were told about the scientific activity of these personalities, whose contribution to the development of scientific knowledge and the evolution of cosmological models was fundamental.

Figure 5. Students looking at pictures and listening narratives related to important astronomers of the past in the Figures Room, Museum La Specola.

5. Assessment and conclusions
The impact and effectiveness of the experience have been evaluated through a questionnaire that students answered at the end of each visit. The questionnaire was built in order to analyse, first, which part of the learning situation surprised them and arose the greatest interest towards the discipline and the particular subjects treated in the visits. Second, the questions also aimed at stimulating a reflection on how they could use the same context for inspiring in young children an interest toward physics and astronomy. These questions indirectly gave us a hint of the activity that was more inspiring for the future teachers themselves. The principal questions proposed were:

- What attracted you most and what would you like to know more about?
- What surprised you?
- What theme would you choose to deepen with the children?

An analysis of the answers has shown that many aspects of the project stimulated students’ interest. They all were very impressed by the amount of information that a single instrument can infer and also by the beauty and perfection of ancient apparatus. In the following, we give some examples of particularly significant answers.

At the Museum of History of Physics:
What attracted you most and what would you like to know more about?

- “I found very interesting the part in which we have been explained about the scientific instruments used by the ancients (astrolabe). To see instruments is always very useful for understanding.”
- “There were many interesting objects, but the attention has been particularly attracted by the objects that we have reproduced during the lectures, as the octant which is similar to the instruments [quadrant] which we have constructed for measuring distances.”

What surprised you?

- “I was fascinated by the number of stories that a single instrument could evoke. Certainly children could absolutely be involved by the history of objects and the history of physics.”
What theme would you choose to deepen with the children?

- “I would choose optics [...]: I think that, with an appropriate presentation, it can be proposed at any age as it is amazing also for grown-up people.”

At the Museum of Astronomy:

What attracted you most and what would you like to know more about?

- “I was intrigued by the Meridian Room and I wonder with which instruments they built the line of meridian, how they decided where to put the hole in the wall in such a way that the sun could reflect [sic] exactly on that line.”

What surprised you?

- “I was very impressed by the fresco in Meridian Room, which represented the Universe known until about the 17th century. I was impressed by the precision with which it has been done.”

What theme would you choose to deepen with the children?

- “With children I would deepen the Figures Room, using the magnificent frescos to narrate the history of astronomy, as pictures are a very good tool to use for presenting a new subject.”

The analysis of the answers showed what were the aspects of the presentation which most impressed future teachers and we could see that both of the goals behind our project were reached. Students were impressed by the stories on the role of instruments and technology in the development of scientific knowledge and so, implicitly, they showed to appreciate the use of scientific museums and historical instruments for presenting scientific issues. In order to check the effective impact of this kind of experience, it would be worth planning an investigation to examine whether teachers who had experience of science museums in their education, more frequently include visits to scientific museums in their science teaching activities.

The students also recognized the advantages of an historical and narrative approach, as they outlined this aspect in most of the answers. Many of them also said they would choose this approach for their future teaching of astronomical issues. One could also plan an investigation on this point, to ascertain whether teachers who experienced an historical and narrative approach in their science education, would really use it in their science teaching.

References


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The Education of Pre-Service Primary School Teachers for Teaching Physics as Part of the Science Curriculum in Slovenia

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Abstract
The curriculum of primary education in Slovenia includes a substantial part of science topics, which are being taught already in the nursery school. Therefore, teaching science in primary schools is very important. The primary school teachers in Slovenia are required to finish a 5-year study programme at the Faculty of Education. In the course of study, they take some science classes (separate subjects: physics, chemistry and biology) intertwining with a didactics of science. The science subjects are considered difficult by the Slovenian pre-service primary teachers. The science curricula for pupils of age 6–10 in Slovenia prescribe that pupils should assimilate the following physics concepts: heat, temperature, density, viscosity, electricity, shadows, weather, movement of liquids, and several other concepts. It is evident that in order to teach the gifted knowledge-seeking pupils and weak pupils, a primary school teacher should obtain substantial knowledge in physics. The article focuses on the teaching module related to the concepts of heat and temperature for the pre-service primary teachers and its evaluation. The results of the pilot pre-post study without a control group performed in spring 2014 demonstrated the impact of the teaching module and confirmed the findings of several authors regarding the difficulties in understanding the content delivered in the module. The results also suggested guidelines for further research.

