Choosing a Textbook for Junior Cycle Science

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Abstract

Students who began their lower post-primary education in Ireland in September 2016 are the first cohort of students to study the new Junior Cycle Science curriculum. One of the main emphases of the new curriculum is that the students experience more Inquiry Based Learning (IBL) and have the opportunity to conduct investigations. Research has shown that the curriculum materials available to teachers has an impact on the probability that they will implement IBL in their classrooms. This paper investigates how three topics (solubility and crystal formation, measuring volume and respiration) are addressed by four of the widely-available textbooks in the Irish market: "The Nature of Science", "Investigating Science", "Exploring Science", and "Essential Science". The paper outlines how the textbooks differ in their likelihood to promote IBL in the classroom based on four aspects: whether the information is presented as fact or as an investigation to be carried out; the level of detail provided to students in conducting the investigation; whether the student is told how to manipulate results obtained (if any); and whether the conclusions obtained from the experiment are presented in the textbook, or left to the student to determine. It was found that the textbooks varied enormously in their approach to the three topics. In some cases, the information was presented as fact, without any accompanying investigation; in others, detailed instructions were given in how to conduct an experiment, including in one case the conclusions to be drawn were given in the textbook; and others yet provided sparse guidelines but left the detail in conducting the experiment to the student. It was concluded that, by choosing the 'wrong' textbook, teachers may reduce the likelihood of true inquiry taking place in their classrooms.

1. Introduction

In September 2016, the new Junior Cycle Specification for Science [1] was introduced for all students beginning their second-level education in Ireland. This science specification replaces the Junior Certificate Syllabus [2] which was introduced in schools in 2003. The 2003 syllabus placed an emphasis on "a practical experience of science" for students, and described amongst the aims and objectives of the syllabus the value of science literacy and scientific investigative skills.

The new 2016 science specification has increased the emphasis placed on inquiry within the Junior Cycle classroom. In this revision, not only has the curriculum material been re-organised into four 'contextual strands': Physical World (PW), Biological World (BW), Chemical World (CW), Earth and Space, but a new strand has been added that should be envisaged as a unifying strand: Nature of Science.

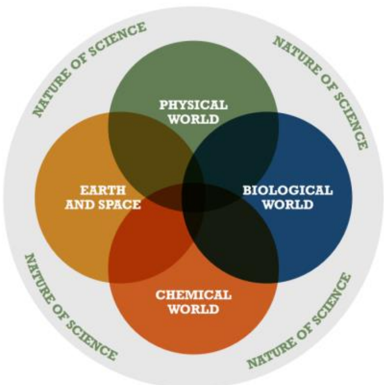

Figure 1: The strands of the specification for junior cycle science [1]

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The specification [1] states that there is no specific content within the Nature of Science strand, but that the learning outcomes from that strand are addressed as the "students develop their content knowledge of science through scientifc inquiry".

2. Inquiry-based science education

Inquiry-Based Science Education (IBSE) is described by the US National Research Council [3] as:

> a multifaceted activity that involves making observations; posing questions; examining books and other sources of information to see what is already known; planning investigations; reviewing what is already known in light of experimental evidence; using tools to gather, analyze, and interpret data; proposing answers, explanations, and predictions; and communicating the results.

The Junior Cycle Science Specification [1] states that students should be given the opportunity to "develop a range of inquiry skills" so that they can progress towards being able to conduct an investigation from beginning to end. As the students' skills develop, they will be able to "progress along the continuum of inquiry", or from one level of inquiry to the next.

2.1 Levels of inquiry

The specification [1] describes the four levels on the continuum of inquiry: limited, structured, guided and open, but does not give further details as to differentiating between the levels. However, the four levels may correspond to those described by Smithenry [4]: confirmation, structured, guided and open; or Blanchard et al. [5]: verification, structured, guided and open. Blanchard et al. [5] describe how the level is determined by who is carrying out each of three activities: posing questions, collecting data, and interpreting the results.

	Source of the Question	Data Collection Methods	Interpretation of Results
Level 0: Verification	Given by teacher	Given by teacher	Given by teacher
Level 1: Structured	Given by teacher	Given by teacher	**Open to student**
Level 2: Guided	Given by teacher	**Open to student**	**Open to student**
Level 3: Open	**Open to student**	**Open to student**	**Open to student**

Table 1: Levels of Inquiry [5]

Although the specification [1] states that the students should "progress" through the levels of inquiry, Donnelly, McGarr and O'Reilly [6] and Blanchard et al. [5] argue that open inquiry, or L3 should not be viewed as the 'ideal' or 'optimal' way to teach science. The level of inquiry used in any particular lesson should depend on the context, the skill level of the student and on the material.

