Outcomes of a Research Based Intervention Module on Fluids for Prospective Primary Teachers

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Abstract

The Physics Education Course for prospective primary teachers (PPT) in the University of Udine offers 15 thematic topics integrating disciplinary education, content research path proposals and laboratory activities. This research based model (Michelini, Santi and Stefanel, 2013) engages students in planning and experimenting teaching intervention modules in school. Here, we analyse the learning outcomes on topic of fluids in terms of planned proposals by PPT.

Keywords: Prospective Primary Teachers, Teaching Professional Development, Research Based Module, Proposals on Fluids.

Introduction

Teaching professional development is one of the most important aspects of education (Elbaz, 1983): it is linked to the possibility of improving students' learning, of renewing the implemented curriculum, of introducing teaching and methodological innovation based on the results of the research (Calderhead, 1996; Borko & Putnam, 1996; Park & Oliver, 2008). In the last 20 years, there has been a growing interest in didactic research for teacher training (Michelini, 2004; Cassan & Michelini, 2010).

The results of international surveys, which highlighted worrying educational shortcomings of students, particularly in the scientific field (IJSE, 2011; OECD, 2007; Holbrook & Rannikmäe, 2001), have focused attention on scientific teaching.

The main focus is on the teachers' needs concerning their subject knowledge and pedagogical aspects in trasmissive teaching. The models used in pre-service teacher education, offered as separate formative areas, are called PK (Pedagogical Knowledge) and CK (Content Knowledge), without providing areas for the construction of the PCK (Pedagogical Content Knowledge). In our research, a formative model focused on the construction of the PCK has been studied and tested, containing design and analysis of learning processes skills. The lack of competences in physics (CK) combined with a separate general education on pedagogical knowledge (PK) produce a double challenge in the PPT professional education on scientific field (Michelini & Stefanel, 2015; Fensham, 2001). As a wide research literature documented and underlined

(Shulmann, 1986; Abell, 2007; Berger, Eylon and Bagno, 2018; Borko, 2004), the need of integration of the knowledge areas require specific dedicated time and activities (Michelini, 2004; Ball & Cohen, 1999). The methodology consisted of finding a significant Rubric for this work, selecting and active design of this selected content.

The personal involvement of PPT in planning and analysing research based educational proposal for primary school and in experience practice in school (Ball & Cohen, 1999; Davis & Smithey, 2009; Imperio & Michelini, 2006) is important. We discuss here the theoretical model and the foundation of the implemented design in the case of perspective primary teacher education on fluids and we analyse the learning outcomes on topic of fluids in terms of planned proposals by PPT.

Intervention module on fluids for prospective primary teachers

The research sample

The Physics Education Course is included in the third year of the course of studies in Primary Education at the University of Udine. Of the 120 students enrolled, about 89% are third year attending students. The Course offers 15 thematic topics (fluids, optics, magnetic phenomena, electric phenomena and others) integrating disciplinary education, content research path proposals and laboratory activities. In this study, we analysed the fluid paths planned by 85 PPT. The PPTs worked to identify the concepts considered fundamental and conceptual knots, designed by means of two standard Rubric (S1 and S2). Moreover, the PPTs prepared the proposal of an educational path for the teachers to guide the children. Of these, 26 PPT implemented the intervention proposals in class with 331 school primary children (Tab.1), after discussion and revision, supported by the physics education course responsible. PPT analysed the pupils' learning process by means of different instruments and methods, and encouraged reflection on their own learning (Elbaz, 1983). In this paper, we analyse how students have taken, used and transformed the concepts of physics, the teaching approach and the associated discussions about basic concepts and specific learning difficulties.

Number of interventions	Class	Number of students
18	3^ CLASS	234
3	4^ CLASS	43
1	5^ CLASS	10
1	2^ CLASS	44
23		331

Table 1 - Primary students involved in teaching interventions

Setting of Physics Education Course

The challenge in teaching professional development is to form together the disciplinary and teaching skills competencies. In the Physics Education Course, this is achieved by focusing on the fundamental critical discussion on disciplinary elements in each thematic topic offered. Therefore, the work consists, on one hand, in the deepening of the physical content and, on the other hand, in a training proposal, which translates into a didactic proposal of contextual elements. In this way, a significant design rubric for this reworking, selection and active design of the selected content was found. The course includes, but is not explained in this work, a more detailed design by the students and an educational intervention that they monitor for the analysis of the learning process of children.

Research questions

The research questions focused in this study are:

1. How does PPT select the conceptual elements contained in the educational proposal on fluids and on the subject related reflection?
2. Does the approach by physics education proposals play a fundamental role in building competence in the subject and process of planning, discussing and proposal revising build the professional competences?
3. How does the implementation in class of a planned proposal and relative monitoring of learning by children contribute to a meta-reflection of the professional development?

