Socrates - Comenius 2-1-2006-1

Improving Quality of Science Teacher Training in European Cooperation - constructivist approach (IQST)

Using Laboratory to Enhance Student Learning and Scientific Inquiry

Bayburt 2008

Unit 1

Constructivist Science and Laboratory Education Resources

Objectives:

- To be aware what constructivist science is
- To know the steps of constructivist science laboratory instruction

Scientific knowledge is comprised of two distinct, yet interrelated, components: theory and empirical evidence. Understanding the interrelations between these two components is crucial to the understanding of what science is and how it works (Havdala and Ashkenazi, 2007; Kuhn & Pearsall, 2000).

The Theory of Constructivism (Shiland, 1999):

The single statement that captures the essence of constructivism is that knowledge is constructed in the mind of the learner. This statement can be expanded to five other propositions or postulates of constructivism, from which implications for lab work will be derived.

1. *Learning requires mental activity*. The process of knowledge construction requires mental effort or activity; material cannot simply be presented to the learner and learned in a meaningful way.

2. *Naive theories affect learning*. New knowledge must be related to knowledge the learner already knows. The learner has preconceptions and misconceptions, which may interfere with the ability to learn new material. These personal theories also affect what the learner observes. Personal theories must be made explicit to facilitate comparisons.

3. *Learning occurs from dissatisfaction with present knowledge*. For meaningful learning to occur, experiences must be provided that create dissatisfaction with one's present conceptions. If one's present conceptions make accurate predictions about an experience, restructuring (meaningful learning) will not occur.

4. *Learning has a social component.* Knowledge construction is primarily a social process in which meaning is constructed in the context of dialogue with others.

Cognitive growth results from social interaction. Learning is aided by conversation that seeks and clarifies the ideas of learners.

5. *Learning needs application.* Applications must be provided which demonstrate the utility of the new conception.

Students are players and protagonists during teaching activities through a continuous process of discovery, investigation, research and synthesis. Students attempt to give answers to multiple questions arising from the observation of scientific phenomena or from the solution of problematic issues. In this context, the building of concept maps allows students to become aware of their knowledge building processes whilst also representing the knowledge synthesis operated by students (Berionni and Baldon, 2006) .

Science laboratory and learning environment (Berionni and Baldon, 2006)

Science laboratory activities are structured around the search for coherent and correct answers to questions aroused in students through random or programmed observation.

The questions asked spontaneously by students are not "basically different" from those that guide and urge investigations, discoveries and definition of scientific theories. Evidently, in view of the very young age of the students, questions arise from within a context of factual experiences where real knowledge may still coexist with misconceptions and fantasy.

Science teaching with a laboratory teaching method orientates the search for answers and coherent and correct explanations through learning processes in which students work and interact to gain the new knowledge that will allow them to read the cause of scientific phenomena or the explanation of observed situations.

In this teaching practice students and teachers play well-defined roles, that is to say invert the direction of traditional transmissive teaching, creating a learning-teaching process in which the student is given a central role as protagonist and the teacher a second-level role as organizer, guide and facilitator of teaching processes.

Designing the learning environment (Berionni and Baldon, 2006)

Designing a science laboratory means to elaborate teaching practice and teaching role in a constructivist approach in which knowledge gained by students is an active process. The teacher prepares and organizes materials, procedures and relevant contexts to urge and guide self-learning processes.

With his/her expert map, the teacher defines:

- the knowledge field to promote
- the aspects to investigate
- the knowledge synthesis at which the students should arrive.

Once activities start, the class of students becomes the protagonist and each student is the main actor in a knowledge process that generates significant learning whenever students structure, integrate and reconfigure their previous knowledge. The teacher recedes from the foreground and only provides inputs, stimuli, suggestions to strengthen and direct the thinking procedures and strategies activated by the students.

Promoting and addressing knowledge processes (Berionni and Baldon, 2006)

Receding from the foreground means for the teacher to avoid giving explanations, examples and direct answers, whilst guiding students towards active processes, such as analysis, observation, comparison, and the search for alternative routes in problem-solving.

Knowledge is considered an active, unique and personal process for each student through interaction and social cooperation with the other students of the class in a perspective that refers to social constructivism paradigms (Varisco 2004). Consequently, the teaching activity is expressed according to three guidelines:

• to address the students' action towards multiple routes, searching for logical, coherent solutions and explanations, solicited and anchored with a concrete context;

• to promote collaboration, discussion, mediation, negotiation with the other students;

• to use language and c-maps as tools for reflection, reasoning, analysis and synthesis.

The science laboratory becomes the learning environment where students work together, helping each other, and learning how to search for and use tools and resources in problem solving situations. The teacher facilitates, encourages, promotes activities in which students interact, design, express and discuss solutions, ideas and theories.

