UNESCO Cairo Office

THE TENTH ANNUAL SCIENCE AND MATH EDUCATORS CONFERENCE (SMEC 10)
November 9th and 10th, 2007

Science and Mathematics Education Center (SMEC)
Faculty of Arts and Sciences
American University of Beirut, Lebanon

SMEC 10 – CONFERENCE PROCEEDINGS

(ENGLISH AND FRENCH SECTION)

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We do apologize for any significant omissions.

SMEC 10 MISSION STATEMENT

The SMEC Conference is an annual event designed to promote the continued development of a professional community of mathematics and science educators across Lebanon and throughout the region. Specifically, the conference aims to:

- Provide an intellectual and professional forum for teachers to exchange theoretical and practical ideas regarding the teaching and learning of mathematics and science at the elementary, intermediate, and secondary levels

- Provide a forum for teacher educators and researchers to share their findings with science and mathematics teachers with a special emphasis on the practical classroom implications of their findings

- Provide an opportunity for science and mathematics teachers to interact with high-caliber science and mathematics education professionals from abroad

- Contribute to the ongoing development of a professional culture of science and mathematics teaching at the school level in Lebanon and in the region

- Raise awareness of science and mathematics teachers about the array of curriculum and supplemental classroom materials available to them through publishers and local distributors

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[1] For contributions in Arabic see Arabic portion of proceedings.

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PLENARY SESSIONS

Mathematics

The Story of Infinity

Azmi Hanna

As the title indicates, I am not reading an article in mathematics. I am addressing mathematicians and non-mathematicians alike, and if you have not forgotten part of your high school mathematics you will be able to make good sense of what I am talking about this evening.

Usually, mathematicians try to illustrate definitions and theorems by concrete examples that are apparently from the real world, or make an introduction. I would like to make a brief introduction because the time available for this lecture is limited to about 50 minutes only. And after giving the contents of this lecture a little thought, I realized that an extended version could be part of the sequence of courses in cultural studies, or equivalently general education.

Quite often people ask me what mathematics is about, and I feel embarrassed for being unable to give a satisfactory answer. Sometimes I use vocabulary that bewilders the person I am addressing. For example, I would say, mathematics is a precise, idealized discipline, and mathematicians adopt a totally abstract point of view of this idealized world and reason with their abstractions in a rigorous and precise fashion. These statements do not make the person listening to me any wiser. So, I illustrate the words, idealized and abstract by examples. Good examples are the set of natural numbers, 0, 1, 2, . . ., notions such as points, lines and planes. These are among the most abstract notions in mathematics, and I challenge the listener to explain what is meant by, say the number 3 without using the word three or threeness. The listener fails the test. I go one step further and say, notions such as natural numbers, points, lines and planes do not exist in the real world. They exist only in our minds.

If natural numbers with which we have become familiar since our early childhood do not exist in the real world, what about infinity and infinite numbers that are the subject of my lecture? In mathematics we have to distinguish between the linguistic and mathematical meaning of our vocabulary. The words infinity or infinite are common words in any natural language. If I ask how many grains of sand are there in Lebanon, I am sure I receive, infinitely many as an answer. Yet, the number of grains of sand in Lebanon is a "small" number. If I ask how many atoms are there in the discovered universe, I receive also infinitely many as an answer. Yet, this number does not exceed 3×10^{75}. This is only a 76 digit number, and since there is on the average one atom in every 7 cubic meters of the discovered space, the volume of this space in cubic meters is only a 77 digit number. It might be a surprise to you to know that amateur mathematicians have discovered giant prime numbers. Up to the year 2002, the largest discovered prime number is a 4 million digit number. And it was discovered by an amateur. The discovery of giant prime numbers by amateurs is a very nice story on which I cannot elaborate any further. I only mention that thousands of people including school children leave their computers operating for many months in their hunt for giant prime numbers.

Our story begins at about 500 B.C., 2500 years ago. The first recorded evidence of the discovery of infinity is from paradoxes attributed to the Greek philosopher **Zeno of Elea** (495 – 435 B.C.). The most well known of these paradoxes is one in which Zeno described a race between Achilles, the fastest runner of antiquity and a tortoise. Because he is much slower, the tortoise is given a head start. Zeno argued that by the time Achilles reached the point from which the tortoise started the race, the tortoise would have moved a distance. Then by the time Achilles has traveled the new distance, the tortoise would have advanced further. And the argument continues in this way ad infinitum. Therefore, concluded Zeno, the fast Achilles can never beat the slow tortoise.

Another of Zeno's paradoxes, the dichotomy, says that you cannot leave the room in which you are right now. First you walk half the distance to the door, then half the remaining distance, and so on ad infinitum.

To block these paradoxes, Zeno argued that time and space are not infinitely divisible. Yet these paradoxes point to the disturbing properties of infinity and the pitfalls that await us when we try to understand the meaning of infinite processes or phenomena. But the roots of infinity lie in the work done a century earlier by Pythagoras and his disciples. They discovered irrational numbers.

Pythagoras (c. 569 – 500 B.C.) was born on the island of Samos off the Anatolian coast. During his youth he traveled extensively. According to tradition he visited Babylon and made several trips to Egypt, where he met with the priests – keepers of the Egyptian records dating from the dawn of civilization. He also discussed with them the Egyptian studies of numbers. Upon his return he settled in the town of Crotona in southern Italy, where he established a school of philosophy devoted to the study of numbers.

The Pythagorians pursued studies of numbers and philosophy. It is believed that Pythagoras coined the words philosophy (love of wisdom) and mathematics (that which is learned). Pythagoras gave two types of lectures: one restricted to the members of his society and the other to a wider community. The disturbing finding of irrational numbers was given in the first lecture and the members were sworn to complete secrecy.

The Pythgorians discovered that $\sqrt{2}$ was an irrational number. This was a devastating discovery to Pythagoras and his followers, because numbers became the Pythagorians' religion, and by number they understood natural numbers and their ratios.

Hippassus, one of the members of the Pythagorian order is believed to have committed the ultimate crime of divulging to the outside world the secret of the existence of irrational numbers. A number of legends record the aftermath of the affair. Some claim Hippassus was expelled from the society. Others tell how he died. One story says Pythagoras himself strangled or drowned the traitor, while another describes how he was set afloat on a boat and drowned at large see. The murder of Hippassus is considered the first scandal in mathematics. There are many others!

Pythagoras died in Merapontum in southern Italy around 500 B.C., but his ideas were perpetrated by many of his disciples who dispersed throughout the ancient world. The center of Crotona was abandoned after a mysterious mystical group called the Sybiris mounted a surprise attack on the Pythagorians and murdered many of them including Pythagoras. Among those who fled carrying the Pythagorian flame, was a group that settled further to the south of Italy. Here

Philolaos was trained in the number mysticism in the following century. Philolaos's writings about the work of Pythagoras and his disciples were brought to the attention of **Plato** in Athens. While himself not a mathematician, the great philosopher was committed to the Pythagorian veneration of numbers. His enthusiasm for the mathematics of Pythagoras made Athens the world's center of mathematics in the fourth century B.C. His enthusiasm for mathematics is evidenced by what he wrote at the door of his academy: "Let no ignorant of geometry enter here." And geometry was mathematics in ancient Greece. The most important member for our story in Plato's academy was **Eudoxus of Cnidus** (408 – 355 B.C.) He and **Archimedes** (287 – 212 B.C.) took up Zeno's idea of infinity. They made use of infinitesimal quantities – numbers that are infinitely small – to find areas and volumes of curved surfaces by dividing them into a large number of rectangles and three-dimensional objects and then calculating the sum of the areas and volumes. Eudoxus demonstrated that we did not have to assume the actual existence of infinitely many, infinitely small quantities in such a computation of total area or volume of a curved surface or solid. All we have to assume is that there exist quantities "as small as we wish" by continued division of any total magnitude, a brilliant introduction of the concept of **potential infinity**. Potential infinity enabled mathematicians to develop the notion of a limit, which was the essential tool to establish calculus on a firm foundation in the nineteenth century.

The work of Eudoxus and Archimedes did not develop further for two thousand years till we had Galileo and Bolzano who discovered one of the most fundamental properties about the nature of infinity. The interests of the Greek was directed to geometry and reconciling the real numbers with the line in geometry.

Galileo and Bolzano.

During the period 1600 – 1800 the theory of calculus and other fields of mathematics were developed. We had Newton, Leibnitz, Euler, Gauss and others. None of these mathematicians, however, dared enter the secret garden of infinity. They used ingenious arguments, where a quantity approached infinity or approached zero. Thus, mathematics dealt only with a potential infinity.

It remained for one of the greatest scientists of all times – but not generally associated with abstract mathematics – to discover one of the key properties of actual infinity. The man was **Galileo Galilei** (1564 – 1642).

In 1629 Galileo put his thoughts about the Copernican theory in a book, *Dialogue Concerning the Two Chief World Systems*. It was in from of a dialogue that takes place between three individuals. Two of them are named after Galileo's friends and hold the "right "view about the earth and the sun. The third discussant is called **Simplicius** and holds the views of the Church. The book became an overnight success.

Soon after Galileo published the Dialogue, his enemies pounced on the opportunity for which they had been waiting. They convinced the Pope that Simplicius was no one else but the Pope himself. Galileo was ordered to Rome to answer the charges against him. The aging scientist, in poor health asked for postponement. His request was turned down by the Vatican and was ordered to appear in front the Inquisition within sixty days. He traveled to Rome hoping to convince the Inquisition of his points of view. He could not and was forced to kneel in front of the Inquisition and recant his views under the threat of torture. The death sentence was commuted to home arrest in Florence for the rest of his life.

While under arrest in his home, Galileo was unable to travel to conduct his physical experiments. He was required to stay at home, his nun daughter reciting for him the number of daily Hail Marys the Inquisition prescribed as part of the agreement to commute his death sentence for stating that the Earth was not the center of the universe. It was during that period of confinement to his home and beautiful gardens that Galileo wrote and published in 1638 a treatise, “On Two New Sciences” in which he discussed various philosophical and mathematical ideas in the form of a dialogue. The intelligent voice in the dialogue is **Salviati**. His opponent is again named **Simplicius**. The dialogue was Galileo’s veiled revenge on the Inquisition, putting the Inquisition views in the mouth of Simplicius.

