Inquiry Based Science Education strategies for Training Teachers of secondary schools in environmental issues: a case-study from Spain.

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Abstract

The Spanish experience in the promotion of the Inquiry Based Science Education (IBSE) strategies using and developing special courses (Course Professional Development, CPD) is presented in this work. The Four Stage CPD Model is proposed in the European PROFILES (*Professional Reflection-Oriented Focus on Inquiry-based Learning and Education through Science*) project and has been performed with pre-service teachers for science in secondary level. The course has been oriented to develop issues related to environment, given its importance as socio-scientific issue. The course promotes IBSE through raising the self-efficacy of future science teachers to take ownership of more effective ways of teaching students. The contribution of the CPD approach to developing teachers' ownership was analyzed according to the reflections of the participants. The findings indicated a gradual increase of teachers' sense of ownership towards IBSE.

Keywords: *IBSE Strategies, Environmental issues, pre-service teacher training, teacher ownership.*

1. Introduction

Large scale international comparative studies in science, as PISA (Programme for International Student Assessment) have shown that Spanish students perform relatively poorly and at a significantly lower level than is expected (OECD, 2017). According to the strategy document of Rocard et al., (2007), improvements in science education should be brought about through new forms of pedagogy, like the introduction of inquiry-based approaches in schools. In terms of student learning, the Rocard-report (Rocard et al., 2007) claims that inquiry-based methods are effective in terms of increase of student interest and attainment levels. Inquiry based learning (IBL) is a teaching pedagogy that already in the 1950s appeared in the western world (Anderson, 2007). IBL has also proved its efficacy (at both primary and secondary levels) in increasing children's and students' interest and attainments levels while at the same time stimulating teacher motivation (Rocard et al., 2007). Today, it is used in several disciplines, and particularly in science, it is called Inquiry Based Science Education (IBSE) internationally.

Several studies have shown the convenience of approaching the science teaching from an inquiry based methodology because it increases students´ interest and attainments levels and stimulates both, students and teachers motivations (National Research Council 1996, Crawford et al. 2014). This change in science teaching, from mainly deductive to inquiry-based methods, implies directly to teachers, key players in the science teaching renewal. Teacher's abilities, self-efficacy and ownership in the implementation of new methods of teaching and their motivation and collaborative reflection with other teachers are essential elements for the success of any scientific educational renewal (Rocard et al., 2007).

In order to address this situation several projects at European level have been funded where the focus is on exploratory and curiosity-driven approaches to learning. One of these project is PROFILES (*Professional Reflection-Oriented Focus on Inquiry-based Learning and Education through Science*) (Bolte et al 2011) which has been supported by the European Union Seventh Framework Programme. The project is focus on the implementation of new material, PROFILES modules, with secondary school level students, based on inquiry science learning. In this way, it could generate new and innovative learning processes in this educational level. The intended outcome is school science teaching becoming more meaningful, related to 21st century science and incorporating interdisciplinary socio-scientific issues and IBSE-related teaching, taking particular note of gender factors. Then, given the importance to promote IBSE at high schools, training pre-service teachers is required.

One of the goals of the PROFILES project was to implement the "Course Professional Development" (CPD) for training pre-service and in-service teachers. The project focuses on "open inquiry approaches" as a major teaching target and pays much attention to both intrinsic and extrinsic motivation of students in the learning of science. The proposed innovation is developed through working with 'teacher partnerships' to implement existing, exemplary context-led, IBSE focussed, science teaching materials enhanced by inspired, teacher relevant, training and intervention programmes. This is undertaken by reflection, interactions and seeking to meaningfully raise teacher skills in developing creative, scientific problem-solving and socio-scientific decision-

making abilities in students (Holbrook 2012). The measures of success are through (a) determining the self-efficacy of science teachers in developing self-satisfying science teaching methods and (b) in the attitudes of students toward this more student-involved approach.

In this work, a description of the courses (CPD) developed by the Spanish group of PROFILES are described, where new modules related with socio-scientific issues, as environmental topics, have been proposed by the pre-service teachers. The course is part of the Four Stage Model design for training teachers. This paper reports on teachers' experiences and reflections about teacher professional development event arranged in connection with the European PROFILES project.

