The Particulate Nature of Matter, Inquiry Based Learning and the Transformative Education of Junior Secondary School Students.

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This work is directed towards promoting students understanding of the Particulate Nature of Matter (PNM) through Inquiry Based Learning (IBL), visualization and modeling. A teaching module on this topic was prepared which included a student workbook and a teaching manual for junior secondary school students. An action-based methodology was employed and student performance was measured using formative and summative testing. Student input was obtained on the learning issues experienced by them via interviews and repertory grid analysis based on Kellyian Personal Construct Psychology principles. Initial results point towards a better comprehension of PNM by the intervention group as opposed to their control group peers. Repertory grid analysis was used to highlight and rank aspects of their affective and cognitive learning experiences. This approach has enabled the systematic metering of student comprehension of chemistry constructs and served to detect the learning gaps in the construct hierarchy encountered by the learners.

FOCUS OF STUDY

McElwee (2010, p.249), states "In the past, there was an undue emphasis on 'knowledge as content' rather than knowledge as a set of thinking skills". The introduction of new curricula, such as Ireland's Junior Certificate Science with its emphasis on inquiry, attempted to address this issue. However, while the curriculum changed, there is concern that the newer teaching methods required were not easily adopted by all teachers. In this study, the researcher explores a change in his teaching pedagogy from a mainly deductive style to using an inquiry-based approach, merged with a modelling and visualisation, to see if it improves the knowledge of first year Junior Certificate science students in the area of the PNM.

LITERATURE REVIEW

The particulate nature of the matter (PNM) is rated by several authors as significant for students long-term success in the pursuit of chemistry, including Ozmen (2011), de Vos and Verdonk (1996), Taber (2001), Snir, Smith and Raz (2003), Liu and Lesniak (2004), Taber (2005), Othman (2008), Adbo (2009) and Newman (2012). In fact, Valdines (2000) saw fit to claim to an appropriate understanding of the particulate nature of matter is essential to the learning of chemistry.

However, Othman (2008) points to several studies (e.g. Albanese & Vicentini, 1997; Ben-Zyi, Eylon, & Silberstein, 1986; Johnson, 1998; Nakhleh et al., 2005), indicating that students' understanding of this model of matter is relatively limited. Childs and Sheehan's (2009) study on Chemistry topics that students at all levels find difficult detail many topics at Junior Certificate level in Ireland with which students struggle. Interestingly, the majority of these topics relate to the area of PNM.

Inquiry Based Learning (IBL)

The National Science Education Standards (NSES) (NRC, 1996, p.2) describe scientific inquiry as “the diverse ways in which scientists study the natural world and propose explanations based on the evidence derived from their work”.

The European Commission (2007, p.9) indicate that the ‘bottom up’ or student centered, inductive approach to teaching science is now mostly referred to as Inquiry-Based Science Education. They cite Linn, Davis and Bell (2004) in describing Inquiry-Based Science Education (IBSE) as:

> *...the intentional process of diagnosing problems, critiquing experiments, and distinguishing alternatives, planning investigations, researching conjectures, searching for information, constructing models, debating with peers, and forming coherent arguments.*

Inquiry-based teaching has been promoted over deductive teaching by Anderson (2002), Llewellyn (2005), Gyllenpalm, Wickman and Holmgren (2010) Bridel and Yezierski (2012) with a view to developing skills of comprehension, learning, critical and creative thinking. Hmelo-Silver, Ravit and Clark (2007) refer to this process as ‘sense making’. Sadeh and Zion (2009) also view IBL’s main purpose as the guidance of students to construct their own knowledge which is echoed by Oliveira (2010).

Furtak (2006, p.454) suggests that it may be useful to think about scientific inquiry as one side of a continuum of different methods of science teaching. At one pole of the continuum is traditional didactic teaching while at the opposite pole, is teaching to an open inquiry approach. This is reflected in Figure 1.

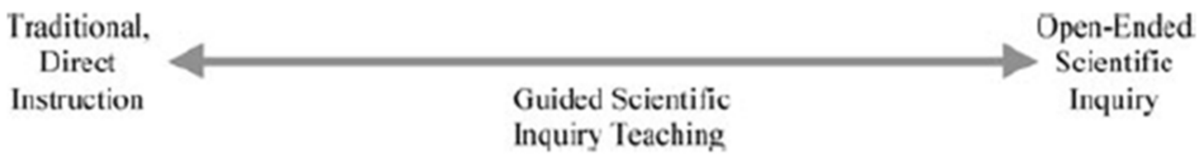

Figure 1: Continuum representing forms of Science Instruction (Furtak, 2006 p 454)

Modelling and Visualisation

According to the literature, modeling is subsumed by visualization. In recent times, Mayer and Moreno (2002), Jones, Jordan and Stillings (2005), Sweller (2005), Waldrip, Prain and Carolan (2006) and Chang, Quintana and Krajcik (2009) advocated the use of physical models, workbooks, computer models and personal modeling. Penner et al. (1997) and Harrison and Treagust (1998) gave modelling their fullest endorsement by claiming that modern chemistry cannot be taught without models.