Salviati explains to Simplicius various aspects of infinity. He starts with the infinity that was well-understood by the ancients as well as renaissance and later mathematicians: the potential infinity of limits which date back to Eodoxus and Archimedes and their method of deriving areas and volumes of surfaces and bodies. He explains further that the same methods were used by **Johann Kepler** (1571 – 1630) to derive mathematically the laws of motion of planets around the sun. By using ingenious mathematical methods, Kepler was able to discover and express by equations the laws of planetary motion. In 1609 he announced the first two laws: Planets moved around the sun in elliptical orbits with the sun at one focus; and the line joining the planet to the sun sweeps equal areas in equal times. In deriving these equations Kepler makes extensive use of potential infinity. He divided areas of ellipses into very many “infinitesimal” triangles, then computed their areas to see what the limit of the total sum of areas would be as the number of triangles increased toward infinity.

Further in his treatise On Two Sciences, Galileo went the extra step – the big leap from potential infinity to actual infinity. Salviati sets up a one-one correspondence between all the natural numbers and all the squares of integers and says “We must conclude there are as many squares as there are numbers”. Thus an infinite set, the set of natural numbers, is shown to be “equal in number” to the set of squares of numbers, which is a proper subset of whole numbers. How can this be possible?????

When Salviati in Galileo’s dialogue concluded correctly that the number of squares is not less than the number of integers, Galileo could not make him say the two sets are of equal number. This was too much for him. He was shocked by the discovery that while there were infinitely many numbers left over – all non-squares – each integer had already been associated with a unique square. Galileo had thus discovered the key property of infinite sets: An infinite set can be equal in number of elements to a proper subset of itself. Infinity is an intimidating concept – one where our everyday intuition no longer serves to guide us. Galileo stopped here. Apparently, the power of the infinite was enough to deter him from writing more about infinity. Unfortunately, the world of mathematics was denied at an early stage the discovery of actual infinity. He was, however, the first person in history to have touched actual infinity and survived the ordeal. In 1642 Galileo died a broken man by all accounts.

The great German mathematician, **David Hilbert** (1862 – 1943) liked to tell to his friends the story of his infinite hotel. The rooms of the Hilbert hotel are numbered 1, 2, 3, ... When you arrive at the hotel the owner tells you there is no vacancy. But then you have an idea and tell the hotel manager to move the guest in room 1 to room 2, the guest in room 2 to room 3, and so on. This way all guests have a room and room number 1 is made available to you.

At any rate Galileo addressed the discrete form of infinity, an infinity that can be counted. Today we call infinite sets that can be counted countable sets or countably infinite sets. Going beyond the countable sets to the continuum was the work of another mathematician.

Bernhard Bolzano (1781 – 1848) was a Cech priest who, like Galileo was shunned by his church because he held progressive views on theology. Rejected by the clergy and confined to his home with a generous pension, Bolzano did what Galileo did after his trial. Bolzano was attracted to the works of the mathematicians of ancient Greece, especially Eudoxus of Cnidus. The work of the Greek explorer of infinity and infinitesimal quantities brought Bolzano to the study of infinity. He studied also Euclid's geometry and the work of Lagrange and Euler. In 1817 Bolzano made an important mathematical discovery. He found a continuous function, which is nowhere differentiable. Decades later Weierstrass made the same discovery and got the credit while Bolzano's work remained unknown. Bolzano turned his attention to mathematics and the concept of infinity. In 1850 two years after his death, Bolzano's book, Paradoxien des Unendlichen (Paradoxes of Infinity) was published by his friend, **Fr. Prihonsky**. Unfortunately, the book received little attention from mathematicians at that time.

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Bolzano began by addressing Galileo's paradox about countably infinite sets. He then asked whether a similar property of infinity might be exhibited by the dense numbers of the continuum. He found that the same property did indeed apply. By the use of the concept of a function, Bolzano was able to establish the same one-one correspondence that Galileo had used in the discrete world of integers, here for two continua of numbers.

The Berlin School of Mathematics.

By the middle of the nineteenth century, mathematicians had been aware of the facts about infinity described earlier. Great mathematicians such as Newton, Leibnitz, Euler and Gauss assumed the existence of a potential infinity and used freely terms such as a quantity "approached infinity" or "approached zero". But none of them dared enter the secret garden of actual infinity. They were satisfied with an unreachable potential infinity. Actual infinity was the discovery of a brilliant mathematician, a few years after graduation from the University of Berlin.

At that time there were four great centers of mathematics in Europe: Berlin in Germany, Paris in France and Milan in Italy. German mathematics began its climb to world fame at the turn of the nineteenth century with the work of the great **Friedrich Gauss** (1777 – 1855). Gauss taught at the University of Göttingen, but his disciples helped found the school of mathematics at the University of Berlin.

Gifted mathematicians in Berlin included ***Bernhard Riemann*** *(1826 – 1866). His work in geometry led Riemann to consider the problem of infinity. The infinitude of straight lines is implied in Euclid's second postulate. Riemann argued that Euclid's lines could also be interpreted as bounded and yet infinite. A great circle on the sphere can be interpreted as a line that is bounded but infinite. Riemann's work on geometry touched directly on the concept of infinity in its treatment of Euclid's theory of space. He discovered what we now call the Riemann sphere. His sphere shows how the infinitely many points of the plane can be made* compact *by adding a "point at infinity" to the sphere.*

Another important mathematician who held a senior position at the University of Berlin was **Karl Weierstrass** (1815 – 1897). Weierstrass is considered by many the father of modern analysis, and it is of interest to say a few words about the unusual way he climbed to fame. For fifteen years, Weierstrass taught school mathematics at small German villages, where good books were not available and where intellectual pursuits and stimulating conversations were hard to find. Throughout this period, Weierstrass worked alone at night developing the modern theory of mathematical analysis as we know it today. In 1854, Crelle's Journal (the German journal, Reine und Angewandte Mathematik) published a paper by Weierstrass, who had finally sent his important work for publication. Overnight, the obscure schoolteacher became a mathematical celebrity. What struck the mathematicians in Berlin was not only the monumental nature of the mathematical developments achieved by an obscure school teacher in a remote village, but the fact that there were no preliminary results to herald the discoveries. Weierstrass had worked patiently and not published earlier results leading to his masterpiece, as others might have done. The result was swift – Weierstrass was offered a professorship at the University of Berlin. To support the appointment, an honorary doctor's degree from another institution was conferred on the bewildered school teacher.

In Berlin Weierstrass continued his studies of functions. His lectures were so popular that the lecture hall was the meeting place of all those who wanted to learn the subject. He developed further the notion of power series. We cannot add infinitely many terms, but as we add more and more terms, the finite sum gets closer and closer to the function of interest. Here, the idea of infinity is crucial, since the sum of functions "becomes" the desired function when one "reaches infinity".

Weierstrass's antagonist at the University of Berlin was **Leopold Kronecker** (1823 – 1891). Kronecker came from a wealthy family of business people and didn't need to work as a mathematician to make a living. As a young man he showed such an aptitude to mathematics that he was offered a professorship at the University of Berlin giving up a brilliant business career. Kronecker's interests were within the theory of algebraic numbers and he wrote his dissertation in this field under **Ernst Edward Kummer** (1810 – 1893), another well-known mathematician at the university.

The conflict between the algebraist Kronecker and the analyst Weierstrass was inevitable. Algebraists deal mainly with discrete entities such as integers, rational numbers and other entities that can be counted. On the other hand, analysts deal with continuous entities and therefore also with irrational numbers. Hence, it was not surprising that Kronecker and Weierstrass did not get along. Kronecker was a tiny man and Weierstrass was huge. People who watched the two men fighting over mathematics were struck by the comic nature of the conflict. It was like a tiny dog going after a St. Bernard.

Unwittingly, a young brilliant student at the University of Berlin would land in the middle of this bitter war between analysis and algebra, and Kronecker would turn all his venom on the newcomer, making him his main victim. Kronecker would single-handedly prevent Georg Cantor from achieving a position at the University of Berlin, although there was no one more deserving.

Cantorian Infinity = Actual Infinity. Calculus was discovered by Isaac Newton (1642 – 1727) and Gottfried Leibnitz (1646 – 1716) during the years 1665 – 1673. Newton discovered calculus only to solve problems about gravitation and astronomy. The notation we use is due to Leibnitz. Many mathematicians developed calculus and classical mechanics to what we know them today. These include the brothers Jacob (1654 – 1705) and Johann (1667 – 1748) Bernoulli, Leonhard Euler (1707 – 1788), Jean Le Rond d'Alembert (1717 – 1783), Joseph Lagrange (1736 – 1813) Pierre Simon Laplace (1749 – 1827), and many others. These mathematicians were careless about their work, especially when it came to problems of convergence and limits and so on. Their main objective was directed toward applications in astronomy, industry, military, navy and manufacturing. They did tremendous amount of work and got correct results.

However, analysis had been going for about two centuries of controversy over the meaning of concepts that Newton and Leibnitz introduced such as the derivative and the integral, since they talked about infinitesimals. These were in fact contradictory, but people accepted them, because they produced correct results, and to find out why they got the right results, clarification of the notions was made. Regiments of mathematicians and logicians put into great efforts to eliminate these contradictions. A few of the people responsible for clarification include Karl Weierstrass, Bernhard Bolzano, **Richard Dedekind** (1831 – 1916) and **Georg Cantor** (1845 – 1918). These people realized that to deal adequately with derivatives and integrals, infinite sets had to be considered and considered precisely. This was the origin of set theory and of Cantor's actual infinity.

Cantor got into set theory from a problem in analysis. He was not trying to define natural numbers or other things that future set-theorists have been doing since. His original motivation was analysis of infinite sets. His proper domain was to solve problems about infinite sets and not problems of definition of primitive concepts. This was done by the logician **Gottlob Frege** (1848 – 1925) in his book of two volumes, *Die Grundlagen der Arithmetik* (1884). There were inconsistencies with Frege's work, but this was put right by **Bertrand Russell** (1872 – 1970).