2. Teacher training through the Course for Professional Development (CPD).

The Course for Professional Development (CDP) has been performed into the Master for training teachers for secondary schools in different subjects. These courses begun in the academic year 2011-2012 and have been taking place until now, every year. These course has been implemented with the pre-service teachers for Secondary School in the Faculty of Education at University of Valladolid (Valladolid, Spain). The CPD has been developed within the subject of "Methodology and Evaluation in Physic and Chemistry", which takes 40 hours, and it is always developed face to face.

We design the CPD following the philosophy of the PROFILES project and focus on topics of environmental education. The course has been designed how is described as follows:

1. The first part takes 5 hours of inquiry based learning of science instruction and the relevance of stimulating intrinsic motivation of students for improving their science literacy. For this part, classical and new bibliography, including that published by members of the project is used. No scientific content is included in these course, given that all of the participants have the Grade in Chemistry and Physics.

2. In the second part, which takes 10 hours, pre-service teachers get familiarized with several PROFILES modules, which are very good examples of the application of the IBSE strategies. For this session, the participants work in small groups (2-3 person), and they discuss about the different activities propose in the modules. At the end of this process, they report each other's the main reflections made in the different groups about the modules analysed.

3. In the third part, they continue working in groups, but now they have to develop a module following the PROFILES guideline and the 3 stages format (Figure 1), and related with an environmental issue. They must take into consideration the importance of choosing relevant approaches for their future students in order to stimulate their motivation. This part takes 25 hours in total, but it is divided in three activities. The first activity is dedicated to design the module, which it takes 10 hours. The second activity, which can take also 10 hours, includes a practical experience in the laboratory, or a virtual experience, which has to be tried by the group of the pre-service teachers, which has to decide about the instructions to be included in it. And, the third activity consists in an oral presentation of the module, with emphasis in the

level of the secondary education within could be implemented, and it takes the rest of the hours available.

When pre-service teachers conclude the CPD, they has to practice in high schools by a period of five weeks teaching. This period can be used for performing their own module, and later, they can do a reflection about the experience, devoted to discuss this approach to teaching and learning sciences and to reflect upon the experience of working with the modules.

The next step, which is it not decided by all the pre-service teachers, is to prepare their master thesis focus on their own experience with developing and implementing IBSE modules with students.

Finally, after that, some of the future teachers decided participate in conferences and workshops with a poster showing their own module and their experience with the students at the high school.

3. Training teachers developing IBSE strategies in environmental sciences issues.

In this section we present an experience carried out with pre-service teachers where they design several modules focus on environmental issues. Several modules were designed during these six CPDs, which are concerning about many environmental topic and problems, as per example, "The importance of recycling. The mechanism of the city where you live for doing it", "Need to know about the meaning of the symbols in the packing when you go to the supermarket", or "Will our coastal areas be submerged because of Global Warming?"

Pre-service teachers were asked to plan an investigation in order to identify the main reasons of the each of the topic chosen. The competences involved are: Investigative skills, manipulative skills, cooperative-work skills, concept understanding, theory development and application, experimental-error analysis, and communication skills. The curriculum content is related to that for secondary level in science, and particularly in Physic and Chemistry. The modules follow the PROFILES three-stage model (Holbrook & Rannikmae, 2007). The module begins with a scenario (Stage 1), where the teacher describes in a few words the main idea under the title and presents to the students the problem. At Stage 2, students have to resolve an inquiry-based problem-solving activity. This activity consists of searching pertinent information that supports student's knowledge and implementing an experimental plan, in every case under study. Additionally, the students have to determine the problems associated to some usual activities in their lives. Lastly, at Stage 3 (Socio-scientific decision making, Fortus et al., 2005), students relate data collected from their search and investigation (observations in the lab and data from internet, per example) in order to give an informed opinion to the question (Bond-Robinson, 2005).

