Research based discussions on optics with teachers to integrate professional development with everyday school work

Francesca Leto, Marisa Michelini, Alessandra Mossenta

Research Unit in Physics Education, University of Udine, Italy

Abstract

Within the Italian project on innovation in teaching/learning IDIFO4, research based labs for in-service teacher professional development was carried out. In the rich environment of 20 kindergarten, primary and low secondary school teachers, the discussion of content knowledge (CK) was integrated with activities on simple experiments proposed in examples of coherent paths, according to Experiential Teacher Education Model (ETEM). Activities were focused on the analysis and the discussion of tested educational paths both on conceptual change, subject matter content and educational plans. Action oriented contents and methods emerge as teaching/learning proposals based on research on children learning processes, where they melt in coherent paths as an outcome of the experienced modules of formative intervention. Optics lab offers an example of this kind of integration between educational research and teacher professional development.

Keywords: kindergarten and primary school teacher education, research based lab, optics

Introduction

The issue of the integration of content knowledge (CK) on subject matter with that producing the competence in creating an educational environment is a multidimensional problem in teacher education (TE). The lack of scientific preparation of primary and kindergarten teachers and of adequate educational tools is pivotal elements in this problem, as well as the need of a qualified in-service TE aimed at the teachers' professional development.

Although the integration of content knowledge (CK) with teaching strategies knowledge (PK) can be favoured by an Experiential Model for TE grounded on the personal involvement of teachers in carrying out the same activities planned for children, it doesn't guarantee the activation of a practice based on intellectually active children [1-7]. Among many reasons expressed by teachers, the most common is the lack of self-confidence on the conceptual discussion and on the organization of the experimental explorative activities. Several studies shown the importance of PCK in order to develop a flexible teaching competence [8-11] but in the context of primary school teacher education, PCK is often left to individual initiative, on the basis of an academic education on CK and PK. It is not easy, therefore, to determine which kind of competences are developed by these teachers and the forms in which personal development takes place. In the context of the Italian Project Innovation in teaching/learning Physics IDIFO, seven educational labs were carried out with the purpose to promote teacher's conceptual change. Each of these labs was devoted to a different topic: energy, time, fluids, interactive white board, sound, electromagnetism, optics. In this paper a case-study is discussed on primary and kindergarten school teachers attending the "Vision and Optics Lab".

Background problems

In order to guarantee an adequate education it is important to take into account some background aspects: primary school teachers tend to teach science as they were taught, they are more familiar with PK than with CK, they don't know research results on students difficulties [12] and don't reflect on this problem in school activities.

Engaging children in activities concerning hypothesis building, eliciting ideas and interpretation of phenomena requires a change in teachers' way of thinking, which is difficult to obtain in this framework [6,13,14]. Building bridges between scientific perspective on the one hand, and common sense ideas and everyday experience on the other hand, is a practice which is more evoked than acted, even when teachers say they put children learning at the center of their work. In professional development we have to take into account the lack of scientific preparation that primary/kindergarten teachers feel to have. Previous experience in this field was acquired in the framework of the IDIFO Project on the Innovation in Physics teaching/learning and School- University Cooperation, where we acknowledged that Primary School Teachers need to improve their professional formation. Teachers claim a lack of self-confidence on conceptual discussion and organization of the experimental explorative activities.

They are interested in learning methods and practical ways to apply innovative educational proposals. Beyond these aspects, they show difficulties in expressing their specific needs for an effective professional development. Several studies have shown that teachers don't really know what PCK is or, at least, it results to be a tacit knowledge and it isn't used consciously by teachers (Kind, 2009). They don't know research results on student's difficulties [12] and they don't reflect on this problem in school activities. A significant teacher's education should guarantee a change in teacher's view on scientific education and the development of awareness on his own educational practices by means of his real engagement in learning processes.

In this empirical study, the Model of Educational Reconstruction (MER) was used both as a frame for research of subject related learning and teaching [16,17], and as a basis for teacher education. According to MER, an essential step in planning educational research is subject matter clarification, meant as a reconstruction of conceptual contents for educational purposes. Within teacher education, we used subject matter clarification as a way to foster in-service teacher reflection on subject matter as well as on the relevant crucial concepts and conceptual knots. The acquisition of a structured CK is the final goal of this reflection process. For what concerns the development of PK, a reflection on pedagogical competences in action was favored. The integration of this CK and PK in action is meant to develop PCK through teaching intervention experiments (monitored for what concerns learning environment and students learning trajectories), and to produce professional development by means of reflection on learning data and the experience done (metareflection).

This project aims at addressing the following facets of PCK: teacher awareness on the role of student learning trajectories in building their scientific knowledge, and the mastery of management of scientific activities based on active learning. At the end of the labs carried out in IDIFO4 project, teachers should be able to build learning environments favouring a gradual construction of knowledge rather than transmission of information. In this context, PK represents a competence in identifying learning paths as well as strategies and methods to promote conceptual change starting from common ideas, by means of research based materials offered during teacher education.