Cantor was jumping ahead at this stage. He got interested in sets themselves to discover how fascinating they were. His results fed back into analysis, and the arguments he used were so revolutionary that they permeated the whole of logic and mathematics, and nowadays computer science, ever since. In studying infinite sets he found out that a lot of them were similar to or have the same power as the set of natural numbers in the sense that they could be put into one-one correspondence with the set of natural numbers. This was known to Galileo, but Galileo was distraught about that and dropped the whole concept as meaningless and destroyed all hope of describing different infinite sets. This was not the case with Cantor who said let us consider them to have the same power. His first discovery was that the set of rational numbers had the same power as the set of natural numbers. This came as a surprise to the mathematical world, since it was known that the set of rational numbers lies dense on the real line, and so if you start counting from the left you run out of natural numbers before you reach anywhere at all. Cantor counted the rational numbers this way: He listed them in a table with infinite rows and columns. He started at the top left and then zig-zagged through them. Since a dense subset of the real line could be counted, one thought that every set could be counted. Cantor showed this was not the case. He showed that the real numbers cannot be counted and this was his second discovery. The proof is termed the second diagonalization process.

He elaborated on this proof and showed that no set can be matched with the set of its subsets or with the set of all functions from a set to itself. In the language of mathematics, the set of subsets of a set has a larger cardinality than the set itself. There is one more step that one can take in this argument: Let *S* be the set of all sets in the universe. Take the set of subsets of *S*. This should have more sets. But one cannot get more sets than there is in the universe. Cantor was aware of this problem, but he took it in his stride, and said let us assume we have consistent and non-consistent sets Russell also found about it, and he was worried. This was the notorious Russell paradox or something like it. Set theory was plagued with paradoxes at its infancy. The Russel paradox was not the first one. It was preceded by the **Cesare Burali-Forte** (1861 – 1931) paradox emanating from considering the "set" of all ordinal numbers. Immediately the first concern of mathematicians became to clean set theory from the paradoxes that may arise. Somehow the set of all sets had to be excluded from the family of all sets. That was not difficult to do, if we view sets as being built up from already established sets such as the set of natural numbers and go beyond that proceeding to sets of higher level of power. You can go one step higher each time and so you never arrive at the universe. This idea was suggested by **Ernst Zermelo** (1871 – 1953) in 1908. The same idea was polished by (**Adolf**) **Abraham Fränkel** (1896 – 1965) and **Thoralf Albert Skolem** (1887 – 1963) in 1922. This became finally axiomatic set theory which avoided all known paradoxes.

Cantor had three concrete infinite numbers of different levels. These were those of the countably infinite sets, that of the real numbers and that of all functions from the real numbers to itself. On June 29, 1877, Cantor wrote a letter to his friend Dedekind. He was excited and bewildered. The letter started with the French sentence: "Je le vois, mais je ne le crois pas" (I see it, but I do not believe it). He discovered a shocking property of infinity: The one-dimensional real line has as many points as the two-dimentsional plane. Continuing to higher dimensions, the real line has as many points as any real space of any finite dimension. This initiated a virulent opposition led by Kronecker at Cantor's set theory. Kronecker called Cantor a charlatan, a renegade, a corrupter of youth. The great French mathematician Henri Poincaré was very uncomfortable with Cantor's infinite numbers. He thought Cantor's infinite numbers represented a grave mathematical malady that would be one day cured. On the other hand Russel described Cantor as one of the greatest intellects of the nineteenth century, and David Hilbert believed Cantor had created a new paradise for mathematicians.

This opposition did not deter Cantor from continuing his investigations of infinite numbers, which he called *transfinite numbers*. He went a step further. Since he had larger and larger infinite numbers, he assumed he could order them as the natural numbers 0, 1, 2, , , , starting with the smallest infinity, the next larger, and then the next larger and so on. He had no proof he could do so. All was a matter of strong belief. He needed a new notation and ended up writing $\aleph_0$ (read aleph zero) for the smallest infinity, the infinity that can be counted. He denoted the immediate successor of $\aleph_0$ by $\aleph_1$, the next immediate successor by $\aleph_2$ and so on obtaining the sequence
$\aleph_0, \aleph_1, \aleph_2, \ldots$
of infinite numbers, with no infinite number intermediate between $\aleph_n$ and $\aleph_{n+1}$. He went also one step further. He denoted the first successor of the sequence $\aleph_0, \aleph_1, \aleph_2, \ldots$ by $\aleph_\omega$ with immediate successor $\aleph_{\omega+1}$ and so on. Finally he associated with every ordinal number μ a transfinite number $\aleph_\mu$, and so on.

Cantor was elated when he also introduced the arithmetic of transfinite numbers. He defined the operations of addition, multiplication and exponentiation of transfinite numbers. While addition and multiplication of infinite numbers did not increase size, exponentiation did. For example $\aleph_0 + \aleph_0 = \aleph_0$, $\aleph_0^2 = \aleph_0$. But $2^{\aleph_0}$ He knew that $2^{\aleph_0} > \aleph_0$. $2^{\aleph_0}$ is the size of real numbers. It must be one of his alephs. But which one? He was convinced that

$$2^{\aleph_0} = \aleph_1.$$

In other words the power of the continuum is the immediate successor of the power of countability. But Cantor had to prove his claim. His formula seemed intuitively to be true, but intuition in mathematics does not always lead to truth. This statement became known as the *continuum hypothesis*. In 1908, this statement was generalized by **Felix Hausdorff** (1868 – 1942) in the form of a *generalized continuum hypothesis*:

$$2^{\aleph_\mu} = \aleph_{\mu + 1}$$

for every ordinal number μ.

Cantor realized that if he ever hoped to prove the continuum hypothesis, he had to have a way to compare transfinite numbers. Doing so would establish that every transfinite number is one of his alephs. He could not even give a convincing proof that $\aleph_1$ is the immediate successor of $\aleph_0$, $\aleph_2$ the immediate successor of $\aleph_1$ and so on. This was done in 1904 by the young mathematician, logician and theoretical physicist **Ernst Zermelo** who proved the well-ordering principle.

The first international congress of mathematicians took place in Zürich in 1997, and it was agreed to hold such a conference once every four years. However, to mark the new century, the second conference took place in Paris in 1900. The 37-year old David Hilbert was invited to deliver the opening talk. Hilbert announced a list of 23 major unsolved problems in mathematics. These became the famous Hilbert problems. The continuum hypothesis topped the list as problem 1. Problem 7 was the Riemann Hypothesis. All problems were solved except for the Riemann Hypothesis which remains the most important unsolved problem in mathematics.

The third international conference took place in Heidelberg in 1904. At this conference, Cantor found himself with an upsetting challenge. Julius König from Budapest appeared in Heidelberg and read a paper which claimed that the power of the continuum was not an aleph. Though successes and failures of mathematics do not make a ripple in the press, König's sensational discovery led the headlines on the German newspapers, and the Grossherzog of Baden called on Felix Klein to explain to him what was going on. In less than a day, Zermelo discovered a flaw in König's proof. This did not bring peace of mind to Cantor and the other mathematicians. Some mathematician might eventually correct König's proof. Zermelo proved this cannot take place.

Within a month of the conference, Zermelo settled the well-ordering principle: *Every set can be well-ordered.* This implied that every transfinite number is an aleph. Hilbert immediately published Zermelo's paper in the *Mathematische Annalen*, and solicited the opinion of the mathematics community. Far from making Cantor's set theory secure, Zermelo's brief paper created one of the greatest controversies in the history of mathematics. The first issue of the 1905 *Mathematische Annalen* included a sampling of the comments on Zermelo's proof of the well-ordering theorem. The English were represented by P. Jourdain who sent his own proof. The German were represented by Felix Bernstein and Arthur Schönfliess. The opposition came from the French mathematician Émile Borel. Borel admitted Zermelo had attempted to solve one of the most important problems in mathematics. But in his proof he made too many choices. This was the birth of the *Axiom of Choice*. This axiom says something that sounds quite trivial: Given a family $(A_i)_{i \in I}$ of non-empty sets, then there exists a choice function c which picks from every set A_i and element $c(A_i)$. Borel argued it was impossible to make a simultaneous choice of the elements in case the index set I is infinite. There was a diversity of opinion among the French mathematicians with Baire and Lebesgue supporting Borel and Hadamard supporting Zermelo.

In 1908 Zermelo published a list of eight axioms, including the axiom of choice as a basis for set theory and mathematics. These axioms blocked all known contradictions. This set of axioms was polished and expanded by one more axiom by Fränkel and Skolem in 1922, and set theory seemed to be safe of comtradictions.

Gödel and Cohen.

As part of its millennium celebrations, Time magazine published a list of the 100 greatest people of the twentieth century. On this list the choice of the greatest mathematician was **Kurt Gödel** (1906 – 1978). If you randomly select 100 people and ask "Do you know who Kurt Gödel is?", it is almost certain you will not receive a single positive answer. That would not be definitely true if you asked about the greatest physicist (Einstein), or the greatest chemist (Linus Pauling?). It might be debatable whether Gödel was the greatest mathematician of the twentieth century. But there is no doubt he was the greatest logician since Aristotle. So who is this giant among all giants and what did he accomplish to deserve this great honor. I shall only make a brief account on one accomplishment in logic and mathematics. He is the author of the greatest theorem in mathematics and logic: *The Incompleteness Theorem.* This theorem says in lay terms, Truth is bigger than proof. That is, there are unprovable true statements.

Encouraged by his success in devising a complete system of axioms for Euclidean Geometry in 1899, David Hilbert asked whether the same can be done for other branches of mathematics. This came to be called the Hilbert Program. In 1931, the 25-year old Kurt Gödel proved that if the formal system of arithmetic is consistent, then no matter how many axioms you write down, any system that contains arithmetic contains true statements that are not provable in the system.

Gödel announced his theorem on October 7, 1930 on the third and last day of a conference in Königsberg on "Epistemology of Exact Sciences." Gödel's proof that there are facts known to be true, which cannot be proven set off tidal waves of discoveries in mathematics, natural sciences, theory of computation and neural networks. It also revolutionized not only mathematics, but also philosophy, linguistics, computer science and even cosmology. **John von Neumann** (1904 – 1955), who attended the conference took the hint and quickly deduced the shocking consequence:

It is impossible to prove the consistency of mathematics.