One of these modules developed by a group of the pre-service teachers, was that entitled "Will our coastal areas be submerged because of Global Warming?" Pre-service teachers were asked to plan an investigation in order to identify the main reasons of the Global Warming. The curriculum content is related to Chemistry, and in particular, to the study of the water properties in solid state, density, hydrogen bond, and others. This module begins with a scenario (Stage 1), where the students are asked about which means the Global Warming, and their opinion about that, if they

think if it is true or false. The module suggests to the teacher to open a brain storming for the student to know about the evidences of the Global warming. The teacher concludes this step presenting to the students the following question: Will our coastal areas be submerged because of Global Warming?" For asking this, the students have to inquire about the probability of losing our coasts if the sea level increases and why? At Stage 2, students working in groups, have to resolve an inquiry-based problem-solving activity. This activity consists of searching pertinent information that supports student's knowledge and implementing an experimental plan, in order to know more about the water-ice mix properties. Additionally, the students have to determine the CO_2 emissions associate to some usual activities in their lives doing some calculations in the web page http://calcarbono.servicios4.aragon.es/index.html. Lastly, at Stage 3 (Socio-scientific decision making), students relate data collected from their search and investigation (observations in the lab and several calculations) in order to give an informed opinion to the question.

4. The study case of Alfonso: reflections of a pre-service teacher

One of our pre-service teachers was Alfonso. He attended to the CPD, and he was part of a group that developed a module on Climate Change. His colleagues, who worked in the same team, wrote in their reflections about the fruitful and pleasant experience they felt working with Alfonso.

> *The fact that we were working as a team during the CPD showed that the networking of teachers improves the quality of teaching and promotes the motivation, especially when working with somebody as enthusiastic as Alfonso.*

Later, during the practice period which involves a teacher's practice period in a High School, he had the opportunity to implement in the classroom the module that they had previously developed "Will our coastal areas be submerged because of Global Warming?" which has been shortly described in the previous section. He was very motivated after the implementation of the module in his classroom, and he wrote about his experience:

> *Using PROFILES modules can help students to get some capacities like motivation, encourage, and reflection about their own work, something useful not only for improving their science knowledge but for their own lives. I can remember as one student told me after using the Module about Global Warming in which we learned curriculum content related to Chemistry, and in particular to the study of the water properties in solid state, density and hydrogen bond: "Something that we have checked will be in our memory better than something that simply we have red or they have explained to us".*

At the end of the course and when the practice period conclude, he decided to prepare his academic Master Dissertation o Master Thesis about his experience with the PROFILES philosophy using IBSE strategies and his own module at the High School. His project, entitled "Preparing IBSE material: teaching science in Secondary Education in an efficacy and amusing way", showed his deep identification with PROFILES and a sense of professional development

during the CPD. He defended the importance of the IBSE strategies in science education, and explained how the experience working with the module in the classroom was, in this way:

> *The way from a transmitting to an inquiry methodology is a long and complicated process, but it really makes sense. I have experienced that students learning are more consistent and permanent. Teachers have to continually encourage students to contribute their ideas and engage in critical problem-solving process in a variety of contexts whether curricular or social. Stimulating student´s curiosity contributes to deeper questions and favours critical thinking.*

After that, he and his colleagues had the opportunity to show the module they developed and implemented on the classroom at the first PROFILES conference in Berlin as a poster (Padilla et al. 2012).

Thinking about his experience of training, Alfonso writes some reflections about his opinion on IBSE strategies in the following terms:

> *Working with the PROFILES philosophy has helped me to confront the idea that we live in a continuous changing world that affects to all of the life fields, particularly at school, as a social microcosms that reflects the environment in which is involved. We are far away from a school full of memory and authoritarian teachers. Today we have students with other characteristics and that demands changes in the competencies of teachers.*
>
> *We, as teachers, have to form citizens able to look for, select, store, organize, and make meaningful the information without getting lost. Moreover, students have to be able of communicate their experience. Because of that, allowing students to experience learning science in a different way showed me that they became more autonomous in their learning, which is essential intellectually and personally.*
>
> *I have noticed how students are much more interested in exploring a topic when they appreciate its relevance to their own live experience.*
>
> *In more traditional classrooms, the teacher is the expert of knowledge and transmits information to students through a well-organized series of lessons. In an inquiry-based learning environment the teacher is a facilitator. Teaching and learning about the natural environment is fundamental to understand global systems. The following cite resumes the idea: "Basic understanding begins with exploring how things happen. Observing how things happen in the natural world is the basis of some of the most ancient and spiritually profound teachings of Indigenous cultures. Nature is the first teacher and model of process. Learning how to see nature enhances our capacity to see other things".*