Keywords
Primary school teaching, heat and temperature, experiments, conceptual understanding

1. The education of Slovenian primary school teachers
A child is enrolled in a compulsory primary school at age of 6 in Slovenia. The compulsory primary school has 9 grades (Figure 1), which correspond to the primary level (grades 1–5) and lower secondary level (grades 6–9) in other countries. The Council of Experts for General Education in Slovenia approves the national curricula and determines the subjects and syllabuses. The teaching methods and textbooks are freely chosen by the teachers. After they finish primary school, the students enter vocational secondary schools, specialized technical schools or high schools. A high school in Slovenia is called gimnazija (Eng. gymnasium), which is similar to countries influenced by the German and Russian education system. The secondary school students gain their qualification after they pass the final exam successfully: the master craftsmen examination, the vocational matura (an English equivalent would be the A-level exams), or the general matura exam. The students who pass the general matura are eligible to enter higher education programs. There are four universities in Slovenia. The higher education in Slovenia comprises three levels. The first level includes higher professional programs (polytechnics) and academic (university) programs, the second level includes master’s programs, and the third level includes doctoral programs. The teachers in Slovenia generally finish a 5-year study program. The Slovenian primary school teachers finish the program called Primary school teaching at Faculty of Education. The primary school teachers in Slovenia can teach all subjects from the 1st to the 5th grade in primary school. The knowledge spectrum of the primary school teachers is considered wide, because it covers Slovenian, mathematics, natural and social sciences, music, physical education, arts, home economics, and English. On some occasions, schools may decide that sports, arts, music, and English are taught by teachers who are specialists in these subjects. The pupils’ first encounter with science, i.e. physics, is in the course of two subjects: Environmental Studies (grade 1–3) and Science and Technology (grade 4–5). The quality of teaching depends on the teachers that are required to possess good understanding of scientific concepts and the didactics of science. They have to be skilled in experimental work appropriate for younger students. Thus, the lecturer is responsible to ensure the adequate level of skills.
Figure 1. The education system in Slovenia. The primary school teachers in Slovenia finish 5 years study programme at the Faculty of Education. They are eligible to teach in primary schools from the 1st to the 5th grade. The physics contents are included in the subjects Environmental Studies and Science and Technology (Edufile, 2014).

In the course of study, the pre-service primary school teachers in Slovenia take science classes (separate subjects: physics, chemistry, and biology) intertwining with the didactics of science. Each science subject has 30 hours of lectures, 21 hours of laboratory work, 5 hours of seminars and 4 hours of field work. The intertwined didactics of science includes 8 hours of lectures and 7 hours of laboratory exercises are planned for the physics part.

The Environmental Studies and Science and Technology curricula prescribe a lot of practical work and skills development. The aim of the physics classes in the Primary school teaching programme is to ensure that students are able to understand and apply knowledge to achieve the curricular goals in the first five years of primary school. The students should also understand the basic laws of physics and be able to develop and implement experimental and other activities. This suggests that the teachers need to demonstrate these competencies and develop them at practical experimental work in the course of study. The students require time to comprehend the physics concepts and their understanding of physics is enhanced by experimental experience. For this reason, we developed a set of simple hands-on experiments that support the basic physics concepts studied at the university level, which may also be adapted for future work in primary schools.

In physics classes, the students attending the Primary school teaching programme are acquainted with the following contents in line with the physics part of the syllabus for Environmental Studies subject and subject Science and Technology: scientific method, basic operational procedures, measurements, mechanics, liquids, sound, thermodynamics, electricity and magnetism, light and colours, astronomy, and weather. The topics are explained at a qualitative and semi-quantitative level. Several laboratory experiments are prepared for the following topics: basic operational procedures, measurements, heat and temperature, light, electricity and magnetism, and weather. This paper discusses the activities related to thermodynamics and their evaluation. The most common misconceptions are examined as well.

2. Understanding heat and temperature

Several studies reported that the concepts of heat and temperature are still considered difficult to understand at all levels of education (Carlton, 2000; Erickson, 1979; Jara-Guerrero et al., 1993; Jasien and Oberem, 2002; Nottis et al., 2009). Our practical experience confirms this finding as well.