Gödel's Incompleteness destroyed Hilbert's Program. Hilbert got angry and is quoted to have said, "Isn't enough that this young Austrian has stolen me the Completeness Theorem of predicate calculus, and now devastates my program?" The completeness theorem was the subject of

Gödel's dissertation, which he wrote under Professor Hans Hahn at the University of Vienna in 1930. However, Hilbert accepted to live with Gödel's shocking result. Many mathematicians and philosophers refused to accept the theorem. It took Gödel some correspondence to convince Paul Bernays at the University of Zürich, and a former assistant of Hilbert of the theorem. Ernst Zermelo rejected the theorem all his life. The impossibility to prove the consistency of mathematics does not bother the mathematics community. Mathematicians had been working with the Zermelo-Fränkel axioms for more than 100 years without stumbling on a contradiction.

After the Incompleteness Theorem, Gödel turned his attention to set theory and in particular to the axiom of choice and the continuum hypothesis. He proved the independence of the axiom of choice from the other axioms of set theory. He proved in 1938 that you cannot get a contradiction using the Axiom of Choice if you cannot get one using the other axioms. This proved the consistency of the axiom of choice with the other axioms. He showed also that the continuum hypothesis and the generalized continuum hypothesis are consistent with the other axioms of set theory including the axiom of choice. His final result was: If the axioms of set theory are consistent, it is impossible to disprove the continuum hypothesis. This does not mean the continuum hypothesis is true. All this was at about 1938. It took another 25 years for another great mathematician to prove the impossibility of proving the continuum hypothesis. This was Paul Cohen.

Paul Cohen (1934 -) wrote an excellent dissertation in harmonic analysis at the University of Chicago in 1958. It earned him membership at the Princeton Institute for Advanced Studies. He did not meet Gödel, who by the way had been a permanent member of the Institute since 1941. After a one-year stay at the Institute he joined the faculty of mathematics at Stanford University. Stanford Univerity has a strong school of foundations and set theory. He arrogantly asked "What problem should I work on that would make me famous?" Some faculty member thought what had this young analyst to do with foundations and set theory. One of them told him, "Solve the continuum hypothesis." A year later, Cohen went to Princeton, nocked on the door of Gödel's house. Gödel's wife opened the door and Cohen gave her a manuscript for Gödel to read. Gödel asked Cohen to come back after two days. When Cohen returned to hear the opinion of the great logician, he was told the result in his manuscript was correct. Cohen proved the missing half of the Continuum hypothesis in 1963. He proved: if the axioms of set theory are consistent, it is impossible to prove the hypothesis. The methods he used to prove this result were so penetrating (and difficult) and had a wide range of applications for the next twenty years all based on Cohen's breakthrough. In 1966, Paul Cohen was a warded a Fields Medal, the highest honor that can be bestowed on a mathematician equivalent to the Nobel Prize in other sciences.

Where do we now stand? According to Gödel and Cohen, the continuum hypothesis is neither *true* nor *false*. It is *undecidable*. And the negation or validity of the continuum hypothesis is consistent with the axioms of set theory. The power of the set of real numbers must be an aleph. Which one? It is not $\aleph_0$. Is it $\aleph_1$?, $\aleph_2$?, . . . $\aleph_{20}$? We shall never know. Hundreds of theorems of mathematics had been proved under the assumption of the continuum hypothesis. Are they all undecidable? We remain helpless hanging up in the air as to whether the continuum hypothesis is true or false.

Thank you and I apologize for keeping you listening to me a few minutes longer than allotted to the lecture.

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Science

Slide 1

Making Science Education More Scientific: Investigations into the Role of Argumentation

Sibel Erduran
University of Bristol
United Kingdom

Science and Mathematics Educators Conference, American University of Beirut, Lebanon, November 2007.

University of BRISTOL

Slide 2

Outline of Presentation

- Theoretical Background
  - Rationale for promoting argumentation in science education
    - Epistemological - Nature of science
    - Cognitive - Role of language in learning
- Empirical Dimension
  - Research Projects
    - *Study 1: Research & development with in-service teachers* - London, United Kingdom (Erduran, Osborne, Simon)
    - *Study 2: Case studies on exemplary teachers (Erduran & Dagher)*
    - *Study 3: Pre-service teachers* - Istanbul, Turkey (Erduran, Ardac, & Yakmaci-Guzel)
    - *Study 4: Primary students* - Santiago de Compostela, Spain (Jimenez-Aleixandre, Rodriguez & Erduran)
    - *Study 5: Theoretical studies* - nature of chemical knowledge & argumentation (Erduran)
- Conclusions & Implications

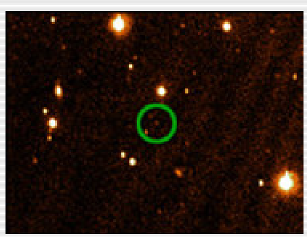
Slide 3

Claims in scientific knowledge

- Matter is made of tiny, indivisible particles
- Day and night are caused by a spinning Earth
- Plants convert light and water into food
    - *How do we know?*

Slide 4

Nature of Science?



- *"..observed by astronomers using California's Palomar Observatory, and has been given the name "Sedna" after the Inuit goddess of the ocean. Astronomers now say they have evidence that Sedna has its own moon, although this needs to be confirmed, and is also very red in colour. There is likely to be some debate about whether it qualifies as a true planet, but some scientists are already saying it re-defines our Solar System."*

BBC, 15 March 2004

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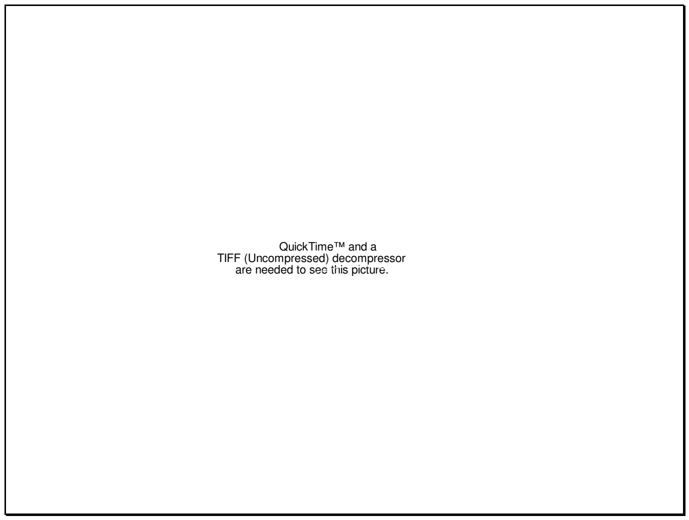

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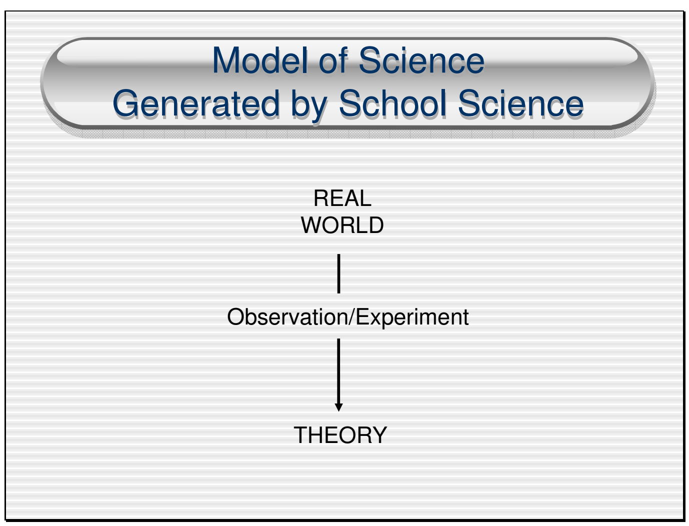

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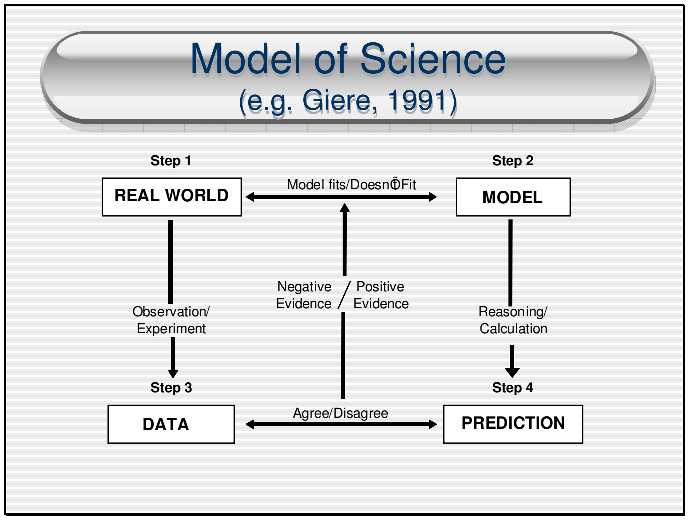

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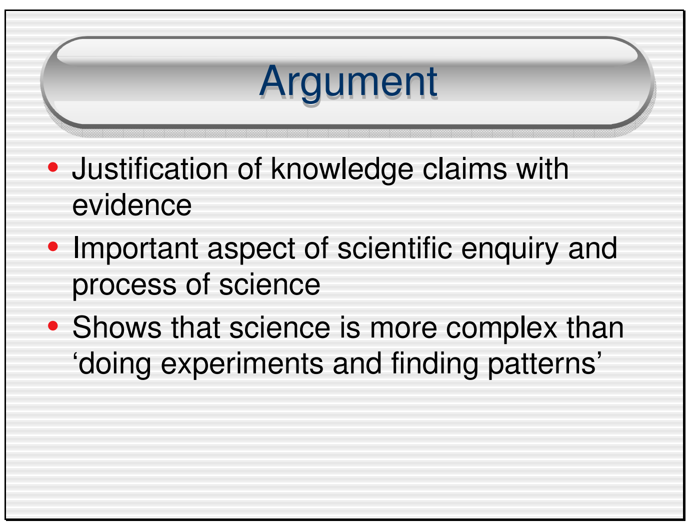

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Why Argument?: Educational Research & Policy