Personal Construct Psychology

This is an optimistic psychology based on constructive alternativism (Kelly, 1955). The approach of Kelly is used in discerning views of subjects as they participate in learning, training and developmental projects. Repertory grid constructs have been applied to business and educational issues (Pope and Watts 1988) and have a role to play in refining the focus of individuals groups and programs.

RESEARCH DESIGN AND METHODS

Action Research with Personal Construct Psychology as an adjunct was used in carrying out the research methodology.

McNiff and Whitehead (2006, p.27) cite Berlin (1998) to indicate that action researchers need to make the following assumptions regarding knowledge:

- Knowledge is created, not discovered, in a process which often involves trial and error.
- All answers are tentative and open to modification.

To this end, the literature was used to inform the creation of a pedagogical instrument in the form of a workbook. The workbook itself was further developed by reflecting on the learners' difficulties in class while working with it. These were noted in a reflective journal. Furthermore, exam answers given by students were analysed and taken into account annually in an iterative process with the aim of optimizing the learning experience of the students. Repertory grid interviews were conducted with students to see if the pedagogical approach (mixture of structured and guided IBL with modeling and visualization techniques) can give the students a positive experience so they can elaborate their construct systems in a 'learning of science' context. In order to do this, it was important to see how students construed themselves as scientists and also how they construed the pedagogical tool (the workbook developed for the study) that was used to promote the form IBL used. This allowed for the acknowledgement of the views of the students in a way that can inform the modification of the pedagogical tool.

SUMMARY OF PRELIMINARY RESULTS

Figure 1 below indicates the % of the intervention (Int) and control (Cont) group that got each question completely correct on the test.

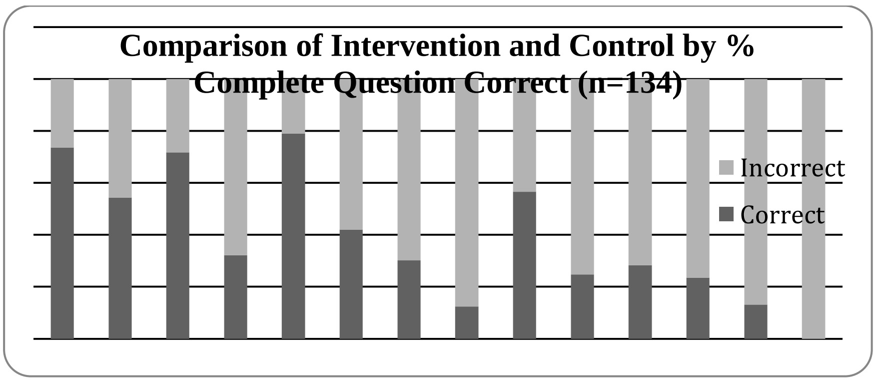

Figure 1: Percentage of Intervention Group who got Complete Questions Correct

The comparison enjoys statistical significance in all but one question (question 6).

PCP as a Navigational Aid to Quantitative Analysis and To Measure Learning Gaps (One example with respect to Question 1)

Question One

1. A blown up balloon with 5g of air in it was brought into a room to help decorate it for Martina's birthday. The balloon burst and the air inside was released into the room. The room already had 1,650g of air in it – did anything happen to the mass of the air in the room. Explain if you think something did.

Table 1: Chemical Concept Construct System Evident From Analysis of Student Data

Superordinate Construct: Students were able to convey a specific quantitative understanding of the conservation of mass.	
Bipolar Subconstructs	
Student has displayed scientific protocol and detail within their answer.	Student has displayed a lack of acknowledgement of scientific protocol or detail within their answer.
Student understands the additive nature of the process and can convey it qualitatively and quantitatively.	Student understands the additive nature of the process but portrays a mainly qualitative understanding.
Student understands diffusion and gives some qualitative and quantitative detail.	Student appears to understand diffusion and gives some qualitative detail but lacks any quantitative perception.
Additive nature of process recognized because they are have an understanding of the law of conservation of mass.	Additive nature of process not recognized because they are likely to have a partial understanding of the law of conservation of mass.
Student understands the law of conservation of mass.	Student has no understanding of the law of conservation of mass.

PCP AS A NAVIGATIONAL AID TO QUALITATIVE DATA

Preliminary findings are presented in terms of two constructs (below) of 'How I see myself as a scientist' in relation to the scientists presented to students as elements in the repertory grid interviews (Gallilleo, Frankland and Fleming). Constructs of 'How I see the pedagogical tool' regarding the workbook that was developed to support IBL are not presented here but are implicitly linked to those shown here.

Note: The outcome of student self-perception are shown below each construct.

Loved what they did ––– Did science for money

Currently, students see themselves as being quite close to the pole 'loved what they did' and *ideally see themselves as being even closer to it*. It is also at this pole where they see scientists.

Confident –--Did not believe in what they did

Students perceive scientists to be at the 'confident' end of the pole of this construct. At the moment they see themselves as being mainly near this pole but some are in the middle. *The respondents almost entirely see themselves as ideally at the 'confident' pole of the construct*.

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