Other important point in order to know how the CPD goes on, it is to identify the main difficulties found by our pre-service teachers in order to improve the development of the course. For this purpose, pre-service teachers were asked for writing their opinions. One of these contributions was

the Alfonso´s reflection about the development of the module on Climate Change during the PROFILES CPD, which is as follows:

> *The design of the module with the teachers' team during the course was a laborious task, not only trying to make it motivational for students but to relate it to their real life and establishing a relationship with the curricular content. We knew that the chosen topic would be attractive for them because students are aware of problems of climate change but we thought a lot about approaching and introducing the topic, the first stage of the module. Finally we decided to propose the idea of the possibility of losing our coastal areas and the fact that I implemented the module next to the summer vacations, which includes beach time for most of them, was a successful way.*
>
> *To develop the scientific content of the module was maybe the fastest part, we felt more confident compiling this part, no so much designing it in an inquiry based approach, in which we wanted to include some laboratory work. Finally, we made the decision of including lab tasks with decision making questions that would force students to debate. The argumentation of their findings among the different groups in the classroom at the end of the work was the most gratifying part for me, as a teacher.*
>
> *Probably following attempts will be easier, I hope, but to get confident when using inquiry based science teaching requires a very reflexive approach and I know teachers in some grades do not have the time that IBSE requires. In any case, the experience was very positive for me, and I think also for students.*

5. Results and discussion

This study presents an overview of the development of the Four Stage Model which is proposed in the European PROFILES project and has been performed with pre-service teachers for science in secondary school. These four dimensions can be seen as constituents of the PROFILES model of developing teachers' ownership towards IBSE (Blonder, Mamlok-Naaman & Hofstein, 2008), which is shown in Figure 1 and includes:

(a) teachers as learners,
(b) teachers as teachers,
(c) teachers as reflective practitioners and
(d) teachers as leaders.

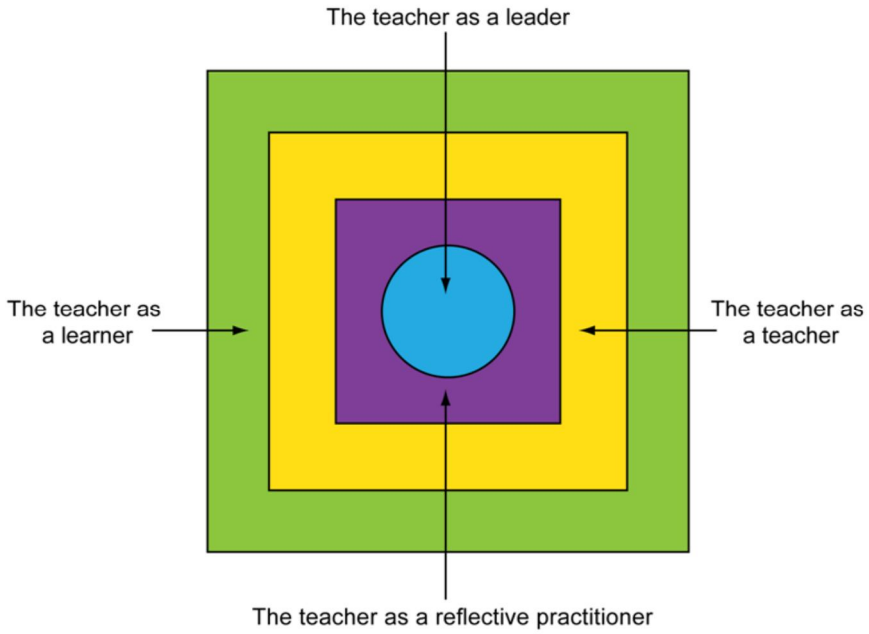

Figure 1. The Four Stage CPD Model (Hofstein et al 2012)

This ownership model provides teachers the opportunities

a) to enrich their pedagogical background about IBSE (Teachers as learners),

b) to design and to implement IBSE modules into their classrooms (Teachers as teachers),

c) to reflect on their experiences and to participate in action research (Teachers as reflective practitioners) and

d) to disseminate the philosophy and ideas to their colleagues and other relevant stakeholders (Teachers as leaders).