- *Research*
  - **Argument is an important aspect of scientific discourse and practice** (Kelly & Takao, 2002; Kuhn, 1991; Pontecorvo, 1987; Walton, 1996; Zeidler, 2003)
  - **Argument skills critical dimensions of learning and reasoning** (Brown, Collins, Duguid, 1989; Brown & Campione, 1994; Cobb, 1994; Driver, Asoko, Leach, Mortimer, & Scott, 1994; Wertsch, 1991; Kelly & Crawford, 1997; Polman & Pea, 2001).
- *Policy Documents*
  - UK - English National Curriculum (2006)
    - 'How Science Works'
  - USA - Inquiry and the National Science Education Standards (NRC, 2000)
  - South Africa - Critical Thinking Skills (Science Curriculum 2005)

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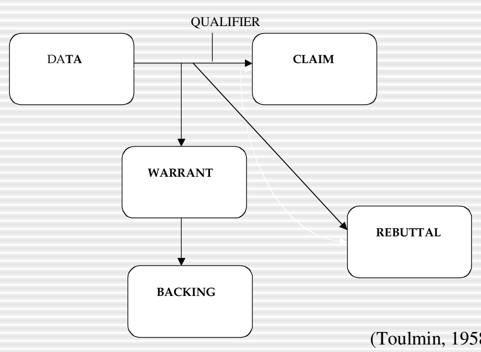
TOULMIN'S ARGUMENT PATTERN



(Toulmin, 1958)

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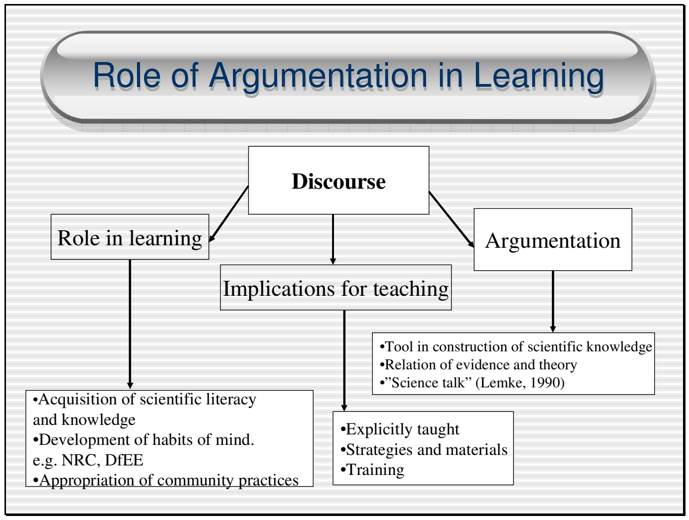

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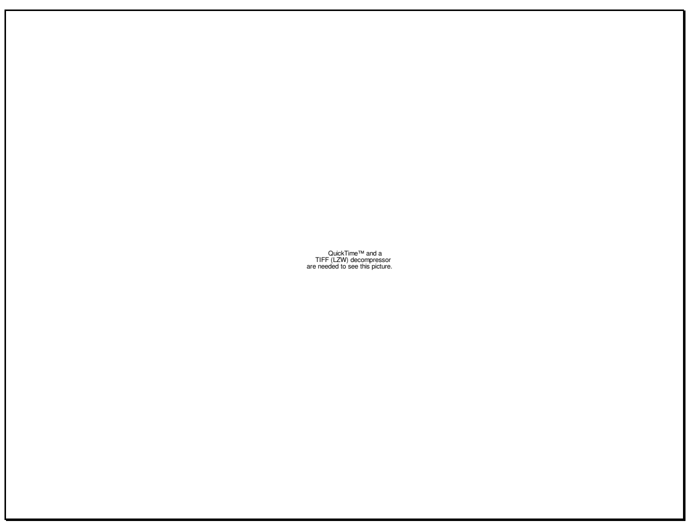

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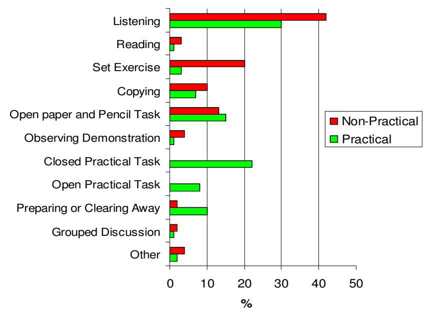
Types of Activity



(Driver et al., 1987)

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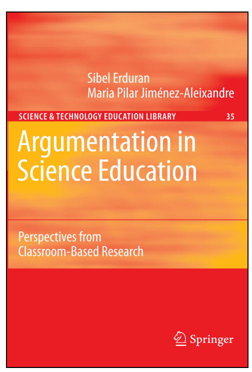

Erduran, S., & Jimenez-Aleixandre, M. P. (2007).

Contributors include Sibel Erduran, Maria Pilar Jimenez-Aleixandre, Gregory Kelly, William Sandoval, Richard Duschl, Dana Zeidler, Troy Sadler, Merce Garcia-Mila, Douglas Clark, Stein Kolsto, Mary Ratcliffe, Laurence Simonneaux and Andree Tiberghien.

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Examples of Completed Projects

- Enhancing the Quality of Argumentation in School Science (ESRC) - 1999-2002
- Ideas, Evidence and Argument in Science Education (Nuffield) - 2002-2003
- Continuing Professional Development in Argumentation (Gatsby) - 2003-2004
- Ideas and Evidence in Initial Teacher Training (Key Stage 3 Strategy) - 2004

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Ongoing Projects

- **Pre-service teaching** (with D. Ardac & B. Y.Guzel, Bosphorous University, Turkey)
- **Primary school context** (with M.P. Jimenez-Aleixandre & R. Rodriguez, University of Santiago de Compostela, Spain)
- **Link to inquiry and bridging research, policy, practice: "Mind the Gap"** (EU FP7-funded, with University of Oslo and 6 other European universities)

Slide 17

Enhancing the Quality of Argument in Science Education Project (ESRC funded)

- It is possible to train teachers to adapt their teaching to place more emphasis on the construction of argument
- Children's skills at argument improve with practice
- Developed a framework for evaluating argument
- Research reported in
    - Erduran, S., Simon, S., & Osborne, J. (2004). TAPping into argumentation: developments in the use of Toulmin's Argument Pattern for studying science discourse. *Science Education*, 88(6), pp.915-933.
    - Osborne, J., Erduran, S., & Simon, S. (2004). Enhancing the quality of argumentation in school science. *Journal of Research in Science Teaching*, 41(10), pp.994-1020.
    - Simon, S., Erduran, S.. & Osborne, J. (2006). Learning to teach argumentation: Research and development in the science classroom. *International Journal of Science Education*, 28 (2 &3), 235-260.

Slide 18

Study 1: Research & Development

(i) identify the pedagogical strategies necessary to promote 'argument' skills in young people in science lessons;

(ii) trial the pedagogical strategies and determine the extent to which their implementation enhances teachers' pedagogic practice with 'argument';

(ii) determine the extent to which lessons which follow these pedagogical strategies lead to enhanced quality in pupils' arguments.

(Erduran et al., 2004; Osborne et al., 2004; Simon et al., 2006)

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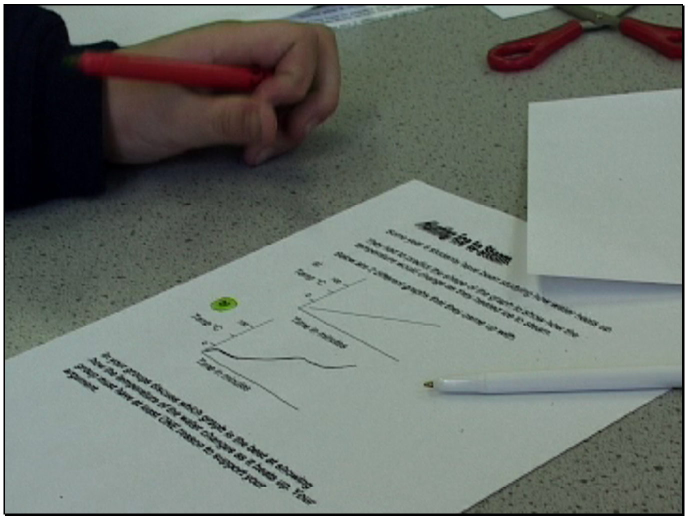

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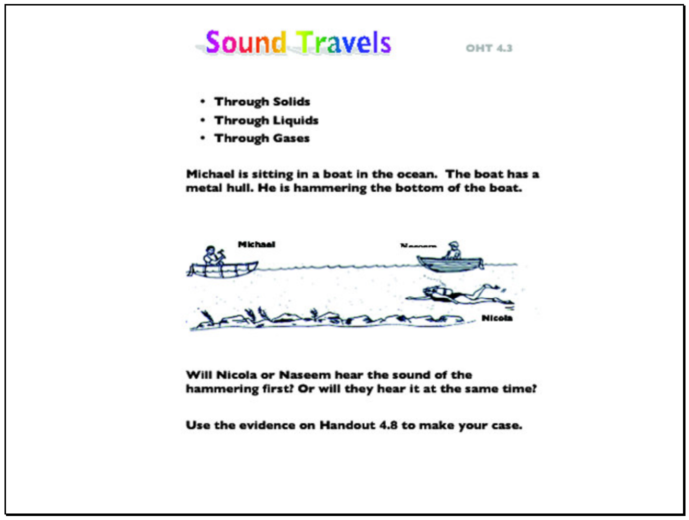

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Slide 23

Slide 24

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Pedagogical Strategies

- Materials for student activities
- Arguing prompts
- Role-play
- Writing frames
- Group presentations

Slide 26

Arguing Prompts

- Why do you think that?
- What is your reason for that?
- Can you think of another argument for your view?
- Can you think of an argument against your view?
- How do you know?
- What is your evidence?
- Is there another argument for what you believe?

