28 Applying Inquiry Based Science Education & Modern Assessment Techniques in the Classroom: A Case Study in Primary School

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28.1 Abstract

In this paper we describe a case study in Primary Education that promotes students' inquiry skills in Physics. The case study was implemented in an authentic primary school class, the learning content is based on the 'Electricity' unit, and the underlying scenario was supported by AESOP's electronic platform. The main target of this study was to investigate effective educational techniques along with the different ways they can be used in order to develop inquiry skills in primary school students. The added value of the specific intervention derives from applying a combination of various modern assessment techniques that can be used to assess inquiry skills in depth as well as from leveraging the electronic platform "AESOP". Finally, this paper includes the evaluation findings of the pilot implementation carried out so as to scrutinize the degree of acceptability, effectiveness and efficiency of the inquiry based science education.

28.2 Keywords:
Inquiry Based Science Education, Inquiry Skills Assessment, Modern Assessment Techniques.

28.3 Introduction

Inquiry Based Science Education (IBSE) has been recognized as an educational priority, which is promoted by both European and international reports on the effectiveness and suitability to increase the motivation and students' engagement in science and officially supported by many countries for the overall improvement of science education (Abd-el-Khalick et al., 2004; Rocard et al. 2007; Minner et al., 2010, Bolte et al., 2012; Wallace et al., 2003). In addition, it has already been established as one of the educational approaches that support several of the features that have been emerged as priorities in the teaching of science, such as developing complex and critical thinking, active learning and in-depth processing of information (Hu et al., 2008; Minner et al., 2010; Bolte et al., 2012; Kostelníková&Ožvoldová, 2013).

The implementation of IBSE in the classroom is related to findings which support the claim that a developmental hierarchy of skills and understanding underlies, and should be identified as an objective of inquiry learning (Kuhn, Black, Keselman, & Kaplan, 2000). The added value of developing inquiry skills is that the latter are directly linked to the so- called "Key Skills and Competences" identified by several frameworks and policy documents as important for 21st Century learners and citizens (Ananiadou& Claro, 2009; Binkley et al., 2010; Minner et al., 2010; PISA, 2010; P21, 2009).

However, there is interest in how education and society, more generally, cannot only advance but also measure the competency, skills and experiences needed by productive, creative students, workers and citizens (Griffin, McGaw, & Care, 2012). In both Greek and international bibliography there has been a significant number of Inquiry based learning scripts for Teaching Science in all levels of education.The main weakness lies in the fact that they do not include assessment methods and tools. In addition, while many projects have focused on the evaluation of conceptual understanding of science principles development, there is a clear need to evaluate other key learning outcomes, such as process and other self-directed learning skills, with the aim to foster the development of interest, social competences and openness for inquiry so as to prepare students for lifelong learning. For the teacher, assessing students' performance in Inquiry based learning scripts is a particularly difficult and challenging venture, as they will have to take into consideration, record and evaluate a variety of parameters (Darling-Hammond & Adamson, 2010). Evaluation of inquiry skills can be supported by modern assessment techniques, such as concept maps, rubrics, peer assessment, self-assessment, the work folder, etc. (Petropoulou, Kasimati, & Retalis, 2015).

The structure of this paper is as follows. In the next session a literature review on Inquiry Based ScienceEducation philosophy, instruction and implementation is presented. Next, we portray our proposed inquiry based learning scenario. Emphasis is given on the ***inquiryskills*** that the educators are expected to nurture their students as well as multiple ***modernassessmenttechniques*** that they utilize in order to assess these skills. The paper ends withconcluding remarks and plans for future work.