The Implications of Constructivism for Laboratory Activities (Shiland, 1999):

From each of these postulates, a corresponding generalization and specific implications for modifying laboratory activities follows.

Learning requires mental activity; therefore modify labs to increase the cognitive activity of the learner.

1. *Have the students identify the relevant variables.* Students can be asked to identify controlled and uncontrolled variables.

2. *Have the students design the procedure or reduce the procedure to the essential parts.* The best labs to decookbook are those that have simple procedures that are easy to explain to the students. If the procedure cannot be designed safely, then the students might be asked to explain why certain steps in the procedure are done in a certain way.

3. *Have the students design the data table.* Designing data tables is an easy first step toward modifying your labs and has been mentioned as a way to move labs toward inquiry.

4. *Use a standard lab design worksheet.* Have a standard format that uses the important concepts in experimental design (problem statement, hypothesis, variables, constants, data tables, summary, and conclusions).

5. *Have students suggest sources of error in the lab and modifications to eliminate these sources of error, and raise questions about the lab.* Comparisons of data between groups in class and between classes may raise questions about sources of variation. Students can produce questions by substituting, eliminating, or increasing or decreasing a variable.

Naive theories affect learning: therefore design labs to learn what these are.

6. *Move the lab to the beginning of the chapter.* Moving the lab to the beginning may create interest in the material to be learned and give the teacher a chance to diagnose misconceptions the student may have. Use the lab as the beginning of a learning cycle.

7. *Have students make predictions and explain them before the lab.* Having students make predictions creates interest in the outcome. In addition, have students explain the basis for their predictions using their present ideas. Ideally, the problem presented will be one which creates dissatisfaction with their present understanding. Challenge students to come up with alternative hypotheses.

Learners must be dissatisfied with their present knowledge: therefore design labs as problems to challenge their present knowledge.

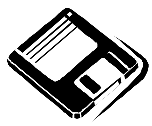
8. *Rewrite the lab as a single problem whose solution is not obvious.* Solutions to the problem cannot be obvious. Change your role in the lab to that of problem poser and facilitator. Some possible topics for chemistry investigations have been given in the literature which essentially involve the statement of a given problem.

Learning has a social component: therefore design labs to include group and whole class activities.

9. *Give the students an opportunity to discuss their predictions, explanations, procedures, and data table before doing the lab, and give them an opportunity to present their results after the lab.* The process of formulating an opinion to express and share with a group promotes reflection.

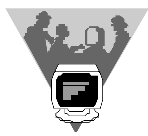
Learning needs application: therefore design labs to require students to find or demonstrate applications.

10. *Give students an opportunity to demonstrate applications after the lab.* Students need opportunities to use new ideas in a wide range of contexts.



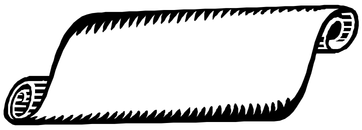
Tasks (assignments)

1. What are the postulates of Constructivism?
2. How can you modify the implications of constructivist laboratory activities?



Case Study

Before the laboratory session; the teacher asked the students to identify controlled and uncontrolled variables of the experiment. He also asked the students to explain why certain steps in the procedure are done in a certain way. He also asked the students to explain and compare the concepts of the experiment (interrelations, differences and similarity etc.). Why do you think so? Are you sure? Why? If the temperature had been higher what would happen? What do you infer from the result of the experiment, why? etc.



Questions to Case Study

1. What may be the target of the teacher with the question to ask the student about the certain steps of the procedure?
2. Why do you think that teacher ask so many questions to the students? Do you think it is necessary?

Summary

Science teaching with a laboratory teaching method orientates the search for answers and coherent and correct explanations through learning processes in which students work and interact to gain the new knowledge that will allow them to read the cause of scientific phenomena or the explanation of observed situations. And also constructivist science teaching plays a crucial role in affective science teaching.

Frequently Asked Questions

I am a trainee science teacher and I am having trouble to find out student misconceptions and naïve theories. How can I improve my ability to find out student misconceptions?

Answer the question above

It is recommended to read the first chapter and try to determine the sample questions types in order to question students to determine their misconceptions and also insufficiencies to explain something.

Next reading

Wiske, M.S. (1998). What is teaching for understanding? In Wiske, M.S. (Ed.) *Teaching for understanding: Linking research with practice.* San Francisco: Jossey-Bass Publishing.

Lazarowitz, R., & Tamir, P. (1994). Research on using laboratory instruction in science. In D.L. Gabel (Ed.), Handbook of research on science teaching and learning (pp. 94–128). New York: Macmillan.