Slide 27

Writing Frame Example

- My idea is…
- My reasons are that…
- I believe my reasons because…
- Ideas against my idea are…
- I would convince someone who doesn't believe me by…

Slide 28

Developing Practice: Data Sources

- 12 teachers of students aged 12-13 years
- Year 1 and Year 2
- Socio-scientific context: funding a zoo
  - Verbal conversations of teachers and students audio-taped in class
  - Observations and video-recordings of lessons
  - Audio-recorded interviews with teachers after each lesson

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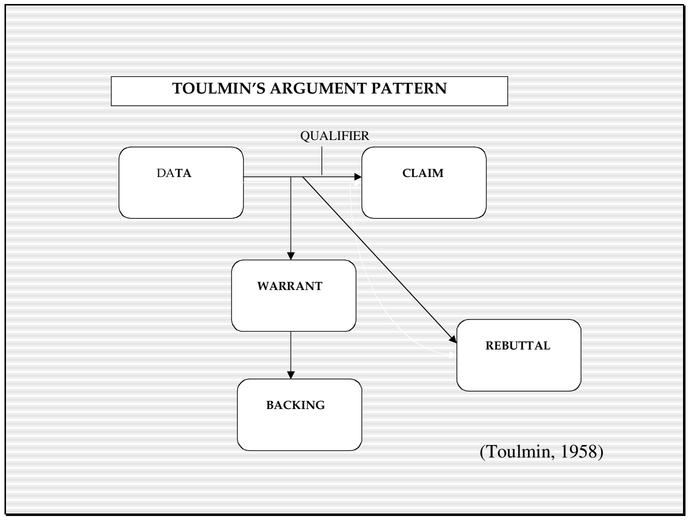

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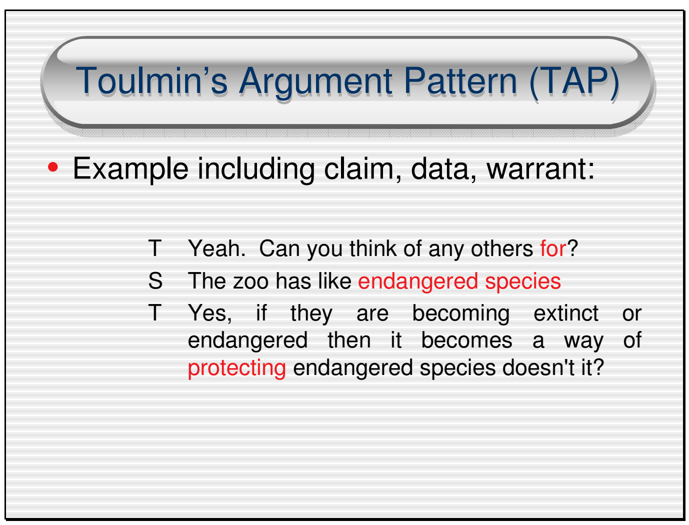

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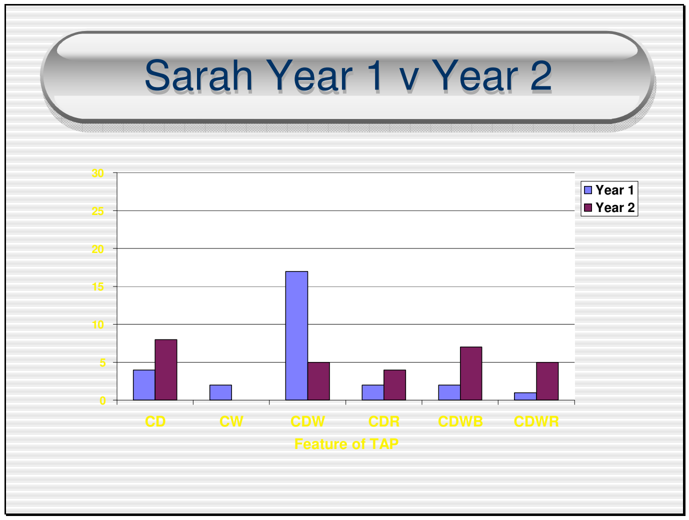

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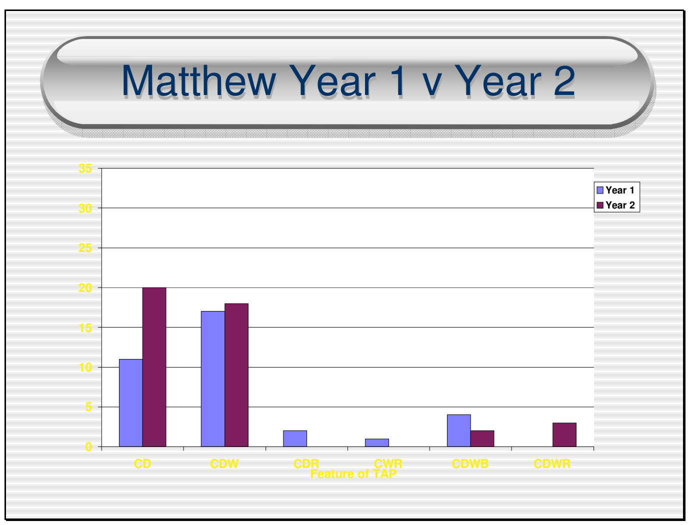

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Teacher	Year	CD, CR	CDW, CDR	CDWR, CDWB	CDWBR	Sig
Jeremy+	Year 1	48	47	5	0	
	Year 2	59	27	14	0	*
Peter	Year 1	41	47	10	2	
	Year 2	23	31	38	8	**
Maureen	Year 1	36	43	21	0	
	Year 2	43	43	14	0	
Frances+	Year 1	33	9	49	9	
	Year 2	52	3	42	3	*
Jules	Year 1	0	82	18	0	
	Year 2	8	44	44	4	**
Patrick	Year 1	48	38	14	0	
	Year 2	25	57	16	2	**
Mary+	Year 1	20	70	10	0	
	Year 2	0	50	50	0	**
Annie+	Year 1	48	32	16	4	
	Year 2	5	85	10	0	**
Sarah+	Year 1	21	68	11	0	
	Year 2	28	31	41	0	**
Katie	Year 1	32	47	16	5	
	Year 2	38	43	19	0	
Jason	Year 1	36	48	16	0	
	Year 2	41	41	14	4	
Matthew	Year 1	31	57	12	0	
	Year 2	46	42	12	0	

Slide 34

Sarah’s view of change

- In terms of her own professional development, Sarah thought that teaching argument had made her “a lot more conscious” about what she was saying and what she was trying to achieve in her teaching.

Slide 35

Matthew's view of change

"I now look much more critically at, both in teaching and setting homework, for questions which require more reasoning and evidence…. whereas in the past I might have thought - well, that's going to be too difficult for them… I think I appreciate the importance of trying to ensure that students see a difference between a statement and a reason for that."

Slide 36

Levels of Argument

Level 1:	**Level 1 arguments are arguments that are a simple claim v a counter claim or a claim v claim**
Level 2:	**Level 2 arguments consist of claims with either warrants, backings or data but do not contain any rebuttals.**
Level 3:	**Level 3 arguments consist of a series of claims or counter claims with either data, warrants or backings with the occasional weak rebuttal.**
Level 4:	**Level 4 arguments consist of a claim with a clearly identifiable rebuttal. Such an argument may have several claims and counter claims as well but this is not necessary.**
Level 5:	**This is an extended argument with more than one rebuttal.**

Erduran, S., Simon, S., & Osborne, J. (2004). TAPping into argumentation: developments in the use of Toulmin's Argument Pattern for studying science discourse. *Science Education*, 88(6), pp.915-933.

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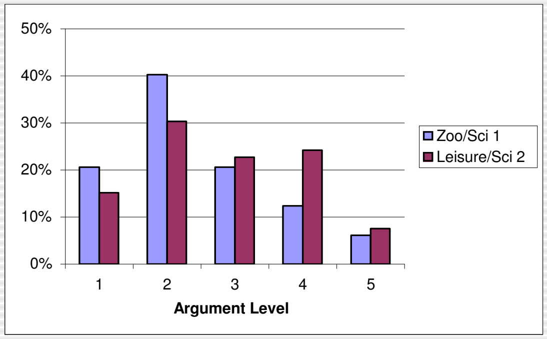
Argumentation by Level: 24 lessons – 48 groups



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IDEAS Project

- Funded by the Nuffield Foundation, 2002-2003
- First published in 2004 and again in 2005
- Aims: To develop
  - A set of innovative materials for the teaching of ideas, evidence and argument in science education
  - A teacher training pack for in-service and continuing professional development of science teachers
  - Video exemplars of good practice

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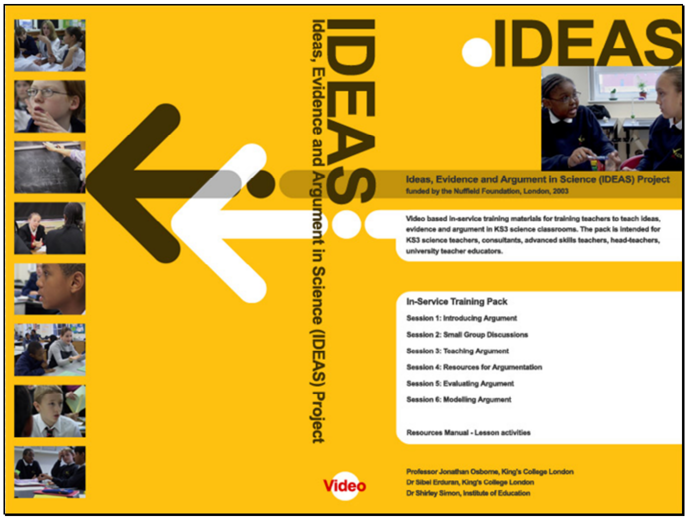

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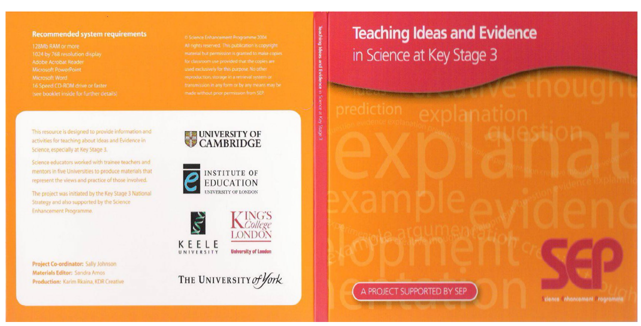
Ideas and Evidence in Initial Teacher Training



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Study 2: Exemplary Teachers

- Coordinate group discussions
- Promote counter-argumentation (playing devil's advocate)
- Quality of feedback
- Nature of questioning
- Use of meta-language of argument

(Erduran & Dagher, 2007)

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Distribution of Arguments

Teacher		TAP/2	TAP/3	TAP/4	TAP/5
Brian	Year 1	48	47	5	0
	Year 2	59	27	14	0
Martha	Year 1	48	32	16	4
	Year 2	5	85	10	0

From: Osborne, J., Erduran, S., & Simon, S. (2004). Enhancing the quality of argumentation in school science. *Journal of Research in Science Teaching*, 41(10), pp.994-1020.