28.4 LiteratureReview

According to Linn, Davis and Bell (2004) inquiry is *"the intentional process of diagnosing problems, critiquing experiments, anddistinguishing alternatives, planning investigations, researching conjectures, searching forinformation, constructing models, discussing with peers and forming coherent arguments."*

Originally, the term *inquiry* is addressed particularly in science education (scientific inquiry) and refers to at least three distinct categories of activities: a) what scientists do, b) how students learn and c) a pedagogical and teaching approach adopted by educators (Minner et al., 2009). Thus, the term Inquiry Based Science Education (IBSE) is used to assign this orientation and to declare an educational approach, which involves teaching and learning of

science and is conducted through the systematic and principled research process of pursuing and refining explanations for phenomena in the natural or material world.
Inquiry is presented as a scientific process of active exploration by which students use critical, logical, and creative thinking skills to raise and engage in questions of personal interests. Driven by their curiosity and wonder of observed phenomena, inquiry investigations usually involve generating a question or problem to be solved, choosing a course of action and carrying out the procedures of the investigation, as well as gathering and recording the data through observation and instrumentation to draw appropriate conclusions. As students communicate and share their explanations, inquiry helps them connect their prior understanding to new experiences, modify and accommodate their previously held beliefs and conceptual models, and construct new knowledge. In constructing newly formed knowledge, students are generally cycled back into the processes and pathways of inquiry with new questions and discrepancies to investigate (Llewellyn, 2002).
IBSE can be organized through various instructional models (such as the 5E model), which can be all considered as variations of the cycle described above and structure the inquiry-based lessons in science. However, they differ on the degree of teacher direction.
The priority on the use and implementation of IBSE is indicated as there have been several large scale projects funded under the European Seventh Framework program such as S-TEAM, ESTABLISH, Fibonacci, PRIMAS, Pathway and SAILS. Although, SAILS is the only one focused on the assessment of the inquiry skills by developing appropriate strategies and frameworks for the evaluation of IBSE skills and competencies. The project team has collaborated with local science teachers to publish a collection of 19 SAILS Inquiry and Assessment Units which showcase the benefits of adopting inquiry approaches in classroom practice, exemplify how assessment practices are embedded in inquiry lessons and illustrate the variety of assessment opportunities and processes available to science teachers (SAILS, 2012).
But how does one assess skills such as developing hypothesis, forming coherent arguments,working collaboratively or carrying out investigations? Evaluation of inquiry skills cannot be adequately supported by traditional assessment methods (teacher asking oral questions, tests etc.) as the use of classified criteria is required. On the other hand, a combination of modern assessment techniques is utilized in order to evaluate such skills. An assessment rubric, for instance, consists of special pre-established performance criteria and may include additional methods, such as peer assessment or self-assessment. However, these contemporary techniques demand great effort for teachers. Therefore, case studies are needed. In this context we developed our current work.

28.5 The case study

The particular case study was implemented by three educators and their fifth grade students (75 in number, mixed ability and gender) at “DE LaSalle” Primary School of Alimos in Greece. The implementation was supported by AESOP's electronic platform (http://aesop.iep.edu.gr/).

28.5.1 Description of the learning script

Students often seem to find difficulty in associating daily phenomena with scientific knowledge. In addition, some students strongly resist new knowledge by maintaining their alternative conceptions of physical phenomena. The specific learning script refers to Physics in Primary Education and it pertains to the section of ‘Static Electricity’. The understanding of static electricity as a concept and as a phenomenon is a prerequisite for the subsequent study and investigation of other phenomena such as electricity and electromagnetism. Students should be able to make reasoning with abstract concepts, such as "current", "energy", "load" etc. However, some students find it difficult to distinguish these concepts. They often use the term "electricity" instead of an appropriate or a more specific term. Moreover, although students have experienced the phenomenon of static electricity in their daily life (lightning, hair electrification, got a jolt), they seem unable to explain this scientifically, which contributes to the maintenance of alternative concepts. It is still likely that many students assume that positive charges move over the negative ones, although the opposite is only valid.

The existence of students' primary ideas concerning physical phenomena like the one we presented bellow has led us to the selection of an "evolving research teaching model" of Schmidkunz & Lindemann (1992) which has been adopted in the curriculum of several primary schools (e.g. in Greece and Cyprus) (Sotiriou et al. 2010). The particular model includes four phases of teaching: (i) Introduction - Stimulus – Hypothesis Formulation, (ii) Experimental approach of the task, (iii) Inference, (iv) Consolidation – Generalization. The underlying learning script consists of four distinct phases, the implementation of which was completed in a six session (6x 45 min) lesson course. Students collaborated in groups of four throughout the procedure. Below are the details of the development and implementation phases.

