Innovation in Kindergarten and Primary School Teacher Education in Physical Sciences

Federico Corni
Faculty of Education – Free University of Bozen-Bolzano, Italy

Stamatis Vokos
Department of Physics, California Polytechnic State University at San Luis Obispo, USA

Innovation in Primary Teacher Education in Physics is crucial at a time of rapid development of science and technology in society and in response to the growing need for a modern scientific preparation of new generations to help them to cope with future challenges. The four contributions in this symposium come from four very different settings, giving fertile ideas that have matured in different contexts. They are united by their grounding in scientific education and primary teacher education research and develop our theme from two relevant points of view, *i.e.,* integration and technology. Two contributions present integrated approaches to teacher education: the first integrates metacultural, experiential, planning and situated activities, while the second integrates nature, human and social disciplines. The remaining two contributions deal with the need to include engineering design and ITC technologies in school and in teacher preparation.

This symposium is sponsored by the GIREP Thematic Group "Physics Preparation of Teachers in Grades K-6" in view of its interest in knowing and discussing promising strategies to professionally prepare a new generation of kindergarten and primary school teachers.

The Contribution of Physics Education Research in Educating Prospective Primary Teachers

Marisa Michelini
Research Unit in Didactics of Physics, University of Udine

Abstract. Basic scientific education and teacher education are two interconnected problems studied in international educational research and physics education research, in particular. The Prospective Kindergarten and Primary Teacher education is a challenge for that scientific education competence that is able to promote children's critical thinking in an interpretative perspective in the exploration of phenomena and in building formal thought. The results of the last 20 years of research experimentation carried out at the University of Udine in the courses of Physics Education (DF) and Laboratory of Physics Education (LDF) in the third year of the five-year Master's program, that have produced the research-based consolidated formative model MEPS, are described in this article, including discussion of the different activities involved.

KEYWORDS: prospective primary teacher education, scientific education, kindergarten and primary education

1. Introduction

Extensive international studies have shown a lack of scientific education at all age levels [1], underlining the need for urgent actions connected to teaching professional education and development [2]. To focus on subject-related professional competence is an urgent challenge.

The traditional models in teacher education, where pedagogical and subject-related education live in separate areas (in parallel or in sequence) leaving the integration to the prospective teacher is not working [3-4].

The future primary teachers have to modify the traditional scientific education, which is sometimes vague and not very incisive, or, on the contrary, is structured in disciplinary and transmissive ways, unable to prefigure the cognitive role of the disciplines, due to a lack of epistemic and methodological attention, which produces mnemonic learning, with poor operational skills, which extinguishes curiosity and reduces the motivation of learners. For Prospective Primary Teachers (PPT) and scientific education, the problem includes three main questions: 1) the need to improve scientific education starting from early childhood [6]; 2) the lack of solid subject preparation of PPT; and 3) the lack of teaching tradition, instruments and methods for scientific education in kindergarten and primary school [7]. Few are the valid teaching supports on which PPT can count, such as textbooks, brochures, software: the available materials for scientific education often present concepts not related to each other, and not infrequently are plagued with methodological errors (and not only). In addition, physics has no didactic tradition at the basic school level and the interdisciplinarity in the scientific field is confused with the generic treatment in popular terms: the formative, methodological aspects and the identification of conceptual elements are completely neglected in textbooks. Physics notions appear in a fragmented way, without founding them in sense-making, while the relationship with mathematics is often treated in other chapters of the same textbook with examples taken by everyday life action without taking the opportunity to explore and interpret common phenomena.

The PPT education is a research problem that goes beyond the integration of differentiated knowledge (Pedagogical and Subject matter knowledge), in favor of the appropriation of those competences that include how to organize teaching/learning path proposals, set up learning environments and activities, as well as knowing how to monitor and evaluate the learning process in the field, during classroom teaching. In Italy, the PPT education began in 2000 with a qualified project in a context unprepared for the task. This produced a research-based experimentation in the different universities [8]. The research-based characteristics and the results of the experimentation conducted in the Physics Education Course (DF) in the master's degree in Primary Science Education (SFP) of the University of Udine in the last 20 years are presented here.