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Roger, G. and Fisher, K. M. (1999) Comparison of student learning about diffusion and osmosis in constructivist and traditional classrooms International Journal of Science Education, 21 (6), 687-698.

Wandersee, J. H., Mintzes, J. J. and Novak, J. D. (1994) Research on alternative conceptions in science. In D. Gabel (ed.), Handbook of Research in Science Teaching and Learning, pp. 177–210.

Shiland, T.W. (1999) Constructivism: The Implications for Laboratory Work, Journal of Chemical Education, 76 (1), 107-109.

Berionni A., Baldon, M.A. (2006) Concept Maps: Theory, Methodology, Technology, Proc. of the Second Int. Conference on Concept Mapping *A. J. Canas, J. D. Novak, Eds.* San Jose, Costa Rica.

Havdala and Ashkenazi, (2007) Coordination of Theory and Evidence: Effect of Epistemological Theories on Students' Laboratory Practice Journal of Research in Science Teaching, 44(8) 1134–1159.

Unit 2

Constructivist Science Teaching Techniques

Objectives:

- to foster a learning environment supporting conceptual understanding;
- to promote positive attitudes toward science learning.

Constructivist Teaching and Learning Models

Constructivism is an approach to teaching and learning based on the premise that cognition (learning) is the result of "mental construction." In other words, students learn by fitting new information together with what they already know. Constructivists believe that learning is affected by the context in which an idea is taught as well as by students' beliefs and attitudes.

Constructivist teaching is based on recent research about the human brain and what is known about how learning occurs. Caine and Caine (1991) suggest that brain-compatible teaching is based on 12 principles:

1. "The brain is a parallel processor" (p. 80). It simultaneously processes many different types of information, including thoughts, emotions, and cultural knowledge. Effective teaching employs a variety of learning strategies.
2. "Learning engages the entire physiology" (p. 80). Teachers can't address just the intellect.
3. "The search for meaning is innate" (p. 81). Effective teaching recognizes that meaning is personal and unique, and that students' understandings are based on their own unique experiences.
4. "The search for meaning occurs through 'patterning' " (p. 81). Effective teaching connects isolated ideas and information with global concepts and themes.
5. "Emotions are critical to patterning" (p. 82). Learning is influenced by emotions, feelings, and attitudes.
6. "The brain processes parts and wholes simultaneously" (p. 83). People have difficulty learning when either parts or wholes are overlooked.
7. "Learning involves both focused attention and peripheral perception" (p. 83). Learning is influenced by the environment, culture, and climate.
8. "Learning always involves conscious and unconscious processes" (p. 84). Students need time to process 'how' as well as 'what' they've learned.
9. "We have at least two different types of memory: a spatial memory system, and a set of systems for rote learning" (p. 85). Teaching that heavily emphasizes rote learning does not promote spatial, experienced learning and can inhibit understanding.
10. "We understand and remember best when facts and skills are embedded in natural, spatial memory" (p. 86). Experiential learning is most effective.
11. "Learning is enhanced by challenge and inhibited by threat" (p. 86). The classroom climate should be challenging but not threatening to students.

12. "Each brain is unique" (p. 87). Teaching must be multifaceted to allow students to express preferences. (http://www.ncrel.org/sdrs/areas/issues/envrnmnt/drugfree/sa3const.htm)

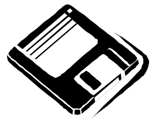
Using ICT (Derek and Campbell, 2005)

Derek and Campbell, 2005 reports about ICT that; in the last few years there has been a shift from the use of science as a vehicle through which students learn to use ICT skills to the use of ICT skills as tools to assist learning in science. There has also been growing interest in the use of ICT to support whole class teaching and learning to complement ICT based activities for individual students. This has led to greater emphasis on the role of the teacher and recognition of the need for training to help them learn operational skills to use new equipment and software and, crucially, application skills to ensure that new technologies add value to learning.

There is considerable evidence that learners are more highly motivated when their learning is supported by ICT. Newton and Rogers (2001) provide a review of claims and evidence. It is now recognized that:

- ICT has a positive impact on teaching and learning in the classroom
- students are more engaged in activities, they show increased interest and demonstrate a longer attention span;
- ICT can provide access to a huge range of resources that are of high quality and relevant to scientific learning.
- However, in some cases ICT resources are less good than conventional alternatives and do not add to learning;
- the multi-media resources available enable visualisation and manipulation of complex models, three-dimensional images and movement to enhance understanding of scientific ideas;
- ICT widens the range of material that can be used in teaching and learning to include text, still and moving images and sound, and increases the variety of ways that the material can be used for whole class and individual learning. This means that a teacher can go some way to meeting the needs of students with different learning styles. ICT also allows teachers with different teaching styles to modify materials and the way they are used in different and effective ways;
- ICT can improve the quality of data available to students. Information gleaned from the Internet can be more up to date, and data obtained from loggers can provide more frequent and more accurate experimental readings;
- Computers allow repetitive tasks to be carried out quickly and accurately so that more student time can be spent on thinking about the scientific data that has been generated;
- ICT can extend learning beyond the constraints of a traditional teaching space. An activity started in one classroom can be continued in a different room later in the day or at home in the evening;
- ICT provides opportunities for science teachers to be creative in their teaching and for students to be creative as they learn.

