Contemporary issues in science learning

Theorists have looked at learning and learners from various perspectives (Murphy et al., 2009). Since theorizing is not done in a vacuum, the various theories of learning were and are influenced by the thinking in various fields and the accepted views in the social and political spheres.

Views of learning in the late 19th and mid-20th centuries were influenced by behaviourism. Similarly to the concept of behaviour as a response to stimuli, learning is viewed as responding to the stimuli, in the form of transmitted knowledge from teacher to learners. According to this view of learning, knowledge travels and arrives intact from the mind of the teacher to the mind of the learner. The student is reduced to merely a passive receiver of information. In the transmission model of learning the teacher is more of a trainer, presenting knowledge to students and showing them how to apply it (Murphy et al., 2009). According to this view knowledge is objective, the only way of representing an objective reality, which holds whatever the social and environmental context. Good students are expected to passively accept what is being transmitted to them.

From my experience as a teacher, this model of learning is still followed in schools, especially in the last 3 years of secondary school, leading to Secondary Education Certificate examinations (the Maltese equivalent of British GSCE O-levels). Using a transmission mode of teaching, in order to make sure that the material laid out in the syllabus is covered in the time available is deemed, it seems, the easiest and safest way forward. A teacher is expected by the school, parents and students themselves to help them get good grades and to coach students to do well in exams.

Another issue which leads to this mode of teaching is that, for example, the chemistry syllabus is heavily fact based. The knowledge transmitted is not at the frontiers of science and more often then not is decontextualized. Knowledge is presented as objective. I feel that the pervasive view is that examinations measure students' knowledge and any issues with students' inability to learn are seen as lack of ability, a lack of memory to learn facts by heart or not enough motivation and study on the students' part.

Theorists such as Galton in 1869 (Murphy et al., 2009, p. 13), influenced by the social milieu of his time put forward the theory that learners abilities are genetically inherited. There are those who are able to learn and will lead society, and those who are genetically condemned to be led and do their masters' bidding. Applied to learning, all students are offered the same methods of learning – teachers transmitting knowledge. Aspects of this view still exist; science teaching according to Holbrook and Rannikmae (2007) is communicating what is important from a scientist's perspective rather than what is important for the learner or for society. In my view, the set up of classrooms further emphasizes the power difference – the teacher's desk and whiteboard at the front of the class, with students' desks lined up in front of the teacher, where students sit and passively listen to the teacher. That different people learn in different ways, others need more time, others need more hands-on activities, is not taken into account. In my opinion different learners have different propensities to learn different subjects and areas of knowledge – some are better at languages, some at art and some at science. Some subjects are portrayed as more important or prestigious than others. Various theorists (Holbrook and Rannikmae, 2007) maintain that different subjects develop different skills. Languages develop communication skills, mathematics develop logical thinking, social science develops cooperative learning and social values, while science teaches psychomotor and problem-solving skills. Holbrook and Rannikmae (2007) ask if all subjects should teach all the skills, with different subjects taking different approaches to teaching these skills. This is an interesting proposition since whereas the same educational goals would be reached different students with different preferences for different subjects would still be exposed to the full spectrum of educational goals. This would avoid having to force students to choose certain subjects. An innate propensity towards certain areas of knowledge, in my opinion, is a reality. An interesting proposal is that of Pearson et al. (2010) who propose collaboration across the curriculum in subjects such as language and literacy and science to support common educational outcomes – using reading and writing as tools to support inquiry-based science.