The focus of the CPD in science education can be categorised broadly into subject knowledge enhancement, management of practical work, pedagogic approaches and leadership. The importance of content knowledge for both primary and secondary teachers cannot be understated and there are many studies to show how confidence in subject knowledge underpins the ways in teachers interact with students. The study of Hoban (2002) is particularly useful in considering what is needed to bring about teacher learning.

Then, it is suggested that in order to develop a sense of ownership among teachers, it is vital to develop the teachers as learners and as practitioners in their classroom. In other words, the goal should be to equip the teachers with the relevant content knowledge (in PROFILES context the scientific content and its related social applications) and the aligned PCK (pedagogical content knowledge). These are teacher-centred approaches in which he/she is in control regarding content, pedagogy and implementation. Initial teacher education should itself be inquiry-based, and should give pre-service teachers the possibility of conducting their own inquiries into practice.

The two developments, namely the teacher as learner and the teacher as teacher, are the two initial and basic components in the Four Stage CPD Model. It is suggested that the 3rd stage, namely the teacher as a reflective practitioner, is the initial stage in which sense of ownership starts to be developed in the teacher's mind. In addition, the fourth stage is the foundation stage for further development leadership oriented characteristics and behaviours (Hofstein, Carmi, & Ben-Zvi, 2003).

Based on the data collected, the approach was successful in helping the teachers develop their sense of ownership of IBSE and become agents of change themselves. The contribution of the course approach to developing teachers' ownership was evaluated, analyzing the written reflection of the pre-service teachers. The findings indicated a gradual increase of teachers' sense of ownership towards IBSE. And, after the implementation CPD with future secondary teachers, we can reported about the Teachers who participated in CPD developed, in themselves, creativity and experimental skills and gained new ideas and perspectives on science education. Many of them changed their teaching style and focused more on an inquiry-based approach. They learned a lot from each other by working together.

Within this intended outcome, and by means of the training/ intervention linked to stakeholders (Bolte et al 2012) support, a key target is to convince teachers that methods they have studied and tried in the pre-service training course can and will strongly improve the quality of their own science teaching (Michelsen & Lindner 2007). Furthermore teachers who participate in the training program course appreciate the need to convince other teachers to interact and seek support (e.g. colleagues in their schools, or from 'nearby schools') by disseminating their new experiences and the PROFILES IBSE-modules through informal and/or formal teacher forums. This can both be through activities organized by the PROFILES consortium partners or follow-up to the longitudinal training programs at a national and Europe-wide level (Bolte et al., 2009, 2011).

Based on the findings from this small-scale study it can be argued that working with teachers on curriculum materials can support teacher learning and professional development (Ball & Cohen, 1999). An interesting, though not entirely surprising, result was that teacher learning was enhanced by collaboration. Collaboration with colleagues can influence the need to explain their beliefs and practices and to articulate rationales for instructional decisions, helping teachers to make their beliefs and understandings visible. Most teachers wanted to cooperate more closely with colleagues about IBSE, which is one of the main objectives of the PROFILES project.

6. Conclusions

The convenience of approaching science education from an inquiry-based strategy has been underlined by several studies, which adduce that both the level of interest and the achievements of students are enhanced, as well as teachers' motivation.

The training course positively influence the teachers' competence and confidence to promote IBSE-related science teaching and hence raise their self-efficacy to teach in an innovative – more student centered, context-led IBSE manner as well as in valuing use-inspired research ideas. This fact supports the need for developing activities in which such competence is promoted.

We have observed that science education courses focus on using students' inquiry learning and teaching experiences stimulate critical reflection and more positive attitudes and beliefs about inquiry approaches, which increase the self-efficacy of pre-service teachers. The Courses for Professional Development (CPD) as a part of the Secondary school Teacher Master program has showed the usefulness also for disseminating the philosophy of the project.

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