Thomaz et al. (1995) summarize five common misconceptions related to heat and temperature: (i) heat is a kind of a substance stored in the objects and it can move; (ii) students are not able to differentiate between heat and temperature (temperature is considered a measure of heat); (iii) the confusion between temperature and the feeling of warmth for an object and students are not aware of the concept of thermal equilibrium; (iv) the application of heat to a body always results in a rise in temperature, and (v) the temperature of a phase transition is the highest temperature of the substance when it is heated.
Albert (1978) reports that eight-year pupils describe heat as something dynamical that flows. The concept of treating heat as a flux between bodies appears at a later stage. The monograph entitled The Kind of Motion We Call Heat Brush (1986) presents misconceptions related to heat as a substance, something like air or stream, which could be added or removed from an object, similar to the caloric theory of heat held by scientists in 8th century. Most students are not able to differentiate between heat and temperature and they tend to use the terms heat and temperature as synonyms (Başer, 2006; Pathare and Pradham, 2005). This was also confirmed by the study of Prince and Vigeant (2006) suggesting that many undergraduate students of mechanical engineering treat heat and temperature as equivalent entities. While describing heat and temperature student descriptions contain phrases such as “Heat is the energy of a hot substance” and “Temperature is a measure of heat”. Furthermore, many of them describe temperature as a measure of how hot or cold an object feels (Carlton, 2000). A number of students believe that heating up an object always increases the temperature of the object (Yeo and Zadnik, 2001). At this point, the experiments involving phase transitions are to be conducted in order to raise awareness that the heating results in an increase of temperature or in phase transition. However, it is very difficult to rift many of the robust misconceptions during traditional lecturing approach (Nottis et al., 2009).

3. Teaching module related to the concepts of heat and temperature
Considering the curriculum for the physics part of science classes for pre-service primary school teachers in Slovenia and previously described misconceptions, a teaching module related to the concepts of heat and temperature was designed. The module includes 4 hours of lectures and 4 hours of experimental work in the course of laboratory exercises. The contents and activities of the module were carefully chosen. They also encompass the aims of the primary school curricula for Environmental Studies and Science and Technology (Kolar et al., 2011; Vodopivec et al., 2011). The aims are as follows: (i) primary school students describe the properties of substances before and after heating; (ii) they predict a change in the properties after heating and re-cooling of certain substances; (iii) they find out that metals conduct heat well; (iv) they know that heat flows from hot to cold objects; (v) they start to distinguish between heat and temperature: when a thermometer is heated, it receives heat, the liquid level in the thermometer rises until the thermal equilibrium is reached and the temperature of the thermometer is equal to the temperature of the substance; (vi) they measure the temperature; (vii) they use the thermometer; (viii) they learn that different substances conduct heat differently; and, (ix) they are familiar with the importance of thermal isolators (Kolar et al., 2011; Vodopivec et al., 2011). For this reason, the following contents are discussed and demonstrated with the experiments during the lectures for the pre-service primary school teachers in Slovenia: the meaning of terms hot and cold; temperature as a property; reasons for temperature changes, e.g. heating, cooling, and mechanical work; thermal conductivity; and phase transitions. During the laboratory exercises, the pre-service primary school teachers gain practical experimental experience they can relate to the concepts explained. They attempt to: a) measure the temperature of the water with fingers and thermometers; b) explore the necessary conditions required to measure the temperature; c) explore the operating principle of various thermometers; d) familiarise themselves with heat conductors and isolators as well as with heat flow; e) draw the graphs of the temperature as a function of time and read the data from them. The experiments covering the aims listed are shortly described below.

In the introductory experiment, the students explore the process of measuring the temperature by using their fingers (Figure 2). The aim of the experiment is to demonstrate why senses are not appropriate instruments for measuring temperature. Then the students carry out an experiment where they put their left forefinger in the glass with cold water and the right forefinger in the glass with hot water and wait for about 20–30 seconds. Afterwards, they simultaneously put both fingers in a glass with lukewarm water. They discuss the feelings (senses) and the results of the estimation of the temperature.
The following experiment is the next logical step in the laboratory exercises, because it leads the students to the knowledge about the thermometers and conditions required to measure the temperature. At this point, the students need to learn how to differentiate between heat and temperature. A thermometer relies on the variation of the thermometric property, e.g. length, colour, resistance (Figure 3). The variation of the property is monitored and the measurement of this property (length for instance) is related to the temperature. The students attempt to use different thermometers as well as describe and explain what happens while measuring the temperature using the laws of thermodynamics. They learn when and how to read the temperature from the thermometer and explore the conditions required to measure the temperature of an object.