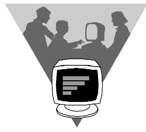
A basic level of skills in the use of ICT hardware and software is required by all science teachers. The role of the teacher in using ICT in science is changing. When ICT facilities are brought into the science teaching space, the teacher becomes the main driver of ICT use.



Tasks (assignments)

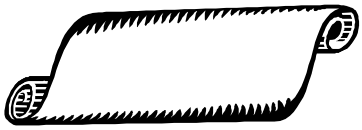
1. What does “each brain is unique” mean?

2. What can you say about the effect of using ICT in science teaching?



Case study

After getting information about students’ pre-knowledge; teacher began to explain the subject. But every student constructed his/her knowledge similarly but also in a different manner. Their emotions, culture was a bit different. But when the teacher began to use data show projection they could see the animations and this made the subject easy to comprehend.



Questions to Case Study

1. Can you explain why do every student constructed his/her knowledge in a different manner?

2. Do you think that the learners are motivated enough when their learning is supported by ICT?

Summary

Students learn by fitting new information together with what they already know. Constructivists believe that learning is affected by the context in which an idea is taught as well by students’ beliefs and attitudes. Effective teaching recognizes that meaning is personal and unique, and the students’ understandings are based on their own unique experiences. ICT provides opportunities for science teachers to be creative in their teaching and for students to be creative as they learn.

Frequently Asked Questions

What is the reason to use constructivism and ICT?

Answer the question above

Meaning is personal and unique and their experiences, emotions, feelings, attitudes affect their learning. The classroom climate should be challenging but not threatening to students.

There is considerable evidence that ICT has a positive impact on teaching and learning in science education.

Next Reading

http://www.ncrel.org

http://www.ccm.ac.uk/ltech/cfet/materials/materials.asp The LSDA Information and Learning Technology (ILT) Materials Downloads are available. The entire collection of video software tutorials from the Ferl 16-19 Conference 2002, together with the conference content material are available at http://ferl.becta.org.uk/ display.cfm?&resid=3784&showArchive=1

http://www.techdis.ac.uk TechDis is a JISC-funded service (Joint Information Systems Committee) which aims to enhance provision for disabled students and staff in higher, further and specialist education and adult and community learning. It has relevance for schools catering for 14-19 year olds and much of the advice it offers it applicable to all learners.

References:

Denby D, edited by Campbell B. (2005) ICT in Support of Science Education, A Practical User's Guide: 2005 Edition, edited by Campbell B; York Publishing Services Ltd. York, UK. ISBN 1 85342 711 X.

http://www.ncrel.org/sdrs/areas/issues/envrnmnt/drugfree /sa3const.htm)

http://www.techdis.ac.uk

Unit 3

Scientific Process Skills and Scientific Inquiry

Objectives:

- to improve scientific process skills;
- to promote positive attitudes toward learning and teaching science.

The Scientific Process (http://www.project2061.org/publications/sfaa/online/chap1.htm)

Scientists share certain basic beliefs and attitudes about what they do and how they view their work. These have to do with the nature of the world and what can be learned about it.

The World Is Understandable

Science presumes that the things and events in the universe occur in consistent patterns that are comprehensible through careful, systematic study. Scientists believe that through the use of the intellect, and with the aid of instruments that extend the senses, people can discover patterns in all of nature.

Science also assumes that the universe is, as its name implies, a vast single system in which the basic rules are everywhere the same. Knowledge gained from studying one part of the universe is applicable to other parts. For instance, the same principles of motion and gravitation that explain the motion of falling objects on the surface of the earth also explain the motion of the moon and the planets. With some modifications over the years, the same principles of motion have applied to other forces—and to the motion of everything, from the smallest nuclear particles to the most massive stars, from sailboats to space vehicles, from bullets to light rays.

Scientific Ideas Are Subject To Change

Science is a process for producing knowledge. The process depends both on making careful observations of phenomena and on inventing theories for making sense out of those observations. Change in knowledge is inevitable because new observations may challenge prevailing theories. No matter how well one theory explains a set of observations, it is possible that another theory may fit just as well or better, or may fit a still wider range of observations. In science, the testing and improving and occasional discarding of theories, whether new or old, go on all the time. Scientists assume that even if there is no way to secure complete and absolute truth, increasingly accurate approximations can be made to account for the world and how it works.