2. Research

For over twenty years, tools, methods and implementation models for the qualified professional education of future primary school teachers (PPT) are studied in the DF [5, 9, 10]. Research experimentation is carried out focusing on different aspects in PPT education [11-15]: 1) curricular contents and relative methods; 2) active role of PPT in their education; 3) instruments and methods; 4) role of planning; 5) integration of pedagogical, subject and transversal contribution in the master's degree; 6) curricular contributions to competence development and relative evaluation; 7) physics education research contributions; 8) role and impact of the school apprenticeship.

The main research questions are

1. How to produce familiarity in producing active scientific education in children starting from poor basic scientific knowledge?
2. How can planning educational paths produce competence in developing and evaluating learning scientific environments?
3. How can physics education research support the PPT education process?

3 Conclusion

Spontaneous teaching style of PPT is mutated by their experience in instruction, therefore is characterized by assertive presentation of notions and scarce involvement of learners: providing answers to questions not posed. Experiments are offered as observational news and interpretations of phenomena are not considered: the lack of relationship between science and math of textbooks is reproduced. The discussion of physics concepts in research-based educational paths produce familiarity with basic conceptual physics knowledge and offers examples of how to support learning experiences in pupils. This Metacultural educational activity is important in methodologic perspective change of PPT, but to gain awareness of the coherence in the educational paths discussed, they need Experiential experience by means of tutorials that they use in the same manner as their future learners: PPT have to experience the learning difficulties that pupils encounter in the learning process (RQ1). Planning educational paths is a useful exercise (RQ2), but can be a reductive reproduction of the research-based educational paths discussed as sequence of activities not well related with a poor attention to the learner role. We gain evidence of the need of the following phases: a) individual task in the perspective to work directly with children in school and attention to how to conduct each step; b) peer discussion in group of the path planned to reach an agreed Teaching Intervention Module (TIM); c) discussion in plenary with the responsible of the DF course of TIM and its revision; d) preparation of education materials for the TIM in classroom with children; e) prepare and use monitoring instruments and methods during the implementation of TIM; e) analysis of the learning process during the intervention; f) reflection with a peer observing the implementation the work done and report on the learning in the field (RQ2).

Physics education research supports each step in each topic of the PPT education (RQ3) and in particular offers: a) research-based science education paths; b) studies on learning difficulties in the different topics; c) tutorials on different topics; d) experiments and educational materials; e) reflection on educational aspects as the interplay between math and physics concepts, interdisciplinarity, role of metaphors, of representations, of exercise, of experiments and exploration…; f) self-evaluation by means of PCK exercises; g) instruments and methods for learning process analysis.

The MEPS model [5] integrating M-metacultural, E-experiential, P-planning and S-situated activities is developed. An important part of the appropriation of competence in science education by PPTs is the integration of the discussions of research-based educational paths, with the designed paths by PPTs, and the analysis of the teaching intervention modules (TIM) prepared by PPT [10]. The outcome of such work makes the acquired skills operational. The Situated learning, produced from the field experiences in real classes and from the monitoring and analysis of children's learning paths and outcomes consolidate the professional competences that are acquired.

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Physics in Swiss Primary Teacher Education: A Multidisciplinary Approach

Angelika Pahl
Bern University of Teacher Education, Switzerland

Abstract.
First, this paper overviews the curriculum organization of science teaching in Swiss primary schools. It becomes clear that science education in primary school is part of the integrated subject “nature-human-society,” which includes different natural and social sciences disciplines. Second, the multidisciplinary approach in teacher training for the subject “nature-human-society” is described, and student teachers’ views are shown, which makes evident that the different content areas of this integrated subject are not equally popular among student teachers.

1 Curriculum Organization of Science Teaching in Swiss Primary Schools

Physics does not appear in the primary school curriculum, but physical contents and practices are still part of primary education. Physics is missing as subject because the natural sciences are usually taught and learned through an integrated subject, namely, science, and not in a disciplinary way [1]. In Swiss primary schools, however, science class does not occur as a single subject, but in still further disciplines integrating subject [2]. Science is merged with humanities and social sciences in one subject, called “nature-human-society.” Since the introduction in 2016 of the new, common curriculum for German-speaking Swiss Primary Schools and the associated redesign of this subject, “nature-human-society” comprises four content areas: (i) nature and technology, (ii) geography, history, and society, (iii) economics, work and housekeeping, and (iv) ethics, religions, and community. With this multidisciplinary curriculum, the “nature-human-society” lessons should support and encourage primary school pupils to explore and understand their natural, cultural, social, economic, and technical environment to act responsibly toward their living environment [3]. The approach should assure a multidimensional view of learning objects and thus avoid children accessing their living environment in a fragmented way [4].