Using different cognitive skills could lead to stronger ‘ connections’ in a learners mind. Whether different learners have different abilities or propensities to learn one subject area over another remains controverial. In an interview on the SEH806 DVD-ROM Professor Greenfield (2008) speaks of the personalization of the brain, with each and every person continuously forming unique connections between brain cells. Greenfield’s view of learning is the formation of special connections in the brain. The environment and personal experiences influence which connections are made. According to this view a person’s brain is like a blank slate and everybody, given the right environment, experiences and stimuli can develop their abilities and knowledge. This view seems to suggest that all learners are equally capable of learning any area of knowledge. A preference for say, art or science, languages or mathematics is seen as a result of experiences and environmental factors rather some innate propensity towards a particular area. Greenfield's (2008) describes ' experience' in learning as showing learners real examples of the use of knowledge and doing real and hand-on tasks and experiments. To me this approach to teaching and learning helps students understand better and helps them construct their own understanding of science. As long, however, as heavily fact-based syllabuses are retained it is only those students with certain cognitive abilities who will succeed. The fact that some students do very well despite the fact and content heavy syllabuses might point an innate ability of these learners to respond to a transmission model of learning, with other approaches serving to reinforce their learning and understanding. Greenfield (2008) speaks against a one-size-fits-all method of teaching but still assumes that everyone can be taught the same things. I agree that different methods will mean that more learners will understand and be helped to construct their knowledge of science, but I am not as yet convinced that everyone can learn science to the same level.

By the late 1960s behaviourist influences in theories of learning science were waning, giving way to Piaget's theories of intellectual development (Murphy, p. 18). Jean Piaget's theory says that learners do not have any innate cognitive structures, and hence knowledge must be constructed by the individual learner (Phillips, 1995). Together with Vygotsky, Piaget focuses on the construction of knowledge in the learner's cognitive apparatus. Other constructivist theorists emphasize how communities of learners build knowledge and others still how the social environment influences the construction of knowledge and the construction of human knowledge in general (Philips, 1995).

Driver et al. (2004, p. 59) speak of scientific knowledge as public knowledge which is communicated through culture and social institutions. Hodson (1998, p. 35) describes the constructivist theory of learning as involving learners who are active constructors and reconstructors of knowledge. Learners bring their own prior knowledge and perspectives to the task of learning, with the teacher participating with the learners in developing their knowledge. According to this model learners have the final responsibility for their learning. Driver et al. (2004, p. 66-71) describe teaching based on a constructivist approach where students are provided with practical activities Students and teacher discuss their views and observations and construct a shared ' common knowledge'. I use this approach sometimes. The problem is that this approach is time consuming and I find myself reverting to a more transmission mode of teaching to make up for ' lost' time. I also find that some topics, such as ' moles', ' concentration' and ' volumes of reacting gases' in chemistry do not lend themselves well for discussion and for ' constructing knowledge' together with my students.

I share some social constructivists' view that scientific knowledge, understood as models to describe phenomena, has been and is being constructed by the scientific community. Learners are being introduced to the symbolic world and culture of the scientific community. However, learners cannot be expected to construct knowledge that comes to the same accepted conclusion as the knowledge that took hundreds of years to be ‘ constructed’ by the respective scientific community.

Learning science can be divided into learning ‘ of science’, ‘ about science’ and ‘ doing science’, with different theorists emphasizing the importance of one or more of these aspects of learning science (Hodson, 1998, p. 117). Learning of science focuses on learners acquiring knowledge of particular content and facts. Learning about science emphasizes the understanding of the processes of science, that is how scientists work and how scientific knowledge evolve. Doing science entails practicing and developing abilities to design, conduct, interpret and report scientific investigations (Hodson, 1998, pp. 148-149).

Hodson (1998, p. 39) quotes four conditions for conceptual restructuring: the new idea must be understandable; reasonable; and fruitful. Learners need to be dissatisfied with their current understanding to replace their ideas with new or better ones. Teachers, according to this theory must create the conditions for this conceptual change to take place. Learners should be shown why their current view is untenable; a conflict must be created. Teachers must show how the new idea is useful to the learner, either to make predictions about phenomena or to make more sense of the world. Gaining marks in tests is also one of the possible fruits of new ideas. In my view it is important to use various tools and approaches to being about conceptual restructuring. Investigations and practical work are, in my view an important way to tie theory to practice. An approach I find useful is to use everyday products for experiments, demonstrations and lessons in certain areas of chemistry, such as tap water from different parts of the country for tests on water and foodstuffs and household products for explaining the ‘ acids and bases’ topic.