2.2 Challenges in implementing IBSE

The organisation of inquiry-based learning is "complex" [7], "challenging" [4], and teachers trying to implement IBSE in their context are faced with a number of "dilemmas" [8]. Amongst obstacles encountered by teachers are a lack of understanding of the new roles to be adopted by teacher and student, difficulties of group work [8], teaching beliefs not aligned with inquiry learning and lack of "access to appropriate inquiry-based curricular material" [4]. Teachers also view inquiry-based learning as "an approach that requires more time and materials to develop" [5].

3. Research Question

The first author teaches science through the medium of the Irish language. There is currently no textbook available in that language to support teaching and planning for the new science specification [1], although Exploring Science [11] is currently being translated into the Irish language.

This paper looks at the provision of materials, in the form of English language science textbooks that have been aligned with the new science specification [1], and whether they support the implementation of IBSE.

4. Methodology
Four textbooks were chosen from the samples that were sent to schools at the beginning of the 2016-2017 academic year. They are “The Nature of Science” (NoS) [9], “Investigating Science” (IS) [10], “Exploring Science” (ExS) [11] and “Essential Science” (EsS) [12]. One topic was chosen from each of biology, chemistry and physics, and the experimental or investigative treatment of these topics in each textbook was studied. In each case, the inquiry level of the practical activity was rated according to the scale as described by Blanchard et al. [5]. These specific topics were chosen as they contain investigations that could be undertaken in an inquiry manner by students at any age or skill level.
The new specification [1] is more vague than the 2003 syllabus [2], and more open to interpretation by textbook publishers and teachers. Therefore, different textbooks include material from the 2003 syllabus that is not explicitly included in the 2016 specification.

5. Results and discussion
Each of the three topics will be examined separately in the subsequent sub-sections, and the treatment of each topic by the textbooks will be described. The inquiry level refers to the highest level that can be reached if the students are using the textbook whilst they are conducting the experiment or investigation.

5.1 Solubility and crystal formation
From the specification [1], the learning outcome for this material is “CW6: investigate the properties of different materials including solubilities...”, and it may be noted that this does not include the concept of crystal formation, nor does it include the variation of solubility with temperature. However, the 2003 syllabus [2] did specifically include both these concepts: “OC15: investigate the solubility of a variety of substances in water and the effect of temperature on solubility” and “OC17: grow crystals using alum or copper sulfate”.

Textbook	Inquiry Level	Notes
NoS	L1	2 experiments: solubility of materials and crystal formation. Temperature dependence OC15 given as L2 investigation.
IS	L2	No expteriment on temperature dependence, gives solubility curve in book. Instructions on experiments sparse.
ExS	L2	One experiment – solubility of materials and temperature dependence in one. No crystal formation experiment.
EsS	L0	No experiment on solubility of materials. Crystal formation and temp dependence experiments give sample results and conclusions.

Table 2: Examination of solubility and crystal formation experiments

5.2 Measuring volume
The learning outcome describing this topic in the specification is “PW2: identify and measure/calculate length, mass, time, temperature, area, volume...”. The corresponding outcome in the previous syllabus was “OP2: measure mass and volume of fixed quantities of a variety of solids and liquids...”

Textbook	Inquiry Level	Notes
NoS	L0	Two experiments at L0.
IS	L2	List of equipment, but no directions.
ExS	L0	Complete directions
EsS	L0	Additionally gives directions if object floats

Table 3: Examination of experiment measuring volume of irregular object

5.3 Respiration
This topic which is slightly vague. In the new specification, the topic of respiration is addressed by “BW7: describe respiration and photosynthesis as both chemical and biological processes; investigate factors that affect respiration and photosynthesis”. The previous syllabus did not compare exactly; the closest outcome was “OB10: demonstrate the products of aerobic respiration”. This caused some discrepancies between textbooks.

Textbook	Inquiry Level	Notes
NoS	L1	Full directions for experiment to show that respiration produces carbon dioxide, and full directions for experiment to show that rate of respiration depends on certain factor
IS	L3	Investigative experiment – “prove that respiration occurs”, with just a list of equipment. However, not directly relevant to learning outcome BW7.
ExS	L1	Experiment showing that energy is released during respiration, but not exactly addressing learning outcome BW7
EsS	L0	Experiment on temperature dependence of respiration has full directions and results.

Table 4: Examination of respiration experiments

6. Conclusions

The first conclusion that can be drawn from the comparison of textbooks is that there is a lack of clarity regarding the exact learning outcomes from the specification, and that there is a wide variation in the material presented in the different textbooks.

Even when the textbooks are addressing exactly the same learning outcomes, as is the case in section 4.2, there is a large discrepancy in terms of the level of inquiry that would take place if the teacher were to use the textbook in class.

The level of inquiry described is the maximum level that can be achieved for that investigation/experiment if the textbook was to be used in class; teacher support, questioning and scaffolding can lower the level of inquiry that is achieved by individual students or groups as they conduct the investigation.

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