2 Multidisciplinarity in Teacher Training and its Acceptance by Student Teachers

The special composition of the subject “nature-human-society” requires special teacher training, which brings the different content areas in the teacher program together without adding them up one after the other in only an isolated way. The training allows students to develop an appropriate understanding of the multidisciplinary subject matter and acquire the subject-integrated pedagogical content knowledge to plan and implement appropriate learning units [5]. At the Bern University of Teacher Education in Switzerland, several lecturers from different disciplines (biology, physics, geography, history, economics, religion, science, and ethics) interact to conceptualize the modules for teacher training in “nature-human-society.” However, due to the great variety of subject content, not all content can be elaborated in detail in the three years of teacher training. Student teachers may at least gain insight into the most basic concepts of all perspectives [6]. A survey conducted at the Bern University of Teacher Education showed that the popularity of the different content areas is not equally pronounced among student teachers. Also within the field of natural sciences were clear differences. Most student teachers prefer biological and dislike physical or technical content [7–9]. Therefore, in a multidisciplinary subject like "nature-human-society," there is always the risk that some content will be neglected in favor of others. Thus, during teacher training, it is even more important that student teachers' interest in and beliefs about different disciplines are worked on to develop a professionally positive attitude toward all perspectives of the subject "nature-human-society".

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Integrating Engineering into Physics for Future Teachers

Leslie Atkins Elliott & ShaKayla Moran

Boise State University, 1910 W University Dr, Boise, ID 83725

Abstract. In the United States, the Next Generation Science Standards calls for engineering — and particularly engineering design — to be part of students' science education throughout primary school, with engagement in engineering practices integrated into students' learning of disciplinary core ideas. We describe how opportunities for engineering emerge in the context of a course on scientific inquiry for future teachers, efforts to expand on those opportunities to better align with engineering design, and how these opportunities differ in important ways from more typical engineering design activities. In addition, we argue that engineering activities can support and sustain rich, meaningful inquiry.

1 Background

The Next Generation Science Standards (NGSS) [1] calls for engineering — and particularly engineering design — to be part of students' science education throughout K-12, with engagement in engineering practices integrated into students' learning of disciplinary core ideas. However, few prospective teachers have an engineering background, nor are they likely to receive even a cursory training in engineering while in their undergraduate degree program. And while designed artifacts (labs, devices) are central to scientific activity — a critical component of how scientific ideas are constructed — curricular examples of engineering for science are rare. Instead, existing curricula that integrate science and engineering primarily treat engineering as an application of scientific theory or a way of engaging students and inspiring scientific questions (e.g., [2]). For programs that hope to prepare science teachers to integrate engineering design into the development of scientific content, in ways consistent with NGSS, there are few models to draw from.

2 About the course

The course described here [3] is taking steps to address this. Initially the course was developed prior to NGSS, when the "inquiry standards" stood alone; therefore we focused on students' constructing and vetting scientific explanations without explicit attention to the correctness of those models or a commitment to the particular content being addressed. While instructors selected a phenomenon to launch our inquiry, this flexibility with content allows the course to be more responsive to questions that emerged. Topics varied, and included light, color, sound, astronomy, energy and time. Materials in the classroom varied as well, and are generally inexpensive, "everyday" materials (flashlights, plastic clocks), or "raw ingredients" (lenses, mirrors, inks, tape, string). These were available in the room or in an adjacent stockroom. When class is not in session, experiments were stored, not disassembled.

With the introduction of NGSS and engineering into primary and secondary education, we noticed the role played by designed artifacts in our course. Students frequently modify materials available, bring in new materials from home, deconstruct and reconstructing physical artifacts to support their inquiry. We identify these as rich moments to engage in purposeful engineering design. Below we briefly describe two exemplar moments. Our presentation will focus on these moments, efforts to capitalize on these for engineering design, and how they support and sustain engineering and scientific inquiry.

2.1 Opportunities for engineering

The two brief vignettes below describe how emergent questions sponsored opportunities for engineering design, which then informed our continued inquiry.