Providing a variety of experiences and engaging students by framing teaching methods to take into account students’ everyday experiences, their perspectives and their interests should make teaching more effective. Making ‘ new connections’ (Greenfield, 2008) in the brain is brought about by exposing students to a variety of experiences. Contextualizing science makes these ‘ connections’ stronger. In my view supporting science learning includes demonstrations, discussing theories and seeing how these explain everyday phenomena. Using case studies and the science behind stories in the media, will, in my view also help students develop conceptual models to explain scientific phenomena. Tytler (2009) speaks of effective science teaching as including attention to student engagement, students’ lives, perspectives and interests and mentions the importance of relating what is taught to the community. Active learning, it is argued, is supported by creating a learning environment in which students can restructure both new information and also their prior knowledge into new knowledge. Using various aids, demonstrations and testing concepts by doing experiments are aspects of teaching which support active learning. An active learner takes control of his or her own learning and pursues open-ended problems to develop conceptual models explaining scientific phenomena. Hodson (1998, p. 152) insists however, that science is a highly specialized area of knowledge and the level of conceptual detail students need to master and therefore ‘ doing science is insufficient in itself to bring about breadth of conceptual development that a curriculum seeks’. In my view though doing science can form a strong basis and foundation on which to build students' appreciation of science. The perennial debate is whether to make all students study science, and if so, to what level.

One of the most pressing issues is that students fail to see science as sufficiently concerned with social and human issues (Van Aalsvoort, 2004). Engaging students means relating science to everyday life, which in my view means more use of case studies, of news stories and experimental work from which a teacher can then move on to describe the underlying scientific principles. My view is that all students should be exposed to a basic introduction to science, especially ' science for life' or ' scientific literacy', but that forcing all students to study single more academic syllabuses, in biology, chemistry or physics, designed to make future scientists out of them, does not make sense educationally.

(2, 055 words)

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Question 2

In my opinion the most important aspect of science which should be taught is the process by which scientists build scientific knowledge and aspects of scientific inquiry and scientific discourse to enable students at the end of compulsory secondary education to understand and evaluate news and issues and engage politically, making them citizens who can participate more effectively in society.

Students do not see science learning as sufficiently concerned with their lives and with social and human issues (van Alsvoort, 2004). It is also pertinent to point out that various studies (Pearson, 2010) contend that to engage with science, students have to achieve a level of literacy which will enable them to use an important tool that scientists use to build and defend their arguments. Literacy is often seen as the domain of other teachers – such as English teachers, but some studies have shown how literacy education can be achieved through science – with each in service of each other (Pearson, 2010). Vygotskian theorists insist that language shapes learners' thinking, so for an authentic learning experience so students must become familiar with the language used by scientists and those who use scientific knowledge. (Hodson, p. 123).

Students' social context features frequently in studies and discussions on how to make the learning experience authentic (Krajcik et al., 2010; Hodson 1998, p. 116). Hodson (1998, p. 116) insists that the social context facilitates learning and also motivates learners since they can see how knowledge can be used in real life contexts. Prior knowledge can come from either real world experiences or previous classroom learning. Krajcik et al. (2010) review interesting studies and programmes which seek to develop literacy in the context of science. Again one important aspect is linking new ideas to prior knowledge and experiences and anchoring learning in questions that are meaningful in the lives of students. Students use various tools such as texts and graphics to help them make sense of the science. In such programmes students are also given opportunities to use science ideas and practice in writing about science. Supporting students' engagement with the discourses of science – the language of science and its practices together with basing teaching on students' interests and backgrounds is intended to promote students' ability to read, write, and communicate about science so that they can engage in inquiry throughout their lives.

I share Hodson's (1998, p. 152) that doing science alone – as in doing experiments, understood as following cook-book style instructions, while having merit in introducing students to laboratory practices and procedures, only opens a window on one small aspect of the culture of science. Making sense of scientific texts is another, important form of scientific inquiry (Pearson et al., 2010). One approach to learning described by Pearson (2010) describes how hands-on and text based inquiries can develop different processes and skills.