![Figure 3. Various example thermometers: resistance, alcohol, and liquid crystal thermometers.](image)

The approach of teaching the students that different substances conduct heat differently and helping them understand the importance of thermal isolators is covered in the activity related to the following experiment. In the experiment, the students are required to arrange plates of different materials from the coldest to the warmest (Figure 4). In this regard, we intentionally avoided using the term temperature. Then the temperature of the plates is discussed and, finally, it is measured by an IR thermometer. The students once again realize that senses are not reliable when measuring temperature. Finger sensors for temperature are relatively correct, but finger temperatures vary if the finger is in contact with a good cold thermal conductor compared to contact with an insulator. To illustrate that this phenomenon is related to thermal conductivity, ice cubes are placed on the plates and the melting process is observed and compared. At this point, the concepts of heat flow and thermal conductivity are discussed in detail.

![Figure 4. Arranging plates made of various materials from the coldest to the warmest.](image)

The heat flow is directed from the object with a higher temperature to the object with a lower temperature. The temperature may change because of the heat transfer. The agreement about the direction of the heat flow and the differences between heat and temperature are discussed after performing the experiment shown in the Figure 5. The students insert a small can into a big can and fill the small can with hot water. Then they fill the big can with cold water. The measurements of both temperatures (for hot and cold water) begin immediately after the cans are filled. Students measure the temperature every 30 seconds in the period of 5 minutes. They draw both graphs of time dependence of temperature in warm and cold water on the same coordinate system. They discuss the data that can be read from the graphs.
In the final experiment, the students discuss the possibilities of reducing the heat flow (Figure 6). The objectives in the experiment include the aims of the experiments from the Figure 4 and Figure 5 and the objective to teach the students how to calculate the amount of heat transferred. The students take a polystyrene glass. The polystyrene glass is split into two halves by a barrier. The polystyrene glass is used to minimize the heat flow to the surroundings. Different barriers are available, for example, plastic as a thermal insulator and metal as a thermal conductor. Jars with hot and cold water are prepared in advance. The students measure the temperature of hot and cold water in the jars. They pour 1 dl of cold water in one half of the polystyrene glass and in the same amount of hot water in the other half. Then they measure the temperature of the water in both halves every half minute in the period of 5 minutes. The students repeat the experiment using a second glass with a different barrier. They present their measurements as graphs and calculate the amount of heat that has been transferred. In addition, the students illustrate the heat flows between parts of the glass and to the surroundings using arrows. The arrows indicate the direction of the heat flow and arrow thickness indicates the magnitude of the flow.

Figure 5. Measuring the time dependence of the temperature in cans with hot and cold water.

Figure 6. Measuring the time dependence of the temperature in both halves of a polystyrene glass with hot and cold water where the barrier is made of a conductor (left) and isolator (right). The experiment shows that the cold compartment absorbs approximately the same amount of heat that is released by the hot compartment.

4. Teaching module evaluation

The teaching module related to the concepts of heat and temperature for pre-service primary school teachers in Slovenia was tested in the course of the pre-service programme for primary school teachers in Slovenia. The aim of the pilot study assessing student prior knowledge and achievements was to answer the following questions: How and to what extent does the teaching module enable the students to comprehend the concepts of heat and temperature?

108 students (102 female and 6 male) in the first year of primary school teaching programme participated in the pilot pre-post study with no control group in spring 2014. The average age of the students was 20 years (SD = 1 year). On average, they achieved 20.0 points (SD = 4.3) out of 34 in the final exam at the end of gymnasium compared to the Slovenian average in the general matura exam that was also 20.0 points in school year 2012–13. Most students did not have any special preferences to physics. Only 4 % of the students chose physics as a subject of assessment in the general matura exam and 14 % of them described physics as interesting.

The module comprised 4 hours of lectures and 4 hours of experimental work in laboratory exercises. In comparison to the laboratory exercises, the lectures are not compulsory. 2 hours of each were performed per week. The students worked in pairs in the laboratory exercises.