Tools and methods

The resources for educational discussion were the documented implementation in primary classroom of the same topic (Michelini, 1995; Michelini, 2004), discussed during interactive lecture demonstration. The selected strategies and methods were ‘Inquiry Based Learning’ and ‘Prevision, Experimentation, Comparison’. A conceptual analysis of the physics involved and the goals addressed was performed in parallel with the educational discussion of the topic. The task to prepare tutorials and educational materials for children (Michelini, 1995; Michelini 2004) produce a continue reflection of the choices for the learning environment and of the step by step approach. During the implementation of the proposed activities of the planned path, the PPT activated a meta-reflection on their educational practices. These models have been integrated with the informal learning acquired during the experience and in the research-action process of the teacher who utilises the didactic methods.

S1 and S2 Rubric

Two standard Rubric, S1 and S2, were designed and provided to the PPTs, who have used them in all the topics covered by the course. The S1 Rubric presents concepts and nodes, in which it is required to list the most important concepts on fluids, to identify the critical aspects and to motivate these choices. The S2 Rubric guides the planning of a didactic path through: 1) the sequence of the addressed contents 2) the map of the selected main concepts, 3) the logic of the planned route, 4) the list of concepts focused in accordance with the line of chosen reasoning; and 5) the questions / items / issues for the Inquiry Based Learning strategy and activities to be implemented in the classroom.

Content and research methods

The physics of fluids

The approach to physics of fluids starts with a comparison of the properties of solid, liquid and gas for the state identification of fluid. These are the following characteristics: the flowing because of the absence, or a minimal amount, of the parallel forces to surface, and the absence of the reaction to shear deformations, having high compressibility in the case of a gas and no compressibility in the case of a liquid. This justified the change of shape according to the container. Pressure becomes the needed quantity in describing action on a fluid system. Compressibility is a relevant property of matter in liquids but not in gases, where Boyle's law can be applied. Density is introduced as one of the main properties of the part of the system in a mesoscopic model. The electromagnetic interaction between close neighbours justifies the Pascal principle and the Stevino law. The equilibrium of part of a fluid offers the formal expression of the same Stevino law, applied in the case of the identification of the isobaric surfaces and equipotential free surface of liquids, it is discussed in the dam profile, communicating vessels and hydraulic press. Different kinds of U-tube manometers are used for exercises, for the analysis of siphons and aqueducts. Measurements offer the awareness that different densities distinguish between liquids and gases. Torricelli's barometer and vapor pressure introduce the analysis of atmospheric pressure and its dependence on density and temperature.

Archimedes' law emerges from the review of the equilibrium in liquids within different liquids and solids, to identify the role of the density of materials in the buoyancy processes. Different situations, for example solids in liquids and liquid cocktails, are used to reflect on Archimedes' law, which is then applied to the case of gases for hydrostatic balloons, hot air balloons, airships and two-arm balances. Case studies help the application of concepts in contexts, for example the pressure a giraffe's heart must create to provide its brain with blood, and the story of the crown of King Heron.

The teaching proposal

The educational path discussed is based on the inquiry approach of explorative experiments and offers a simple implemented path in primary school. The first step offers the opportunity to classify, in three boxes, a cluster of objects having different shape, volume and materials, as well as fluids in bottles and gases, to discuss the properties of the solid, liquid and gas states. Perfume collected in a bottle by means of water displacement, together with the vapour of boiling water, help recognizing the gas state and to consider an empty box as actually being a box full of air. Balloons filled with air and with water are pressed in a bowl; the air-filled balloon has its volume reduced, while the water-filled one changes only its shape. The great compressibility of gases is discovered by pressing an equal quantity of water and air in a syringe. Poking holes in a closed water bottle laid on its side produces jets of water on the opposite far side; this is explained by the Pascal principle. In fact, the jets of water produced by a bottle standing regularly are also equal in pressure. The different jet of water produced by poking holes at different heights to the same standing bottle of water introduces the Stevino law. The case of a bobble of air in a syringe of water offers the opportunity to analyse the Pascal principle's role in overcoming the well-known conceptual misunderstandings on the dimension, position and shape of the bubble when the piston is pressed. The concept of pressure is discussed in depth by understanding it as a force distributed on a surface, on the state property of pressure and on the effect of volume change produced by increasing or decreasing pressure. The increase in pressure and compressibility are analysed in relation with the kind of liquid and gases considered. The interpretative plan introduces an objectual model of the mesoscopic fluid model: a water tank is replaced by water balloons (and then, by equivalent foam balls) to represent the mesoscopic portions of the fluid. The equivalent tank of balls is pressed by a piston (Fig. 1) and all the balls appear deformed by the interaction of the close neighbours, showing how the Pascal principle works. So does the foam ball in a lying down tub when we press on one of its sides. Putting the same tube in a vertical position, the balls at the bottom of the tube are deformed more than those above them, in accordance to the Stevino law (Fig. 2).