An interesting example, called ' a multimodal approach to learning', described by Pearson (2010) explains the approach used to learn about the concept of erosion:

DO-IT – Students model the process of erosion by shaking hard candies in a jar and observing the candies getting smaller.

TALK-IT – Students discuss the risks of building a house on a cliff overlooking the ocean.

READ-IT – Students read a book about erosion and the natural forces that can cause it.

WRITE-IT – Students create an illustrated storyboard to chronicle the erosion of a cliff.

McGinn and Roth (1998, pp. 99-113) describe a very similar approach to learning, emphasizing science learning as learning about the nature of science and scientific enquiry, that is how scientific knowledge is created, how it is used and how it is reported in the media and influences society. The contend that scientific knowledge is far more complex than implied by the myth of the scientific method. In my opinion it is precisely this image of science as a kind of elite, infallible ‘ religion’ and its decontextualized curriculum content that makes students miss the point of how pervasive it really is in their lives.

Echoing Pearson’s (2010) descriptions of methods of teaching and learning science in McGinn and Roth’s (2004, pp. 99-113) view students learn more authentic science when they are free to pursue investigations in their own interest. Something which they comment will even lead to them learning things outside of and beyond those prescribed in the syllabus. They propose the reading, discussing and role playing of scientific controversies. Using projects to help students see situated, contingent and contextual features of scientific knowledge and science as one of society’s many endeavours. Learning about science also means learning and using the discourse of science or its sub-disciplines. Arriving to using a shared language is a very important aspect of learning science. This approach requires the use of a wide range of resources including reference books, computer software, models, tools, newspapers, science magazines, science and current affairs programmes relating to issues with a scientific content, video cameras, recording equipment, the internet and other material.

I will now use apects of the approach described above to describe how I would teach topics in chemistry to 14 year old secondary school students. I will follow approximately the scheme proposed by Leach and Scott (2004, p. 91). At this stage the basic concepts of science should be introduced. Even these concepts can be constructed by using learners' experiences and tying these concepts to social contexts.

Taking acids and bases as an example, the knowledge to be taught would be:

Action of acids and alkalis on indicators;

The pH scale to measure acidity and alkalinity;

Reactions of acids with metals, bases and alkalis and carbonates;

The topic can be introduced by discussing with students what they think acids are and their characteristics. Foodstuffs which are acidic can be used as examples – their taste, the effect of eating too much of these, how cola drinks makes coins shiny. The effects of acids on limestone can be discussed since students are surrounded by limestone buildings and effects of weathering is a common experience. Alkalis and bases can be introduced again through a discussion about limestone and mortar (calcium oxide). Students can then be introduced to scientific terms and concepts with terms such as neutralization, indicator and pH introduced. Students are very surprised that stomach acid has a pH of between 1 and 2 and relate experiences of the pain of stomach aches to this high pH. The learning demands are identified at this stage – in my experience it is getting students to use the scientific terms used by scientists. Other learning demands are the concept of acids and alkalis as hydrogen and hydroxide ions, and emphasis that a hydrogen ion is different from hydrogen gas. Giving them opportunities to practice formulas, and balancing equations and relating this topic to the metal reactivity series and the position of ' H' (hydrogen in the series) serves to reinforce previous topics.

As a teaching sequence for this topic I would build on ideas of acids and bases in everyday products and things surrounding students. Current political debates such as reducing emissions of acidic gases from power plants can be used as an example of science in the public sphere. Hands on science would include testing for the pH of different substances starting from foodstuffs and cleaning agents before moving on to laboratory solutions of acids and alkalis.

Concepts can be strengthened by getting students to interview a dentist, maybe one of the students' parent, about the effects of acidic beverages on teeth. A short video clip can also be produced of the effects on limestone (a carbonate) in areas close to industrial areas.

The problem with such an approach is that it is very time consuming. The strength is that starting from what the learners see around them and contextualizing knowledge, together with using a variety of media should increase their motivation and internalization of knowledge.

(1, 296 words)