An Inquiry-Based Approach to Physics Teacher Education: the Case of Sound Properties

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Abstract
In this paper we describe some results of an experimentation on Pre-Service Physics Teacher Education performed with a group of non-Italian Trainee Teachers engaged in one-month mobility activities at University of Palermo, in the framework of the EU Project "Move'in Science". Some preliminary results of the experimentation of a Teaching/Learning Unit about Mechanical Wave propagation are presented, with particular reference to mental models about wave propagation evidenced by Trainee Teachers. Their understanding of the relevance of pupils' mental model knowledge, in the framework of what a teacher should do to be an "effective" teacher, is also discussed.

1. Introduction

The design and validation of new models for pre-service and in-service science teacher education is a key subject in today's Science Education Research. Many literature results show the pedagogical efficacy of educational approaches where teachers work in special-designed teaching/learning environments, concentrating on inquiry-based laboratory and modelling activities [1, 2].
The growing awareness of the centrality of teachers in all learning processes [3, 4], has pushed the research community to focus on teachers' knowledge and how it can be directed towards an appropriate form for teaching [3, 5] by integrating subject matter knowledge and pedagogical knowledge into a form of knowledge appropriate for teaching, the Pedagogical Content Knowledge (PCK) [6, 7].
Research has built on educational models scaffolding the development of PCK in in-service and pre-service teachers, by analyzing its construct in experienced school teachers [8], or designing and experimenting learning environments based on the Educational Reconstruction model [2, 9, 10]. Different PCK features have been found that can help the researcher to define and shape PCK building in teachers [11]. Particularly, Park & Oliver [8] have found that teachers' understanding of students' misconceptions (or common sense mental models, see [12]) is a salient factor that can shape PCK in planning and conducting instruction and assessment, and is, so, important to develop.
In this paper we describe some phases of an approach to Pre-Service Physics Teacher Education developed at University of Palermo and implemented in different contexts [2, 13, 14]. In particular, we here refer to the implementation of this approach in the framework of the EU Project "Move'in Science" [15]. The Project, dealing with Physics and/or Mathematics Pre-Service Teacher Education, involved seven Institutions from six different European Countries: Belgium, Germany, Lithuania, Italy, Romania, and Slovak Republic. It was aimed at proposing transformation of the teacher education approach to get to new models of PCK building in Trainee Teachers (TTs). The Project general approach was to stimulate an inquiry-based set up in teacher education, where TTs start from problematic situations commonly found in real life and are guided to test on their own understanding the same teaching/learning tools they are supposed to use with their future pupils.

Here we discuss some phases of a Workshop (W) on Mechanical Wave propagation administered to a group of non-Italian TTs engaged in the one-month MiS mobility activities at University of Palermo.

2. The Workshop on Mechanical Wave propagation

The W (30 hours) has been structured in different phases, which analysed the basic physics knowledge concerning mechanical wave propagation. In detail, the W focused on

1. the analysis of pupil mental models about wave propagation;
2. the study of real life situations concerning waves and sound;
3. the preparation of teaching/learning sequences to be experimented in Upper Secondary School classrooms.

The W development shared many characteristics with the Italian approach to Science Teacher Education, that can be defined as a "sequential" approach. This means that the acquisition of the disciplinary knowledge is intended as a pre-requisite to education for teaching. As a consequence, our hypothesis about PCK construction involved that TTs had a basic knowledge of the physics subject matter. A detailed description of the whole W is reported on the Project web site (http://www.mis.unipa.it/handbook/item3/partner1/intro.html), as well as the experimentation results

Here we will concentrate on the first phase concerning the analysis of pupils' mental models (MMs) about wave propagation. It has been divided into two sections where TTs were requested to attend different kinds of activities: a) to answer an open questionnaire, drawn from literature [16], where they were requested to describe, predict and explain some everyday wave phenomena; b) to analyse questionnaires and interviews administered to pupils in different countries and reported in literature, in order to draw some common conceptions, held by high school pupils, concerning the functioning of some wave phenomena.

3. Study description and methods

3.1 Research questions

The study here described was devoted at verifying:

a) if the nature and level of the TTs' initial understanding of physic subjects were adequate to describe/explain everyday phenomena and develop the disciplinary competencies required by a teaching approach based on inquiry;
b) if the knowledge of spontaneous models of pupils and of typical pupils' learning difficulties was considered by TTs a relevant competency for a teacher.