Scientific Knowledge Is Durable

Although scientists reject the notion of attaining absolute truth and accept some uncertainty as part of nature, most scientific knowledge is durable. The modification of ideas, rather than their outright rejection, is the norm in science, as powerful constructs tend to survive and grow more precise and to become widely accepted. For example, in formulating the theory of relativity, Albert Einstein did not discard the Newtonian laws of motion but rather showed them to be only an approximation of limited application within a more general concept. (The National Aeronautics and Space Administration uses Newtonian mechanics, for instance, in calculating satellite trajectories.) Moreover, the growing ability of scientists to make accurate predictions about natural phenomena provides convincing evidence that we really are gaining in our understanding of how the world works. Continuity and stability are as characteristic of science as change is, and confidence is as prevalent as tentativeness.

Science Cannot Provide Complete Answers to All Questions

There are many matters that cannot usefully be examined in a scientific way. There are, for instance, beliefs that—by their very nature—cannot be proved or disproved (such as the existence of supernatural powers and beings, or the true purposes of life). In other cases, a scientific approach that may be valid is likely to be rejected as irrelevant by people who hold to certain beliefs (such as in miracles, fortune-telling, astrology, and superstition). Nor do scientists have the means to settle issues concerning good and evil, although they can sometimes contribute to the discussion of such issues by identifying the likely consequences of particular actions, which may be helpful in weighing alternatives.

Scientific Inquiry

Fundamentally, the various scientific disciplines are alike in their reliance on evidence, the use of hypothesis and theories, the kinds of logic used, and much more. Nevertheless, scientists differ greatly from one another in what phenomena they investigate and in how they go about their work; in the reliance they place on historical data or on experimental findings and on qualitative or quantitative methods; in their recourse to fundamental principles; and in how much they draw on the findings of other sciences. Still, the exchange of techniques, information, and concepts goes on all the time among scientists, and there are common understandings among them about what constitutes an investigation that is scientifically valid.

Scientific inquiry is not easily described apart from the context of particular investigations. There simply is no fixed set of steps that scientists always follow, no one path that leads them unerringly to scientific knowledge. There are, however, certain features of science that give it a distinctive character as a mode of inquiry. Although those features are especially characteristic of the work of professional scientists, everyone can exercise them in thinking scientifically about many matters of interest in everyday life.

Science Demands Evidence

Sooner or later, the validity of scientific claims is settled by referring to observations of phenomena. Hence, scientists concentrate on getting accurate data. Such evidence is obtained by observations and measurements taken in situations that range from natural settings (such as a forest) to completely contrived ones (such as the laboratory). To make their observations, scientists use their own senses, instruments (such as microscopes) that enhance those senses, and instruments that tap characteristics quite different from what humans can sense (such as magnetic fields). Scientists observe passively (earthquakes, bird migrations), make collections (rocks, shells), and actively probe the world (as by boring into the earth's crust or administering experimental medicines).

In some circumstances, scientists can control conditions deliberately and precisely to obtain their evidence. They may, for example, control the temperature, change the concentration of chemicals, or choose which organisms mate with which others. By varying just one condition at a time, they can hope to identify its exclusive effects on what happens, uncomplicated by changes in other conditions. Often, however, control of conditions may be impractical (as in studying stars), or unethical (as in studying people), or likely to distort the natural phenomena (as in studying wild animals in captivity). In such cases, observations have to be made over a sufficiently wide range of naturally occurring conditions to infer what the influence of various factors might be. Because of this reliance on evidence, great value is placed on the development of better instruments and techniques of observation, and the findings of any one investigator or group are usually checked by others.

Science Is a Blend of Logic and Imagination

Although all sorts of imagination and thought may be used in coming up with hypotheses and theories, sooner or later scientific arguments must conform to the principles of logical reasoning—that is, to testing the validity of arguments by applying certain criteria of inference, demonstration, and common sense. Scientists may often disagree about the value of a particular piece of evidence, or about the appropriateness of particular assumptions that are made—and therefore disagree about what conclusions are justified. But they tend to agree about the principles of logical reasoning that connect evidence and assumptions with conclusions.

Scientists do not work only with data and well-developed theories. Often, they have only tentative hypotheses about the way things may be. Such hypotheses are widely used in science for choosing what data to pay attention to and what additional data to seek, and for guiding the interpretation of data. In fact, the process of formulating and testing hypotheses is one of the core activities of scientists. To be useful, a hypothesis should suggest what evidence would support it and what evidence would refute it. A hypothesis that cannot in principle be put to the test of evidence may be interesting, but it is not likely to be scientifically useful.