Phase 1. Introduction - Stimulus – Hypothesis Formulation

The first phase was an introduction to the concept of static electricity and its derivatives (transfer of charge, attraction, repulsion, and grounding). Activity A(Introduction and stimulus) served as an opportunity for students to review prior knowledge and develop hypotheses. In this initial activity students were introduced to three examples of static electricity from everyday life-lightning, hair electrification and attraction between a balloon and a fur- by watching three related videos. Then group discussions were used to develop hypotheses, which they can investigate through experimentation. Groups posed their conjectures by completing two concept maps in Worksheet 1.

Phase 2. Experimental approach of the task

The second phase was about investigating experimentally the proposed hypotheses. The students *carried out investigations* (Activities B- C) in order to test the hypotheses they developed in the previous activity (Activity A).
In Activity B(Experimental), students implemented two scientific experiments in the laboratory to explore electrical charge of various materials by rubbing one with another, as well as the upcoming attraction or repulsion between them. Each student was given a specific role in their group –Director, Facilitator, Materials Manager or Technician (The science penguin, 2013).
Then, in Activity C (Simulations), students used the information they had just collected to explore the visualized movements of the negative charges over materials and how this transfer of the charge could make sparks fly.Subsequently,each groupwrote down their

observations and formulated their results using the scientific terminology suggested in their Worksheets (2& 3). When the experimental approach of the task was finished, each group used two holistic rubrics in order to assess themselves in working collaboratively and carrying out investigation skills.
The educators had provided the rubrics prior to the experiments and explained the assessment criteria.

Phase 3.Inference

In this phase Activity D (Everyday application), looked at the application of acquired knowledge in everyday life, enhancing students' *scientific literacy and reasoning* through understanding of real world applications of static electricity. In this phase gained knowledge was connected with everyday life. Each group answered some questions, which derived from two videos of static electricity in everyday life (Worksheet 4).Students used their worksheets to support their answers. The answers were peer-assessed through aholisticrubric, which evaluated the accuracy and entirety of students' answers. The educators provided the rubricin advance and explain ed the assess ment criteria and weight factor of each one. When groups finished this activity, there was a classdiscussion, guided by the educators, to facilitate the final correction of the answers.

Phase 4. Consolidation – Generalization

The final phase focused on drawing general conclusions and deliberating on the whole procedure. In Activity E (Conclusions and Hypotheses testing), students consolidated and interpreted their final results and related them to their initial hypotheses. During this phase, each group summarized through discussions their observations from the previous activities, drew conclusions based on the evidence they had collected and related them to their original hypotheses. The students returned back to their initial conjectures and made corrections by filling out anew the concept maps given in Activity Ausing Worksheet 5.
Afterwards each student assessed themselves in working collaboratively using a rating scale.

28.5.2 Skills to be assessed

There were five worksheets provided in each phase to collect evidence of both content knowledge and development of inquiry skills. Assessment opportunitiesincluded a set of modern assessment techniques. The following skills were assessed in this case study (Table 1).

	Skills	Assessment methods
Phase 1	Developing Hypothesis	Rubric
Phase 2	Carrying out investigation Working collaboratively	Intergroup assessment rubric
Phase 3	Forming coherent arguments	Peer- assessment rubric
Phase 4	Developing hypothesis Working collaboratively	Worksheet 5: Intergroup assessment- Hypotheses Testing Self- assessment rating scale

Table 1. Skills assessed and Assessment methods

Developing hypotheses

This skill was assessed by the educators using a holistic rubric when reviewing students' artefacts from Activity A and Activity E. Groups were judged on completing the concept maps and reasoning their initial and final conceptions.

Carrying out investigation

The assessment of this skill was carried out during the second Phase by using an intergroup assessment rubric for both Activities B and C.Each group put their final score after considering the assessment criteria, such as the level of completion and accuracy of their answers, the runtime management etc.