The interplay between researches based educational proposals and educational experiments carried out in the class aims at producing discussion and sharing of PCK elements.

Our proposal for professional development: educational labs in which is activated a co-design between researchers and teachers

In the framework of Scientific Degree Plan (PLS), University of Udine is leader partner in the IDIFO Project on Innovation in teaching/learning Physics with primary, kindergarten and secondary school teachers. In this context, seven educational labs were carried out inside a period of five months on different topics as indicated in Table 1. The labs aimed at:

- Helping teachers become aware of their educational practices in order to activate a meta-reflection on it.
- Offering examples of pupils engagement in learning processes.
- Building bridges between scientific perspective, common sense ideas and everyday experience in science (Michelini, 2006).
- Promoting transformation from skills to deep competences in order to shape the educational path.

Each lab lasted 15 hours and was organized in the following stages:

1. Design of an interview with students, including discussion of questions to be posed.
2. Interview with teachers by means of validated questions taken from research literature on conceptual knots.
3. Collective discussion on teachers answers and key-concepts of the scientific content addressed in the lab.
4. Analysis of an educational path and development of teacher knowledge on knots and on conceptual issues (Metacultural Model).
5. Experimental exploration of educational instruments used during the educational path (Experiential Model).
6. Sharing a micro-teaching project and a monitoring of learning.
7. Educational intervention of each teacher in his/her own class (Situated Model).
8. Collective analysis of data obtained during educational intervention in class and design of a new educational intervention on the same topic (learning environment, strategies, methods and contents).
9. Teachers discussion with their own students on the results of data analysis and promotion of an action research process shared between teacher and students, in which teachers acquire a new competence and students experience active-learning.
10. Collective discussion between teachers and researchers.

The activities of the IDIFO educational labs suggest a gradual change in teachers' view of scientific education. The labs furthermore offer significant examples of pupils engagement in learning processes, center the scientific education practices on children eliciting of ideas, hypothesis and interpretation of phenomena, put in action the central role of pupils learning.

Table 1. Different educational labs

LAB	CONTENTS	TEACHERS
TIME	Time measurement – Instant and time interval Periodic events – Contemporary events	-2 kindergarten -3 primary
FLUIDS	Properties of fluids – Density and viscosity Pressure – Weight and volume – Principles of Archimede and of Pascal	-9 kindergarten -3 primary
SOUND	Wave nature of sound – So und sources Intensity-frequency – timbre – Sound propagation	-7 kindergarten -2 primary
ENERGY	Energy without work – Energy transformation Energy conservation – Types of energy vs energy sources	-14 primary
ELECTRO MAGNETISM	Interaction between ferro-magnetic objects Interaction between magnets The electromagnetic field	-8 kindergarten
INTERACTIVE WHITE BOARD	Use of interactive white board referring to - Optics Model - Motion	-2 primary
OPTICS	- the students' models of vision - the nature of light - reflection - refraction of light - color of light - decomposition of white light	-3 primary -1 kindergarten

Methods

During the labs, the professional development of teachers was supported by different tools referred to Science Education Research:

- Research materials to activate collective discussions on stimulus questions, interactive lessons and hands-on experience of teachers.
- Step by step research discussion on active teaching: an iterative process of co-design of researchers and teachers, data analysis of classroom products and analysis of key concepts and pupils previous work (statements, drawings) according to the research practices.
- Research based educational path as experimental explorations of open hands-on tools [15].

We recorded on audio tape each collective discussion and data analysis made by teachers together with our research group, writing down CK/PK statements, questions posed, operative proposals, teachers' ideas/models/beliefs on specific topics, in order to monitor conceptual change during the labs.

We used tutorials to deepen the explanation of teacher's ideas on «optics» and then we applied the co-design between researchers and teachers in order to identify worksheets to be administered to pupils.

Qualitative data analysis of children products in the class (texts, drawings, audio recording of verbal explanations of the formers) was performed during stage 8 of each lab, identifying categories on the basis of conceptual elements introduced by student answers/drawings.

Data analysis of teachers learning was performed in two steps: the first one inside stage 10 on a collective level, and the second one by researchers. The latter included A) a phenomenographic analysis of conceptual change profiles emerging from audio-recording and transcripts of every statement made by teachers during the labs; B) analysis of teachers reports according to the following rubric: knots (on the basis of teacher statements and children's products), key-concepts, internal coherence of the path, innovative elements, teacher autonomy in planning activities, methods used during educational interventions in the class.

Features of Optics Lab

Optics lab engaged three in-service primary teachers and one kindergarten school teacher, all working in schools close to the Udine (less than thirty kilometres). All of them are female. All but one have been teachers in-service for at least 7 years. Among these teachers, only one has earned a master's degree, the others only high school diploma. The instructors are two researchers of 50 and 31 years old, respectively senior researcher and young researcher, the first one with a physics master degree and long experience in science education research, the latter with a primary school education master degree and in her first years in research.