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Research Questions

- Having participated in argumentation projects for about 5 years and been identified as effective teachers,
  - What are teachers' views and knowledge of teaching and learning of argumentation?
  - What do teachers perceive as goals, constraints and successes of teaching argumentation?
  - What shifts do the teachers perceive in themselves as teachers?
  - What recommendations do they have for professional development?

Slide 44

Study

- 1 male and 1 female teacher in their early 30s teaching in London schools
- 5 years' of involvement in argumentation projects ranging from basic research to professional development
- Semi-structured pair interview lasting for about 1 1/2 hrs

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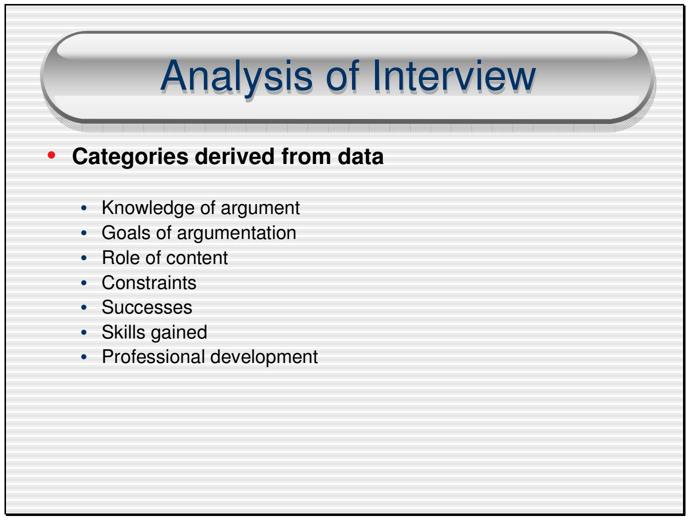

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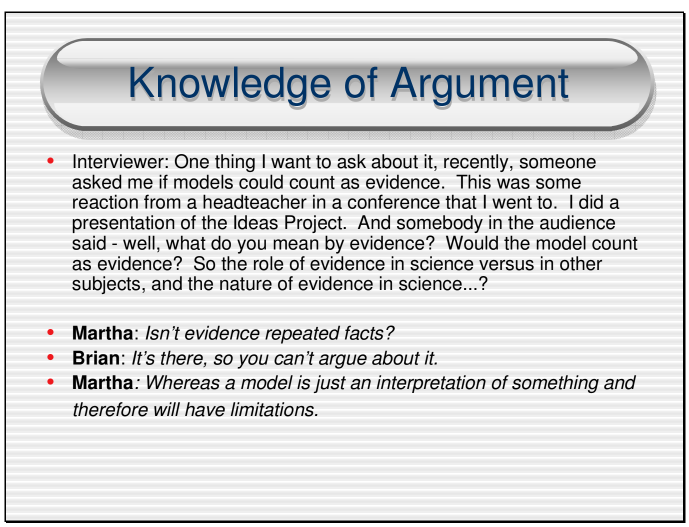

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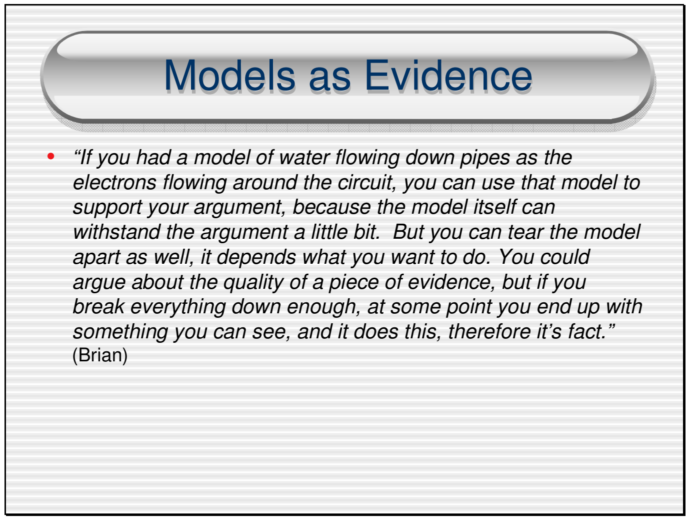

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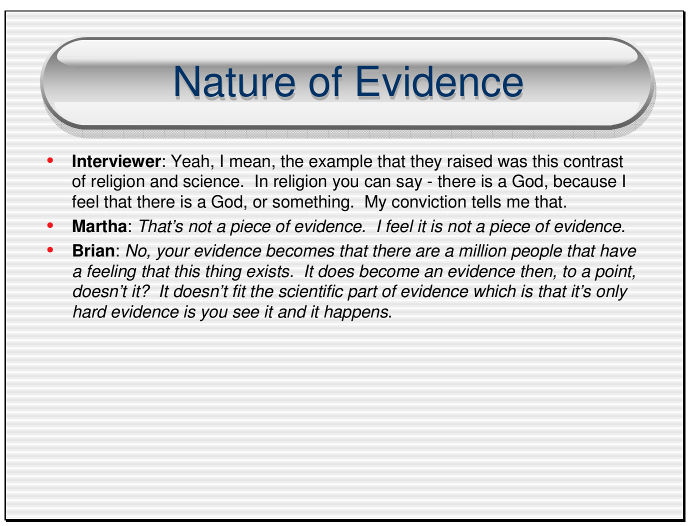

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Types of Evidence

- *"There are definitely different types of evidence. Models are a collection of other bits of information to make evidence isn't it? The model itself has to be based on its own evidence. Otherwise it's not a model. A model is based on some things that happen. A collection of evidence. You don't just get a model out of thin air, do you? Even the religious models are a collection peoples' view of something that happened. And hence that's the evidence."* (Martha)

Slide 50

Goals of Argumentation

- To inspire students, not to create scientists (democratic goal)

- To teach students a new skill (cognitive/social goal)

Slide 51

Dreaded Situations

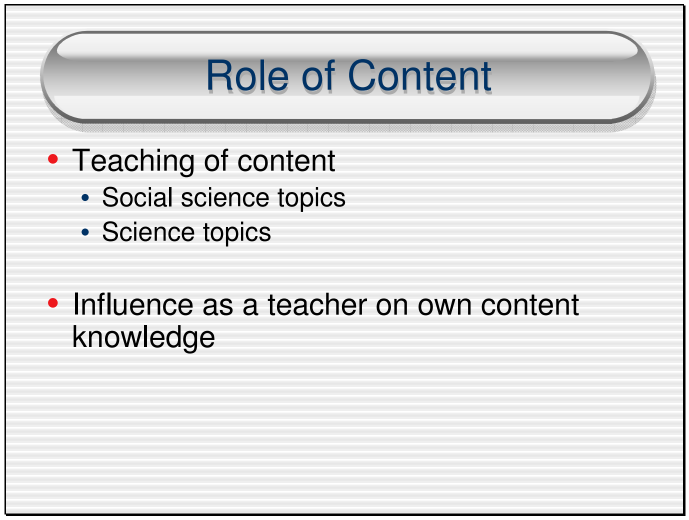
- Students arrive at multiple explanations with evidence
- Students accept wrong explanations without questioning them

Slide 52

Use of Argumentation

- *"All of the skills are very transferable. If they learn how to argue successfully, with science, probably more so, they can probably argue with everything. I suspect it's easier to transfer ... trying to argue about science concepts is actually quite tricky because their evidence bank isn't huge. They need to recognise they must understand more science in order to argue the point well."* (Brian)

Slide 53



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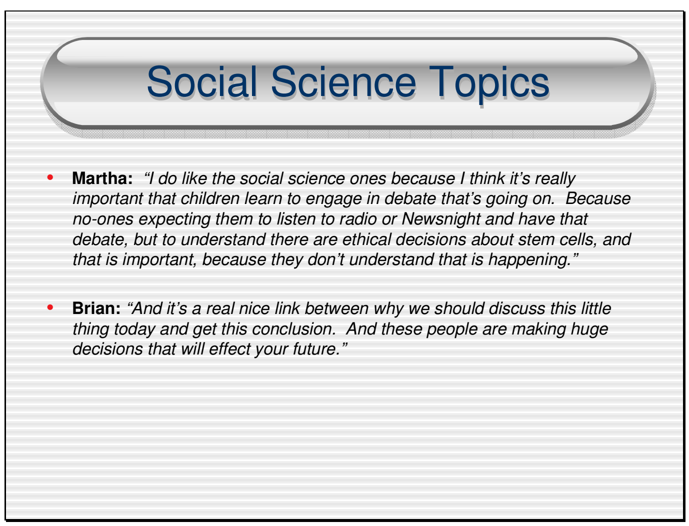

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Science Topics

- *"I suppose, in some respects, I found it easier to do things that were outside of physics because I am less obsessed with the correct answer. I didn't really know, in biology or chemistry, whereas in physics…"* (Martha)

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Influence on Content Knowledge

- **Interviewer**: Which brings me to the question of do you think that being involved in these projects you might have evolved in other ways, as a teacher? Say, in terms of content knowledge?
- **Brian**: *More biology than chemistry maybe.*
- **Martha**: *I suppose we did, but I'm not sure through doing this than any other project. I don't think that particularly argumentation...*

Slide 57

Constraints

- **Resources:**
  - Coordinating resources when lessons can extend beyond appointed time
  - Need for special resources
- **Time:**
  - Need time
- **Management:**
  - Good management is key
- **Incentives:**
  - Financial incentives for teacher participation
- **Professional development:**
  - Need to see same lesson taught to variety of students
  - Video clips inadequate, need to see whole lessons especially for new teachers