3.2 Participants, data collection and analysis

Ten TTs (6 female, 4 male) attended the W activities. They were graduated in physics or mathematics and came, in couples, from the partner countries. TTs' disciplinary knowledge was heterogeneous, as 6 of them studied physics in their university curricula with a sufficient degree of deepening, while the remaining 4 attended just an introductory physics course during their university studies.

As pointed out by Kagan [17], a whole set of instruments is needed to capture the complexity of teachers' knowledge. A combination of approaches that can give detail about what teachers believe, what they know, what they do in class, and why, is necessary to verify PCK acquisition. With respect to the session on MMs we discuss here, we collected data from answers given by TTs to a questionnaire, from interviews and from observation reports regarding TTs' participation to the pedagogical activity. Data coming from the analysis of the teaching/learning sequence prepared by TTs at the end of the W were also took into account,

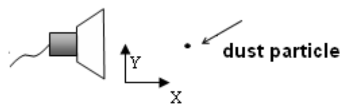
in order to verify if the relevance of using pupils' MMs in teaching has been grasped by TTs during the W development.
Two researchers were involved in the study, administering in turn the pedagogical activities and recording questions and problems posed by the TTs, concerning physics content and pupils' MMs. Two "independent" observers participated to activities; they watched the pedagogical activities being not directly involved in the teaching/learning processes. They audio-taped and transcribed all activities, and interviewed TTs during and after the session, to go into detail about specific points of strength or weakness of the approach.
All data were analyzed independently by the two researchers, trying to reach a consensus when any disagreement was found during analysis. The focus was on the identification of regularities and patterns in questionnaire answers, observation and interview transcripts, in order to present a comprehensive analysis of TTs' participation to the session from several perspectives and to enhance the internal validity and reliability.

4. Findings and discussion

The analysis of TTs' mental models about wave propagation has moved from the recalling of the theoretical model of the Educational Reconstruction and the introduction to the knowledge of pupils' mental models as a relevant point of a teacher professional knowledge. A class discussion has been developed, in order to clarify the meaning of the expressions "Common Sense Knowledge" and "Mental Models". Then, an open questionnaire drawn from literature [16] has been administered to TTs, where they were requested to describe, predict and explain some everyday wave phenomena.
TTs' written descriptions were classified in categories on the basis of a close reading of their explanations within a framework provided by domain-specific expertise. We identified TTs' mental models through the definitions supplied by their descriptions, as well as through the set of properties identified by TTs as characteristic of the analysed situations. Through triangulation we verified that model definitions came out from TTs' statements and were not imposed on them.
One of the questionnaire items is reported below. The item is followed by a table, resuming the typical answers given by TTs and the MMs evidenced by them, with their main characteristics. For more detail see [15].

ITEM 1

A dust particle is located in front of a silent loudspeaker. The loudspeaker is turned on and plays a note at a constant pitch. Predict the motion of the dust particle and explain the reasons of your prediction.



Category	Characteristics	Typical answers (no. of TTs giving the answer)
MM_A - 1	No motion (sound propagation does not perturb the dust particle)	*Sound does not influence the dust particle which remains still* (1) *Dust particle continue to move randomly (sound does not influence it.* (1)
MM_B - 1	Forward motion (sound, or loudspeaker, pushes molecules in a forward direction as a sound wind)	*It moves forward due to loudspeaker push* (4) *It moves because waves push it forward* (1)
MM_C - 1	Oscillation (loudspeaker membrane produces vibration in	*The particle oscillates back and forth due to the motion of air molecules around it*

	the air molecules, or dust particles, which oscillate forward and backward)	(3)

In the second section, TTs have been made aware of some common conceptions, held by high school pupils, concerning the functioning of some wave phenomena. TTs analysed questionnaires and interviews administered to pupils in different countries, concerning the topic we were interested in. They analysed the explanations supplied by pupils and identified one (or more) representations/mental models that, in their ideas, were responsible of the different answers. TTs worked in groups of two, by following a prepared worksheet where they reported the pupils' answers and their inferences about the kinds of pupil Mental Model that could be responsible of such answers.

Another point deepened by the interviews in this section has been the TTs' initial perception of the usefulness for a teacher of the knowledge of pupils' mental models. The need to take into account pupils' spontaneous models during teaching was well acknowledged from the very beginning by the great majority of TTs. However, the personal experience of TTs can make such idea not so obvious; in fact, we want to evidence the attitude of one of the TT teams, whose components, when faced with the need to take into account common sense reasoning and pupils spontaneous models, clearly stated that taking into account these aspects of pupils' knowledge could distract teachers from their task.