Figure 1 - The model: the box with pistons and the transmission of pressure

Figure 2 - The model: the horizontal cylinder - the syringe full of water with the air bubble

In fact, if a person wears a glove and puts his or her hand at the bottom of a tank of water, then the glove is compressed. The hydraulic press is assembled by a syringe of water connected by a little tube to a bag for hot water. By pressing the piston of the syringe, the hydraulic press raises a two-kilogram brick. In a bottle connected to a small tube, an inverted balloon is placed inside the neck of the bottle, which inflates the balloon, showing that it is, in any case, the difference in pressure that inflates a balloon.

A little U-shaped tube becomes a manometer exploring the pressure in the depth of a water pitcher (Fig. 3).

Figure 3- Manometer

The case of the Cartesian devil absorbs the attention of pupils and students in the related problem solving and reinforces the concept of the different compressibility of gases and water.

The buoyancy is explored in three ways: 1) by measuring the length reduction of a spring holding an hanging body; this weight reduction is due to the Archimedes force, depending on the volume of the body and on the liquid density; 2) by exploring the buoyancy conditions of different objects of different materials and plotting the volume against mass of each; and 3) by exploring the buoyancy gradually by weighing small plastic eggs using sand of the same volume and repeating this exploration with eggs of greater volume.

The problem solving for the density of liquids using three different methods offers the opportunity to reconsider the manometer, the density definition and the buoyancy of the bodies, inventing a densimeter done by a drinking straw closed at one end, weighing it down to make it stand upright, and placed vertically inside different liquids to measure how much it sinks.

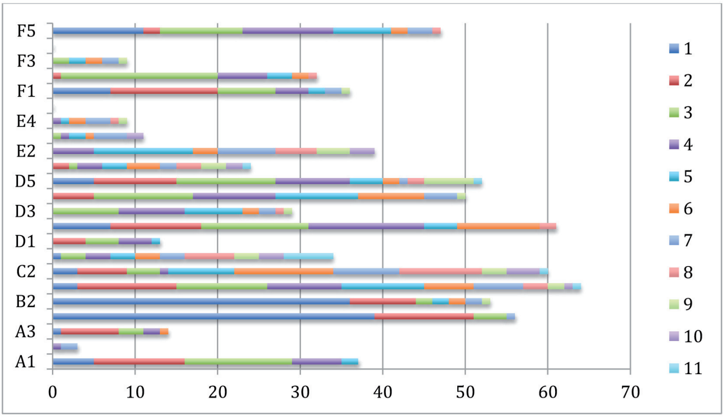
Data analysis

We analysed the S1 and S2 Rubric design of all 85 PPT and the content of the final projects and paths made by 26 of these, using a grid of relevant properties of ideal fluids structured into six areas, as shown in Table 2. The presence of the contents and the order in they were presented in class emerges from the analysis. This offers an insight into how the training intervention is capable of producing disciplinary skills and how these are transformed into professional skills.

Relevant properties of ideal fluids	
A. Properties of ideal fluids	**E. Applications**
A.1 flowing	E.1 communicating vessels
A.2 density	E.2 manometer and U tube
A.3 compressibility	E.3 hydraulic press
B. State properties	E.4 dams
B.1 liquids and gasses	E.5 levels
B.2 solids	**F. Property characteristics**
C. General laws	F.1 viscosity
C.1 Pascal	F.2 surface tension
C.2 Stevino	F.3 capillarity
C.3 Archimedes	F.4 formation drops
D. Quantities and basic concepts	F.5 compressibility
D.1 F//=0 absence, or small value, of the parallel forces to free surface	
D.2 pressure	
D.3 equilibrium properties	
D.4 mesoscopic model	
D.5 density	

Table 2- Grid of relevant properties of ideal fluids

The distribution of content provides information about the contents addressed in the training.



Graphic 1 – Contents of PPTs works

Data analysis shows the type of content and the large number of topics included in the work of the PPT; this emerges from Graphic 1. The topics that were treated the most are the general laws of Pascal and Stevin (first and third place), the pressure and density of the basic concepts and quantities (second and sixth) and the state properties (fourth and fifth). The approach to the topic of fluids is, in order, state properties (B.1 56/85 and B.2 53/85), compressibility (F.5 47/85) and equilibrium properties (D.3 29/85).