Contents explored include student models of vision, the nature of light and the ray model, interpretation of light according to geometric and physics optics, reflection, refraction of light, color of light and decomposition of white light, spectrum of emission, perception of color as interaction between light, eye and object, sources, propagation phenomena and light-matter interaction.

Concerning content structure, the lab dealt with three different aspects of the optical processes: sources, propagation phenomena and light-matter interaction. From these perspectives physics education researchers and teachers addressed student ideas on the models of vision; they discussed pupils spontaneous statements concerning the word 'light' and light-phenomena, light sources and vision models, collected in teachers classrooms. They discussed in cooperative way children emergent ideas in classroom activities.

Teachers suggested pupils to elicit their opinion about light by means of drawings, writing answers/stories and recorded discussion sentences. During the meetings, we recorded teachers' questions and their answers to stimulus questions asked by researchers. Teachers asked for example "How could we make clear physics content hidden behind experiments? Pupils usually focus on the game and don't understand the content".

Table 2. Typical questions asked by teachers

Teachers	Typical questions
Primary	What is the difference between an opaque object and one that makes shadow? What is the difference between reflection and the shadow? Is refraction similar to reflection?
Kindergarten	Is the color of an object a feature specifically possessed by the object? Does the color exist by itself?

Work and data analysis methods, their results and teachers' opinions on the role of the activities in their professional development are significant for in-service teachers education in order to promote integration between research and education.

Main Results

The educational lab started with a critical discussion on what kind of questions a teacher should ask children in order to elicit their ideas about vision and optics.

The interview design activity (stage 1) elicited teachers' approach to the topic: all of them formulated extremely abstract and global questions concerning the identification of light as an entity (e.g. "what is light in your opinion?"). Three teachers on four also asked about unspecified examples and experiences of light phenomena: "tell me what light does around us", "talk about your experience with light".

After lab activities described in stages 2-6, a significant conceptual change was observed. In stage 7 teachers asked pupils specific questions on optics from a scientific point of view:

- "what do you need to see?"
- "how do you see?"
- "draw a picture in which you relate different elements necessary to see"
- "write three things that make light"
- "write three sentences with the word "light""
- "find pictures in which you can see things that reflect themselves"

Sixty percent of questions taken from literature were used by teachers in the original form (2) or with some changes in order to adjust them for smaller pupils with respect to their spontaneous ideas elicited in teacher's data analysis (2).

By using validated research based materials, teachers faced questionnaires, interviews, worksheets where topics aren't addressed in a generic and naive way, but with methods favouring student reasoning on scientific content. In this way, we meant to promote teacher's reflection on scientific content (light rectilinear propagation and its effects: shadow, upside down images in a camera obscura, reflection, diffusion, refraction, absorption, colour) as well as their reflection on educational paths and on the design of new proposals grounded on reasoning coherence and on the link between phenomena and formal thinking. Different strategies for the building of formal thinking were planned (trajectory - objectification with a wool wire, tracking of the optical path of a reflected and refracted light ray; reconstruction of a refracted image; identification of the position of virtual image in a mirror).

Step by step discussions on active teaching promoted the explanation of educational practices in order to become aware of the different components needed for an effective scientific education and to address the role of the exploration of phenomena in learning processes, children's ideas and difficulties, their reasoning in relationship with phenomena and finally how to address the development of formal thinking. Teachers reports concerns at least four teaching intervention in class. Related logbooks include wider and wider information with respect to the learning processes of observed children. Already in the second teaching intervention, they include – as terms of comparison or alternative proposals - references to paths presented in the lab and discussed with colleagues during teacher formation activities. Gradually the design of the future activities became more tightly linked to the experiential exploration activity offered and to the different reasoning paths of students. However no teacher presented a complete report on each student's educational learning process: generally, teachers mentioned only those typical sentences and reasoning of students they found interesting, and reported frequencies in as semi-qualitative way (a few, some, many, etc…).

Conclusions

By unifying the contribution of each model in the framework of MER, we can promote not only PCK achievement but also a conscious process in doing it. In fact, in the final stage (stage 10) all teachers discussed by means of a grounded meta-cultural list on the basis of the results of their educational intervention in class (stage 7) and identification of knots and key-concepts. Together with researchers, they developed instruments for empirical research independently from their immediate use in the class, but as a guide for future investigations on the ideas of their student.

Physics education researchers and teachers addressed pupils' ideas on the models of vision, discussed pupils' spontaneous statements on 'light' and light-phenomena, light sources, vision models collected in teachers classrooms to make the path suitable to specific children population, discussed children's ideas in cooperative way during classroom activities for a continuous link with the real practice.

Students' ideas on light phenomena and teachers' opinions on their educational role are significant for an analysis on in-service teachers professional development and promote an integration between research and education.

It is important to identify methods to improve teacher awareness of their needs, in order to create a real co-design between researchers and primary school teachers. We suggest that by means of educational labs it is possible to elicit teacher's needs, suggesting educational paths suited to pupils.

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