The students showed little interest to cooperate in collecting data, thus only short paper-pencil questionnaires related to heat and temperature were applied (3 times). The questionnaires were applied for the first time
before the start of lectures in the beginning of April 2014, then immediately after the laboratory exercises (post-test 1) in the end of April 2014 and as a part of the exam in June 2014 (post-test 2). Some of the questions not present on all questionnaires are marked with a forward slash “/”. Field notes were taken as well.

5. Results and discussion
After the student answers were analysed, we divided the results obtained into 4 groups: heat, phase transitions, thermal equilibrium, and heat transfer.

The first task the students were required to perform was to describe the concept of heat. The most common student answers related to heat are presented in Table 1. In the pre-test, 40% of students wrote that heat is a type of energy and 13% of students wrote that heat tells us how hot or cold the object is. In the post-test 1, the percentage of students who related heat to hot and cold object was lower (5%), while the percentage of students who wrote that the heat is a type of energy increased to 44%. Heat is energy, which was transferred from an object with higher temperature to an object with lower temperature, wrote 29% of the students in the post-test 1 compared to only 7% in the pre-test.

The second set of tasks was related to the temperature of the phase transitions and graphs. The two tasks were very similar, because the students were required to draw a graph illustrating the time dependence of temperature for the experiment described. The experiments conducted were as follows: (i) a student puts a thermometer in 1 l of tap water in the bowl and heat it for an hour; (ii) the student puts the thermometer in bowl with a mixture of ice and water for one hour. The percentage of students who drew the graphs correctly for the experiment (ii) was higher in the pre-test compared to the post-test 1 (Table 2). In part, this may be attributed to the fact that students were not willing to fill in the questionnaires. However, the percentage of students who draw the graphs correctly in the exam was the highest (about 50%). The most common mistakes were an unmarked axis and straight line drawn without realizing that phase transition appears at a certain temperature and it is determined by the substance. The straight line as a graph partly confirms the findings of Thomaz et al. (1995) that the application of heat to a body always results in a rise in temperature. These results correlate to Carlton’s study (2000) reporting that many students are unwilling to accept that solid ice, melting ice, and liquid water can all exist at the same well-defined temperature. The opposite task where students are required to read the melting point of the mixture seems easier for students, because 87% of them read the information from the graph correctly.

Table 1. Percentage of students who described heat as: a) something related to how hot or cold objects are; b) as energy; and c) as energy that spontaneously flows from a higher temperature to a lower.

<table>
<thead>
<tr>
<th>Description of heat</th>
<th>Hot and cold objects</th>
<th>Energy</th>
<th>Energy + transfer $T_h \rightarrow T_i$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-test</td>
<td>13 %</td>
<td>40 %</td>
<td>7 %</td>
</tr>
<tr>
<td>Post-test 1</td>
<td>5 %</td>
<td>44 %</td>
<td>29 %</td>
</tr>
</tbody>
</table>

Table 2. Percentage of students who correctly drew the temperature shown on a thermometer, put it in melting water and boiling water and read the melting point of the substance from the graph.

<table>
<thead>
<tr>
<th>Graphs</th>
<th>Melting ice</th>
<th>Heating of water</th>
<th>Reading the melting point</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-test</td>
<td>22 %</td>
<td>38 %</td>
<td>/</td>
</tr>
<tr>
<td>Post-test 1</td>
<td>22 %</td>
<td>31 %</td>
<td>/</td>
</tr>
<tr>
<td>Post-test 2</td>
<td>49 %</td>
<td>46 %</td>
<td>87 %</td>
</tr>
</tbody>
</table>

When do objects achieve thermal equilibrium? Thermodynamic equilibrium is achieved when there is no heat flow. This helps define the temperature. Laypersons usually relate thermodynamic equilibrium to the equal temperature of the objects. Table 3 shows that 44% of students in the post-test 1 wrote that 2 objects are in the thermal equilibrium if they have equal temperature, while 28% of students also added that there is no transfer of heat. While the thermometer is in the room, it maintains thermal equilibrium with the surroundings. The sketch of the graph time dependence of the temperature in this case was an easy task for
students, because 98 % of students draw it correctly in the post-test 2. Carlton (2000) found out as well that most often students are able to recognize that if two bodies are left in a room at a constant temperature for long enough, they will eventually reach the same temperature as each other and the room. 73 % of students correctly marked the area on the graph time dependence of the temperature for the mixture where it is in thermal equilibrium with the surroundings. In the next version of the teaching module, we will add two simple experiments to the laboratory work: the melting of ice and heating of water accompanied by the measurements of temperature which will clearly show that the temperature during the phase transitions is constant.