In relation to the grid of the properties of the highlighted ideal fluid: the flowing is the most discussed topic; the state properties liquids and gases, followed by solids, are the most presented topics. Among the general laws, Pascal's law is the most treated, followed, in order, by the laws of Stevin and Archimedes. For quantities and basic concepts, pressure is the most treated topic, followed by the density and the mesoscopic model.

The applications are all by Stevino and the most presented are the manometer and the U-tube. Among the characteristics of properties, compressibility is the first topic, followed by viscosity.

Results

1. The conceptual elements selected from PPT, contained in the educational proposal on fluids related to the subject reflection, are the same ones we have proposed with activities during the course, while aspects known as being crucial from the conceptual point of view (flowing and surface tension, for example) are less

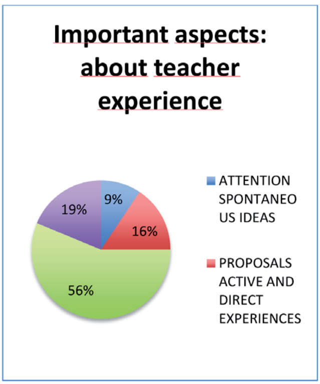
evident. Conceptual nodes emerge, that makes it seem like the representation of the concepts considered are important for the teacher and that the teacher fears that they are not learned, rather than the real difficulties that children encounter while trying to learn the concepts.

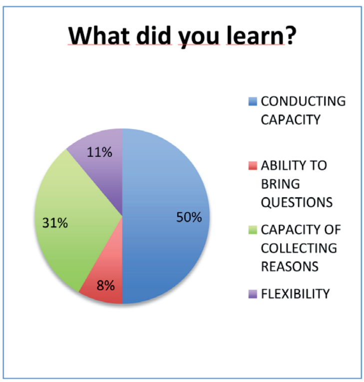
2. The approach by physics education proposals plays a fundamental role in building competence in the subject. The process of planning, discussion and proposal revision that builds the professional PPT competences re-elaborated the activities in their own path, in the light of:
   a) critical observations of the teacher and of the primary training students involved;
   b) preparation and development of materials necessary for educational intervention;
   c) planning of differentiated tools and methods for the collection of learning data during the intervention (with the qualitative analysis methods, monitoring of the Etkina type discussions, which is never summative).

   The proposal and the discussion of didactic paths during the course have implemented the activities with the children on the same topic. These models have been integrated with the informal learning acquired in the experience, in the research-action process of the teacher who utilises these teaching methods.

3. The implementation in class of a planned proposal and relative monitoring of learning by the children contributes to a meta-reflection of the professional development; in fact, PPTs have learned to examine many aspects related to children's learning.

   The experimentation in class of a planned proposal and the related monitoring of children's learning contribute to a meta-reflection of professional development. Graphic 2 presents the aspects that the PPT considered important in their class experience. The PPTs have reflected on the learning of children and on what they have learned themselves during their teaching experience (Graphic 3).





Graphics 2 and 3 – Relevant aspects of PPT meta - reflection

Conclusions

The analysis of this project provides a relevant indication regarding the way in which the PPT uses the subject knowledge and how they fit it into the projects and to what extent they are able to reuse the teaching and laboratory activities they have experienced directly in the educational proposal.

It also offers the possibility of comparing the consistency between the planning and the implementation of educational paths. The analysis of the reports highlights the ability of PPTs to collect children's spontaneous ideas through meaningful questions, to analyse learning data and to represent them, which, consequently, results in the understanding of the learning processes during the meta-reflection phase.

We have seen that the students have been able to apply the skills acquired in other contexts, when it comes to design skills and monitoring of learning.

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Bio-notes

Emanuela Vidic has been a primary school teacher at the Istituto Comprensivo di Faedis (Udine-Italy) since 2008 and has been part of the school management team since 2016. Under the guidance by professor Michelini, she has been involved with the Research Unit in Physics Education at the University of Udine since 2007 where she participated in a number of initiatives in the field of pre-service and in-service teacher professional development. She has also co-

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Marisa Michelini is Full Professor in Physics Education at Udine University, where she is rector delegate for Didactic Innovation. She manages the Research Unit in Physics Education. She is president of the International Research Group in Physics Education (GIREP), director of the Italian University Consortium on Education and Guidance, committee member of the Multimedia Physics Teaching and Learning, board member of the EPS-PED division and honorary member of the Italian Association for Physics Teaching. She founded the Centre for Research in Education, the Lab Centre for Physics Education, the Centre for Guidance, the Research Unit in Physics Education. She has published extensively in her field of expertise.

Rita Maurizio has been a kindergarten teacher since 1977. She was part-time supervisor for pre-service primary teachers at Udine University between 2006 and 2010 and part-time coordinating tutor since 2017. She also forms part of the Research Unit in Physics Education for research on informal learning, early year learning in scientific education and prospective primary teacher education.