> Q: *do you think that searching for common sense knowledge models used by students and identifying their common reasoning strategies is useful for a teacher?*
>
> A: *We are not used to doing this in our country. Learning that there is a whole branch of research devoted to this aspects of pedagogy was an interesting experience but we feel that a teacher should not bother to know what are the student's spontaneous models and, more generally, why she/he does not understand.*
>
> Q: *Why do you think that a teacher should not take care why a student does not understand?*
>
> A: *A teacher usually does not have time to stop her/his lesson and analyze all pupils' difficulties. ... the teacher simply has to teach and the student has to learn the subjects, substituting her/his wrong ideas with the scientific ones.*

This radical attitude was shown by both the members of the team. However, the analysis of the final teaching/learning sequence prepared by TTs and the observation reports of their apprenticeship activities in real classrooms pointed out that after the W these two TTs somehow modified their mind. Their TLS was planned by making an acceptable use of learning tools aimed at mixing up pupils in the pedagogical activities, orienting them towards an inquiry based approach and identifying as starting points some relevant pupils' learning difficulties identified in the previous phases of the section.
The analysis of all data collected in the session on MMs allow us to report the following considerations, with respect to 4 main aspects of our TT sample:

1) Only 3 TTs showed to possess mental models in good accordance with scientific ones. They were graduated in physics and had previously studied the subject of mechanical wave propagation, with particular attention to experimental, as well to modelling activities. 3 TTs showed a knowledge about wave propagation just adequate for

teaching but the remaining 4 evidenced naïve mental models, similar to those evidenced by pupils.

2) The analysis of pupils' answers has been actively performed by the majority of TTs, even if their initial personal beliefs were not resonant with the idea of listening to spontaneous models and common sense reasoning to build effective pedagogical activities. The analysis of TTs' final teaching/learning proposals have shown that more or less all of them have perceived that a major goal of scientific education is to link what pupils learn with their spontaneous conceptions and, more generally, with their everyday lives.
3) Only a few TTs were able to identify relevant learning knots of the subjects. The learning knot mainly identified was that many pupils think that sound is a thing (like a substance) propagating across the matter molecules.
4) All TTs participated with interest to the activities, but not all have been really engaged in the initial open questionnaire. In particular, two TTs, graduated in mathematics, did not show great interest in the test. When interviewed about their attitude, they answered that they never studied physics in depth; they were afraid that this could affect their answers and, for this reason, they were not answering to the questionnaire.

5. Conclusions

The analysis of data previously reported allow us to draw some conclusion with respect to our research questions. On the basis of the initial open questionnaire results and of the interviews and observations we can infer that the initial general subject-matter understanding of the majority of our TTs was not adequate to develop the disciplinary competencies required by teaching approaches focused on inquiry. Some TTs showed a good knowledge of mechanical waves, evidencing mental models about the subject in good accordance with scientific ones, but only a few were equipped with a deep knowledge of some significant factors which are considered relevant in influencing learning, such as: to encourage accurate observations of phenomena, to carefully plan experiments and to search for predictive explanations. Other showed a knowledge of mathematical laws but were not able to provide coherent explanations for their observations and ideas about how the world works.

The initial perception of teachers' understanding of students' common sense mental models as a salient feature of PCK that is important to develop was somehow mixed. 8 out of 10 considered relevant the knowledge of student learning difficulties and agreed on treating naïve conceptions as the starting point for effective teaching activities. Class discussion made evident their awareness of teaching as an activity addressed at coherently modifying naïve ideas, redirecting them towards scientific reasoning. Yet, two TTs evidenced poor initial attitude at reflecting on student learning difficulties and did not considered the understanding of students' spontaneous models as a really relevant PCK competency.

It must be taken into account that very often prospective teachers (and sometimes experienced teachers) show the same learning difficulties and representations of their future pupils. This fact points out the need to supply TTs with tools aimed at a deeper understanding of specific topics. Other results involving our W structure [2, 13, 14] have pointed out the importance of a TTs' thorough and coherent knowledge of subject matter. In our view, the value of PCK lies essentially in its relation with specific topics. Therefore, PCK is to be discerned from general pedagogical knowledge on the one hand, and from subject-matter knowledge on the other.

As the global results of our W show, the W organization supplies insight into the ways physics teachers can transform their knowledge of mechanical waves to stimulate pupil understanding of this topic as well as to gain a better understanding of the topic. The case study here described shows that to reflect on pupils' common sense mental models and to compare these models with their own representations of phenomena supply TTs insight in identifying the crucial learning knots, by providing them with a knowledge base enabling to teach specific topics in more effective and flexible ways.

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