The use of logic and the close examination of evidence are necessary but not usually sufficient for the advancement of science. Scientific concepts do not emerge automatically from data or from any amount of analysis alone. Inventing hypotheses or theories to imagine how the world works and then figuring out how they can be put to the test of reality is as creative as writing poetry, composing music, or designing skyscrapers. Sometimes discoveries in science are made unexpectedly, even by accident. But knowledge and creative insight are usually required to recognize the meaning of the unexpected. Aspects of data that have been ignored by one scientist may lead to new discoveries by another.

Science Explains and Predicts

Scientists strive to make sense of observations of phenomena by constructing explanations for them that use, or are consistent with, currently accepted scientific principles. Such explanations—theories—may be either sweeping or restricted, but they must be logically sound and incorporate a significant body of scientifically valid observations. The credibility of scientific theories often comes from their ability to show relationships among phenomena that previously seemed unrelated. The theory of moving continents, for example, has grown in credibility as it has shown relationships among such diverse phenomena as earthquakes, volcanoes, the match between types of fossils on different continents, the shapes of continents, and the contours of the ocean floors.

The essence of science is validation by observation. But it is not enough for scientific theories to fit only the observations that are already known. Theories should also fit additional observations that were not used in formulating the theories in the first place; that is, theories should have predictive power. Demonstrating the predictive power of a theory does not necessarily require the prediction of events in the future. The predictions may be about evidence from the past that has not yet been found or studied. A theory about the origins of human beings, for example, can be tested by new discoveries of human-like fossil remains. This approach is clearly necessary for reconstructing the events in the history of the earth or of the life forms on it. It is also necessary for the study of processes that usually occur very slowly, such as the building of mountains or the aging of stars. Stars, for example, evolve more slowly than we can usually observe. Theories of the evolution of stars, however, may predict unsuspected relationships between features of starlight that can then be sought in existing collections of data about stars.

Scientists Try to Identify and Avoid Bias

When faced with a claim that something is true, scientists respond by asking what evidence supports it. But scientific evidence can be biased in how the data are interpreted, in the recording or reporting of the data, or even in the choice of what data to consider in the first place. Scientists' nationality, sex, ethnic origin, age, political convictions, and so on may incline them to look for or emphasize one or another kind of evidence or interpretation. For example, for many years the study of primates—by male scientists—focused on the competitive social behavior of males. Not until female scientists entered the field was the importance of female primates' community-building behavior recognized.

Bias attributable to the investigator, the sample, the method, or the instrument may not be completely avoidable in every instance, but scientists want to know the possible sources of bias and how bias is likely to influence evidence. Scientists want, and are expected, to be as alert to possible bias in their own work as in that of other scientists, although such objectivity is not always achieved. One safeguard against undetected bias in an area of study is to have many different investigators or groups of investigators working in it.

Science Is Not Authoritarian

It is appropriate in science, as elsewhere, to turn to knowledgeable sources of information and opinion, usually people who specialize in relevant disciplines. But esteemed authorities have been wrong many times in the history of science. In the long run, no scientist, however famous or highly placed, is empowered to decide for other scientists what is true, for none are believed by other scientists to have special access to the truth. There are no preestablished conclusions that scientists must reach on the basis of their investigations.

In the short run, new ideas that do not mesh well with mainstream ideas may encounter vigorous criticism, and scientists investigating such ideas may have difficulty obtaining support for their research. Indeed, challenges to new ideas are the legitimate business of science in building valid knowledge. Even the most prestigious scientists have occasionally refused to accept new theories despite there being enough accumulated evidence to convince others. In the long run, however, theories are judged by their results: When someone comes up with a new or improved version that explains more phenomena or answers more important questions than the previous version, the new one eventually takes its place.

Tasks (assignments)

1. Do you think that one day in the future, can a scientific law be change? Why?

Case Study and Summary

Development of a Simple Theory by the Scientific Method:

- **Observation:** Every swan I've ever seen is white.
- **Hypothesis:** All swans must be white.
- **Test:** A random sampling of swans from each continent where swans are indigenous produces only white swans.
- **Publication:** "My global research has indicated that swans are always white, wherever they are observed."
- **Verification:** Every swan any other scientist has ever observed in any country has always been white.
- **Theory:** All swans are white.

Prediction: The next swan I see will be white.

Note, however, that although the prediction is useful, the theory does not absolutely *prove* that the next swan I see will be white. Thus it is said to be falsifiable. If anyone ever saw a black swan, the theory would have to be tweaked or thrown out. (And yes, there are really black swans. This example was just to illustrate the point.)