**Table 3.** Percentage of students who: a) described the thermal equilibrium with temperature and heat; b) correctly represented thermal equilibrium with the graph $T(t)$; and c) identified the thermal equilibrium from the graph.

<table>
<thead>
<tr>
<th>Q, equal T equal T</th>
<th>T of thermometer in room</th>
<th>Reading the graph</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-test 3 % 38 %</td>
<td>80 % /</td>
<td></td>
</tr>
<tr>
<td>Post-test 1 28 % 44 %</td>
<td>86 % /</td>
<td></td>
</tr>
<tr>
<td>Post-test 2 / /</td>
<td>98 % 73 %</td>
<td></td>
</tr>
</tbody>
</table>

In the fourth group of results, we sought answers to the questions When does heat flow?” and How much heat is transferred? Table 4 indicates that 15 % of students in the pre-test and 51 % in the post-test 1 thought that heat flows from higher temperatures to lower temperatures, while 22 % of students in the post-test 1 still wrote that the difference in temperature does not cause the heat flux. The students were also required to draw a sketch of heat flows between parts of the cup with hot tea and its surroundings using arrows. A wide arrow represents a large heat flow. 24 % of students draw it correctly in the pre-test and 74 % in the exam (post-test 2). The percentage of students who draw it correctly was the highest immediately after a similar activity during the laboratory exercises (in the post-test 2). One third of the students encountered difficulties in the exam when reading a data about the area where there is no heat transfer between the mixture and the surrounding from graph $T(t)$.

**Table 4.** Percentage of students who: a) described the spontaneous heat flow without and with difference in temperature of the 2 objects; b) drew the sketch of heat flows for hot tea correctly; and c) recognized the area on graph $T(t)$ where there is no spontaneous heat flow between the mixture and its surroundings.

| no dT dT Sketch cup Reading the graph |
|-------------------|------------------|-----------------|----------------|
| Pre-test 36 % 15 % | 24 % / | |
| Post-test 1 22 % 51 % | 82 % 38 % | |
| Post-test 2 / / | 74 % 67 % | |

The results clearly indicate that the students were on average more familiar with the concepts related to heat and temperature, such as phase transition, heat transfer and thermal equilibrium after the application of the module. However, we also observed that some students regarded the experimental work only as a recipe showing how to conduct an experiment without trying to explain the physics behind it. In the new version of the module, we will add questions that would encourage student consideration from this point of view. The pre-service primary school teachers observed showed little interest to cooperate in collecting of data (except in the exams), therefore the questionnaires were very short. This is the main reason why we failed to gain the full impression of student knowledge, which partly limits the conclusions. The data was collected only by means of very short paper-pencil questionnaires with a few questions. Most questions were structured in a manner challenging only the lower cognitive level. However, to evaluate the real understanding of the concepts it is necessary to perform semi-structured interviews which can provide insights into student reasoning. For this reason, we have to schedule the preparation and implementation of semi-structured interviews before, in between and after the implementation of the teaching module. The prior study was conducted without a control group, therefore limiting the results. This might lead to a wrong conclusion regarding the influence of the experimental module related to the concepts of heat and temperature on achievements on test of knowledge. In the study, many suggestions for improvement of the module as well
as some instruments for collecting data were put forward. As many of these suggestions as possible will be considered when preparing the classes related to heat and temperature in the new school year. In this way, the impact of the module on understanding basic concepts related to heat and temperature might be described to a greater extent.

6. Conclusions
This paper describes the educational process of primary school teachers in the Slovenian school system. Primary school teachers teach all subjects, including physics contents in the subjects Environmental Studies and Science and Technology, from the 1st to the 5th grade. The concepts of heat and temperature are difficult to understand for pupils and students. For this reason, a teaching module related to heat and temperature for the first-year students of primary school teaching programme in Slovenia was designed and evaluated. The module leads the students through 8 hours of theoretical discussion on heat and temperature as well as experimental laboratory exercises that bring the concepts closer to students. The results show that the percentage of students who are able to discuss the meaning of thermal equilibrium, heat, and temperature increased after the application of the module. However, some gaps in their knowledge remain. Considering these results, a new version of the module will be prepared, the questionnaires will be updated and a pre-post study with a control group will be conducted in the school year 2014–15.

References

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