1. **Absorption of light.** As students in one course modeled shadows, a question emerged regarding the absorption of light: after how many reflections was our light too dim to be seen? One student constructed a kinked construction paper tube with a flashlight at one end. By placing the kinks so that she could no longer see the flashlight bulb, she was able to determine that, after 4 reflections, light from the bulb was essentially all absorbed (for black paper; 6 for white).
2. **Measuring speed.** In a semester focused on energy, students were using a Gaussian Gun to model energy transfers and transformations [4]. A debate arose as to whether the magnet itself provided energy to the ball; to resolve this students needed to measure that speed – for a ball accelerating rapidly over a very short distance. Among the more creatively engineered methods was the 3-d printing of a surface on which the balls would roll so they could record the sound and, from this, determine speed, seen in Figure 1.

Fig. 1 A ridged surface to measure the speed of a ball

3 Conclusion

This presentation describes how opportunities to engage in meaningful engineering emerge in scientific inquiry, and how we have capitalized on those moments to support engineering and sustain the inquiry as well.

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The virtual voice assistants in early science learning: an opportunity in Early Childhood Education

José Cantó - *Experimental and Social Sciences Teaching Department - University of Valencia (Spain).*
Almudena Marín - *Advisor to the Child Education Training Center - Generalitat Valenciana (Spain).*

Abstract. Technology is present in our lives and is also increasingly present in the classroom, as an educational tool. This fact must also have its transposition in the initial teacher training. This contribution presents a work in which virtual voice assistants are introduced as a tool in the teaching of science in early childhood education. We want to show the ideas from a group of 40 future teachers in their last year of the Degree, about the usefulness and the didactical possibilities of using virtual voice assistants as a tool in the teaching of science in early childhood education.

1 Introduction

In recent years, the common use of Information and Communications Technology (ICT), artificial intelligence and robots has spread across all educational stages including Early Childhood Education [1]. Consequently, children are exposed to digital devices from an early age. In addition, it has been proven that students work well in these digital contexts and even enjoy their use and the fact that they can speak directly to the machines [2] [3]. In this way it is not strange that in the educational field, we find that robots have been used as classroom assistants [4], or that they are even used as a tool to meet special needs in the classroom such as functional diversity or autism [5]. In this work we intend to reflect upon and investigate the usefulness of a particular multimedia resource that, for the time being, has not expanded into classrooms like those mentioned above: virtual voice assistants (VVAs).

Some works [6] [7] showed that VVA can have a greater impact on a child's cognitive development than when interacting with other devices such as computers or smartphones. In addition, they can also serve to modify many social dynamics both in the school environment and in the family environment. The key to the use of VVAs in Early Childhood Education for science is that the user interface is oral and is therefore accessible to children at this educational stage. To this, we must add that there have been significant improvements in current VVAs regarding the so-called error rate when specific questions are asked that allow a more fluid interaction with them. In this perspective, VVAs can be an effective tool to develop the potential of younger children while becoming a facilitator element for the teacher and allowing for autonomous learning. Other advantages of its use are its ease of installation (it only requires a power outlet and internet connection), its low economic cost, as well as the diversity of models available on the market (Amazon's Alexa, Apple's Siri, Google voice search...).

2 Methodology

Through focus group work, 40 students in the last year of the Infant Education Teacher degree at the University of Valencia (Spain) have reflected on the possibilities of using virtual voice assistants as a tool for teaching science in early childhood education. They have to address some questions, such as: What are the potentials of using VVAs in the classroom of childhood education as a teaching resource for science education? What needs come to cover these devices? How does the use of VVAs affect the role of the educator?

3 Conclusions

Students, analyze the different teaching uses that VVAs could have in the classroom of childhood education for science. Some of the conclusions they reached were the following:

- Stimulate oral communication since, with VVAs, can work communicative competence through the channel most suitable for one's age. This is essential so that children can express their ideas about natural phenomena.
- Be used as a source of information when researching in the classroom about a certain aspect of science that interests them to investigate.
- Use as a translator if a student who does not master the language of use is present in the classroom or you need a translation for some materials.
- Become an effective tool to accompany certain students who have special educational needs or even problems relating to their peers.
- Be search engines and narrators of oral resources for science education (stories,...).

The students concluded that the use of AVV can be very useful when considering the teaching of science in this educational stage. We believe that the use of AVVs can be a didactic tool that should be present in the science training of early childhood education teachers. For this reason, we are conducting a pilot study of its use in schools, where students in training train active teachers in its use.

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