Real scientific theories must be falsifiable. So-called "theories" based on religion, such as creationism or intelligent design are, therefore, not scientific theories. They are not falsifiable and they do not follow the scientific method (http://www.wilstar.com/theories.htm).

Frequently Asked Questions

How can I differ a scientific law from a scientific theory?

Answer the question above

A **scientific law** describes the behavior of something that occurs. It is often described in mathematical relationships. For example the general law of gravitation describes the force between objects of various masses at various distances. A **scientific theory**, however, attempts to describe why something works. There are several theories of gravity, which attempt to explain why it occurs as it does. Both **Scientific Theories and Laws** are based upon observation and experimentation; they can be disproved or modified to accommodate new discoveries, and must make predictions about future experiments and observations.

Next Reading

http://wiki.answers.com/Q/How_is_a_scientific_law_different_from_a_scientific_theory

http://evidence-based-science.blogspot.com/2008/02/what-is-scientific-law-theory.html

http://www.wilstar.com/theories.htm

References

1. http://www.project2061.org/publications/sfaa/online/chap1.htm

2. http://www.wilstar.com/theories.htm

Unit 4

Meaningful Learning, Nature of Science etc.

Objectives:

- to comprehend the nature of science;
- to improve meaningful learning.

Defining Meaningful Learning

Our working definition of meaningful learning is *achieving deep understanding of complex ideas that are relevant to students' lives*. Because knowledge and understanding reside in the mind of the knower, obtaining multiple perspectives can deepen our understanding of meaningful learning and its significance. We are going to mention about only two perspectives of meaningful learning.

According to Jonassen et al. (1999), meaningful learning is:

- **Active**. We interact with the environment, manipulate the objects within it and observe the effects of our manipulations.
- **Constructive**. Activity is essential but insufficient for meaningful learning. We must reflect on the activity and our observations, and interpret them in order to have a meaningful learning experience.
- **Intentional.** Human behavior is naturally goal-directed. When students actively try to achieve a learning goal they have articulated, they think and learn more. Articulating their own learning goals and monitoring their progress are critical components for experiencing meaningful learning.
- **Authentic.** Thoughts and ideas rely on the contexts in which they occur in order to have meaning. Presenting facts that are stripped from their contextual clues divorces knowledge from reality. Learning is meaningful, better understood and more likely to transfer to new situations when it occurs by engaging with real-life, complex problems.
- **Cooperative.** We live, work and learn in communities, naturally seeking ideas and assistance from each other, and negotiating about problems and how to solve them. It is in this context that we learn there are numerous ways to view the world and a variety of solutions to most problems. Meaningful learning, therefore, requires conversations and group experiences.

Wiske (1998) provides another perspective about meaningful learning with a focus on subject matter content. She calls for teaching subject matter that is:

- **Central to the domain or discipline.** Every academic discipline has elements that are regarded by those in the field as the ideas and methods of inquiry that are central and controversies that are enduring. Teaching aimed at meaningful learning encompasses these aspects.
- **Accessible and interesting to students.** Topics must be significant from a student's perspective. Teaching about the Monroe Doctrine, for example, must enable students to make meaning from its tenets in the here and now.
- **Exciting for the teacher's intellectual passions.** For a topic to be generative, the way it is taught is as important as the substance. The teacher's curiosity, zeal and genuine wonder are infectious and serve as a model for students to imitate.
- **Easily connected to other topics, whether inside or outside the discipline.** Students benefit most when they can link their previous experiences and knowledge to other important ideas.

We encourage you to use this information together with the other suggested resources to enrich your understanding of meaningful learning.

Nature of Science

Understanding how science works allows one to easily distinguish science from non-science. Thus, to understand biological evolution, or any other science, it is essential to begin with the nature of science.

What is Science?

Science is a particular way of understanding the natural world. It extends the intrinsic curiosity with which we are born. It allows us to connect the past with the present, as with the redwoods depicted here.

Science is based on the premise that our senses, and extensions of those senses through the use of instruments, can give us accurate information about the Universe. Science follows very specific "rules" and its results are always subject to testing and, if necessary, revision. Even with such constraints science does not exclude, and often benefits from, creativity and imagination -with a good bit of logic thrown in- (http://evolution.berkeley.edu/evosite/nature/index.shtml).

History of the Nature of Science

Over the course of human history, people have developed many interconnected and validated ideas about the physical, biological, psychological, and social worlds. Those ideas have enabled successive generations to achieve an increasingly comprehensive and reliable understanding of the human species and its environment. The means used to develop these ideas are particular ways of observing, thinking, experimenting, and validating. These ways represent a fundamental aspect of the nature of science and reflect how science tends to differ from other modes of knowing.