Forming coherent arguments

This skill was assessed by using a peer- assessment rubric when reviewing other group's artefacts in Activity D (Everyday application). Groups were judged on the level of completion, preciseness and reasoning of others.

Working Collaboratively

An intergroup assessment rubric and a self-assessment rating scale were used. Each group used a peer assessment rubric in Phase 2. A self- assessment rating scale had been also utilized so that each student could personally assess themselves and their working group. This scale was provided in Phase 4, when students had finished the majority of the activities. The assessment criteria included collaboration, time, function and material management.

28.6 Results

The results from three rubrics and a rating scale for educators and students making judgements of inquiry skills are presented below.
The score students were aspiring to achieve in each one of the assessment tools (rubrics and the rating scale) was 20 points.

28.6.1 Developing hypothesis

Educators used a rubric with 4- level criteria for making judgements of *developing hypotheses* skill and applied these criteria to written responses students handed in from Activities A and E. Results indicated that the majority of groups (15 out of 18) received over 15 points out of 20 as a final score.
Groups also evaluated their *developing hypotheses* skill by using Worksheets 1 and 5 while implementing Activity E: Conclusions and Hypotheses Testing. Examination of the records showed that 67% of the groups completed the hypotheses testing and managed to achieve a

higher level of performance. Also, 16 groups indicated that they had changed their initial ideas. All groups mentioned that they had improved whilst using scientific vocabulary and 14 groups identified some improvement in their scientific reasoning skill.

28.6.2 Carrying out investigation

Each group of students completed a rubric with a 4- level criteria for making judgments of *Carrying out investigation* skill. The assessment was based on group's recorded answers on the Activities B and C in the second phase. The intergroup evaluation showed that the final score for each group was over 17 points.

28.6.3 Forming coherent arguments

Each group of students, also completed a peer- assessment rubric with another 4- level criteria for estimating another group's performance in *forming coherent arguments* skills. From the results there was a variance in the final scores. Though, 67% of the groups were given over 15 points out of 20.

28.6.4 Working Collaboratively

Each group used an intergroup assessment rubric with a 4- level criteria in Phase 2. The intergroup evaluation showed that 100% of the groups' final scores were over 17 points.
Students, also, used a rating scale with another 4- level criteria in order to assess themselves in working collaboratively during the whole scientific process in Phase 4. From the results taken 77% of the students graded themselves over 15.

28.7 Conclusion

In this paper, a case study on assessing inquiry skills in classroom was attempted. The specific learning script follows the principle of IBSE and proposes the use of modern assessment techniques. The evaluation of the findings from the pilot implementation emphasizes on the activities, the aimed inquiry skills and the assessment methods and stresses the importance of achieving correlation between them when designing an IBSE unit. For instance, selecting the criteria while making a rubric is a demanding process. The latter had to match the content of the activities as well as the skills assessed.
In addition, IBSE is demonstrated as a challenge. Educators faced difficulties during the implementation of the scenario as they were not thoroughly used to IBSE and Assessment. So was for the students. Most of the contemporary assessment techniques (such as rubrics) were not familiar to them. As a consequence, considerable direction during the implementation was needed and much more time was spent than intended.
Nevertheless, both of them finally seemed to become acquainted with a novel process of learning and assessment, they accepted with sheer enthusiasm. The evaluation showed that all worksheets were fully completed by the majority of groups (72% on average) and this was rising during the implementation of the script. According to the findings, Inquiry Based Learning activities greatly improved the process of restructuring the students' primary ideas.

Educators, by implementing a combination of modern assessment techniques, evaluated with as much completeness as possible their students' performance. This case study verifies that multiple modern assessment techniques can support the evaluation of 21st century skills.
Our short term goal for the future is to design, develop and implement in our school further learning scripts around scientific concepts, as well as adapting new and enhanced assessment methods that should provide better understanding of skills that students develop during IBSE, in order to make the most of the added value of Inquiry Based Learning and Assessment in classroom.

28.8 Bibliography

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