It is the union of science, mathematics, and technology that forms the scientific endeavor and that makes it so successful. Although each of these human enterprises has a character and history of its own, each is dependent on and reinforces the others. Accordingly, the first three chapters of recommendations draw portraits of science, mathematics, and technology that emphasize their roles in the scientific endeavor and reveal some of the similarities and connections among them.

Third and fourth units lay out recommendations for what knowledge of the way science works is requisite for scientific literacy. These chapters focus on three principal subjects: the scientific world view, scientific methods of inquiry, and the nature of the scientific enterprise (http://www.project2061.org/publications/sfaa/online/chap1.htm).

Making sense of the nature of science (NoS) (http://www.tki.org.nz/r/science/science_is/nos)

Science as a human activity

The integrating strand: Making sense of the nature of science (NoS) is about science as a contemporary body of knowledge, created by people, to help understand the world around us.

Nature of science themes

To support Achievement Aim 1 of the NoS strand, the Ministry of Education has identified key themes. These NoS themes can be used by teachers to enrich their understandings of the nature of science, and better integrate this strand with the contextual strands in science activities.

Select a NoS theme from the lists below for supporting concepts, teacher's notes, questions to help build your understanding of the nature of science, and example science activities.

Exploring science ideas

- Scientists turn their science ideas into questions that can be investigated
- Scientists' observations are influenced by their science ideas
- Scientists' investigations are influenced by their communities
- Scientists' predictions are based on their existing science knowledge
- Scientists design investigations to test their predictions
- Many different approaches and methods are used to build scientific investigations
- When scientists carry out investigations they aim to collect adequate data
- Scientists think critically about the results of their investigations

Forming scientific explanations

- Scientific explanations may involve creative insights
- There may be more than one explanation for the results of an investigation
- Scientific explanations may be in the form of a model
- When an explanation correctly predicts an event, confidence in the explanation as science knowledge is increased

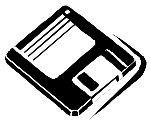
Science knowledge

- Scientific explanations must withstand peer review before being accepted as science knowledge
- New scientific explanations often meet opposition from other individuals and groups

- Over time, the types of science knowledge that are valued change
- All science knowledge is, in principle, subject to change

The culture of science

- Open-mindedness is important to the culture of science
- Scientific progress comes from logical and systematic work, and also through creative insights
- Science interacts with other cultures

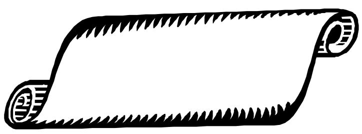


Tasks (Assignments)

1. Do you think there are similarities with the aims of constructivist science education and meaningful learning?
2. Is it compulsory to know the NoS to understand scientific process?

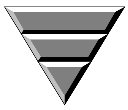
Case Study

During the science lesson teacher asked a lot of questions to the students in order to understand their understandings of the concepts. And also teacher used some models and analogies to teach them. Teacher tried to teach them the similarities, differences, interrelations, cause, effects of the concepts.



Questions to Case Study

1. After such a long lesson can you say that his/her students had a meaningful learning?
2. What may be the benefits of knowing NoS on meaningful learning?



Summary

Meaningful learning is *achieving deep understanding of complex ideas that are relevant to students' lives*. Because knowledge and understanding reside in the mind of the knower, obtaining multiple perspectives can deepen our understanding of meaningful learning and its significance. Understanding how science works allows one to easily distinguish science from non-science. Thus, to understand biological evolution, or any other science, it is essential to begin with the nature of science.

Frequently Asked Questions

How students can explore the nature of science?

Answer the question above

Students can explore the nature of science by investigating:

- how science knowledge is developed by scientists
- the processes and practices of the science community
- how science shapes the world we all live in
- the history of science (processes, knowledge, and purposes).

Next Reading

1. http://evolution.berkeley.edu/evosite/nature/index.shtml
2. http://www.tki.org.nz/r/science/science_is/teaching_science/types_investigation_e.php
   Types of investigation
3. http://www.tki.org.nz/r/science/science_is/teaching_science/teaching_models_e.php
   Teaching with models

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Abd-El-Khalik, F.,&Lederman,N.G. (2000). Improving science teachers' conceptions of the nature of science: A critical review of the literature. *International Journal of Science Education,* 22, 665–701.

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Jonassen, D.H., Peck, K.L., & Wilson, B.G. (1999) *Learning with technology*. Upper Saddle River, NJ: Merrill Publishing.

Wiske, M.S. (1998). What is teaching for understanding? In Wiske, M.S. (Ed.) *Teaching for understanding: Linking research with practice*. San Francisco: Jossey-Bass Publishing.

http://www.tki.org.nz/r/science/science_is/nos/ entrance: 30.07.2008

http://evolution.berkeley.edu/evosite/nature/index.shtml entrance: 30.07.2008