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Example

- *"... but again it would have to fit with what your scheme of work. Because if you've got five days arguing about the ethics of genetic engineering and you've only spent half a lesson on it, that's four and a half lessons that you've lost. So it's getting that balance right. And I see more of it coming down to, actually, much shorter things within lessons. And actually more regular. As opposed to a whole lesson. We were told to do a whole lesson, but sometimes it would have been a bit snappier if they were shorter sometimes. Because you'd just focus on a point."* (Martha)

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Successes

- Access to a bank of lessons
- Trial and error
- Sharing resources
- Building confidence
- Perseverence
- Being adventurous
- Open-mindedness
- Being a good teacher

Slide 60

Skills Gained

- Managing student groups (composition and number)
- Seeking and presenting evidence
- Reflecting on the lesson outside of the classroom
- Thinking from point of view of students

Slide 61

Professional Development

- *"I always think that's the trouble with every bit of training I've seen. And I like doing varied things. But the most useful thing for me to see is someone teach a good lesson from start to finish. And I know that's never ideal because you always have one set of kids in front of that person. And really, what you need to see is that lesson taught to weak, able and very able classes, the same lesson. And watch what they do. And you can actually, genuinely see - that's how you approach that, that's how you deliver that. It's still very bitty. It does provide food for thought but I don't think it teaches them how to deliver the lesson."* (Brian)

Slide 62

Study 3: Pre-service Teachers

- 14 trainee teachers (9 females and 5 males) enrolled in science teacher certification course at an English medium university in Istanbul, Turkey
- Trained using the IDEAS pack over 6 weeks in Spring 2005
- Audiotaped argument lessons from each teacher implementing lessons in Istanbul secondary schools
- Selection of topics to adapt for argument lessons by trainees (e.g. Periodic Table, Acid Rain, Mercury: metal or non-metal?, Radioactivity)

(Erduran, Ardac, & Buket-Yakmaci-Guzel, 2006)

Slide 63

Data Sources

- **Teacher talk**
- **Student group talk**
- Students' written work
- Teacher lesson plans
- Teacher interviews after training
- Teacher written responses to argument questions

Slide 64

Research Questions

- How are trainee teachers interpreting argument lessons in their teaching?
  - Are they using the strategies promoted in the training sessions?
- What are the argument outcomes in students' learning?
  - What is the nature of their arguments and argumentation?

Slide 65

Analysis 1: Teaching Strategies

- **Teaching strategies**
  - Structuring of the task
  - Use of group discussions
  - Questioning for evidence and justifications
  - Modeling of argument
  - Use of presentations and peer review
  - Establishing norms of argumentation
  - Feedback during group discussions

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Analysis 2: Student Outcomes

- **Student outcomes**
  - Nature of arguments
  - Nature of questions
  - Criteria for evaluating evidence
  - Use of opposition including how counterarguments are ruled out

Slide 67

Lesson Overview (Hulya)

- Introduction to the history of the Periodic Table
- Establishing the need for classification of missing elements
- Group activity (use of writing frames)
- Envoys to groups
- Presentations
- Summary

Slide 68

Teaching Strategies: (Hulya)

- **Lesson:** Periodic Table
- **Task structure:** Competing theories
  - Placing of missing element in the Periodic Table and deciding whether or not it is a metal or a non-metal
  - "You need to judge the evidence to decide whether this can be a metal or not."
- **Questions:**
  - "How did you classify this element? Why?"
  - "How do you know that?"
- **Modelling:**
  - "If you look at this one, it can't be a metal because…"
- **Use of presentations: Envoys**
  - "You will swap seats and tell your friends what you have done and how you reached your conclusions."
- **Norms of argumentation:**
  - "I know that you know this by heart but what I want is for you to find out why it's there."

Slide 69

Student Outcomes (Hulya)

- **Nature of arguments**
  - Claims with data: “It could be aluminium because it dissolves in water.”
  - Claims with data, warrants, backings: “We are sure about this one because it has all the properties. It’s soft and it’s close to these so this one also is…”
- **Nature of questions**
  - “Are we considering the rows or the columns?”
- **Criteria for evaluating evidence**
  - “We could see if it’s a metal, non-metal or semi-metal.”
- **Use of opposition including how counterarguments are ruled out**
  - “I said this but he comes up with something else.”

Slide 70

Lesson Overview (Nil)

- Introduction including modeling and main question: *Is mercury a metal or a non-metal?*
- Group work
- Presentations
- Summary

Slide 71

Teaching Strategies: (Nil)

- **Lesson:** Is mercury metal or non-metal?
- **Task structure:** Competing theories
- **Questions:**
  - “How do you know that it forms compounds with non-metals?”
  - “What sort of an experiment can you do?”
- **Modeling:**
  - “You are presenting a strong argument. Mercury is a metal because it conducts electricity, because metals conduct electricity.”
- **Use of presentations:**
  - “You have to convince us through your presentations.”
- **Norms of argumentation:**
  - “You can say it reacts with noble gases but you have to have evidence.”
  - “If you cannot provide evidence then you have to be careful about your claims. I heard it’s like that is not enough.”

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Writing frame designed by Nil

Mercury is a metal because…	Mercury is a non-metal because…
The strongest reason that justifies mercury being a metal…	The strongest reason that justifies mercury being a non-metal…
Conclusion reached	
Your full argument	

Slide 73

Student Outcomes (Nil)

- **Nature of arguments**
  - Claims with data: "It is a metal because all its properties are consistent."
  - Claims with data, warrant, backing: "We think mercury is a metal because it has a d- orbital and it can conduct electricity. It has a shiny appearance."
- **Nature of questions**
  - "Is the boiling point of mercury 140C?"
- **Criteria for evaluating evidence**
  - "You think it being a liquid is not a physical property. Its being a liquid is because its melting point is low and that's a chemical property."
- **Use of opposition including how counterarguments are ruled out**
  - "The only property that suggests it's a non-metal is its liquid state but this can be changed. We can turn it into a solid but we can't play around with the number of electrons in its orbitals."

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Results: Teaching Strategies

- There is evidence on all aspects of teaching strategies investigated that the trainees are using argumentation techniques in their classrooms
  - Structuring of the task
  - Use of group discussions
  - Questioning for evidence and justifications
  - Modeling of argument
  - Use of presentations and peer review
  - Establishing norms of argumentation
  - Feedback during group discussions

Slide 75

Differences Across Trainees

- Evidence of implementation of all strategies across teachers
- Extent of modeling, meta-talk, feedback?

Slide 76

Meta-Language on Argument

- *"What did you tell me to oppose this point of view? You showed me evidence. During a discussion, what do you need to do in order to make a claim acceptable? You have to base your claim on real evidence. Definitions can be right or wrong. Whichever definition you are supporting or not supporting, you will have to decide. For that position you think is right, you can provide extra evidence. Let's say one definition is right and another wrong. You will prove to me using evidence or your knowledge how this position is right. This is right because…I want you to make me believe in what's right. Whoever reads this will have to be convinced." (Nil)*

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Study 4: Pupils' Argumentation at Primary Level

- Participants: 25 4th grade students, aged between 9 and 10 years and their teacher
- Context: participation of pupils in the design and evaluation of the learning tasks
- Data: Collected from 4th grade in a primary school in Galicia, Spain. Focus on a sequence lasting 10 days. Classroom conversations, videotaping selected sessions, keeping field notes as a participant observer, collecting pupils' productions & interview teacher
- Analysis: Involved several cycles of data immersion, coding, and refining of the instrument

(Jimenez-Aleixandre, Rodriguez & Erduran, in press)

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Coding scheme from Erduran *et al* (2004) modified

Level 5	+1 rebuttal connected to several W or D (from the opponent's evidence)
Level 4	1 rebuttal connected to 1 D or to 1 W
Level 3	without rebuttals including at least one D or W, with 3 or + components
Level 2	Claim or counter-claim without rebuttals, with 1 D or W
Level 1	Claim or counter-claim, without data, warrants or rebuttal

Slide 79

"Catching animals" - Levels 1 & 2

Level 1:

Hugo: Thus, wait until they are unaware, they feel safe... until they are not on their guard, to be able to catch them.

Level 2:

Cosme: I think that we cannot pick plants and catch animals like that... you catch them and... for instance, imagine that in the pond there is only a family of frogs... then you catch the frog and after that there is no pair left, so... later on there is nothing in the pond

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"What to study: frogs and tadpoles?" - Level 3

Level 3:

Hugo: I think that frogs and tadpoles... look, in a way it is easy and in another is very difficult — Claim & Qualif

because seeing frogs and tadpoles, we are going to see lots of them, sure — Warrant 1

but what our group wants to study about the frogs and tadpoles, it is going to be difficult — expands claim

What we are going to do is seeing them, see frogs and tadpoles, sure — W1 repeated

but then to study, for instance, what do they eat or how do they reproduce, or something like that is going to be very difficult — Warrant 2

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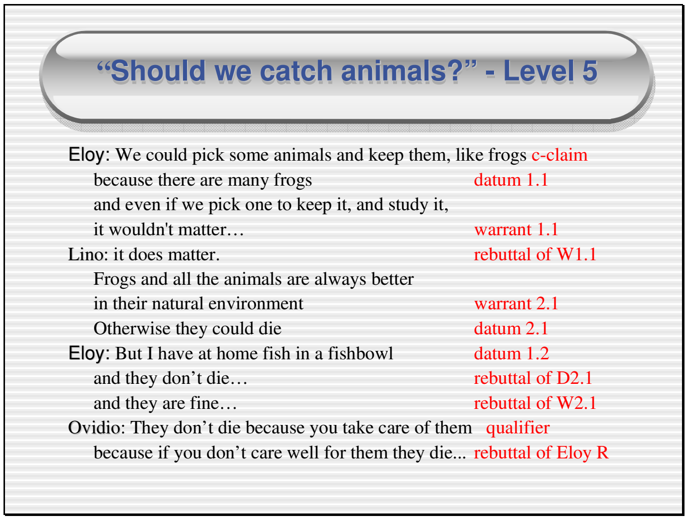
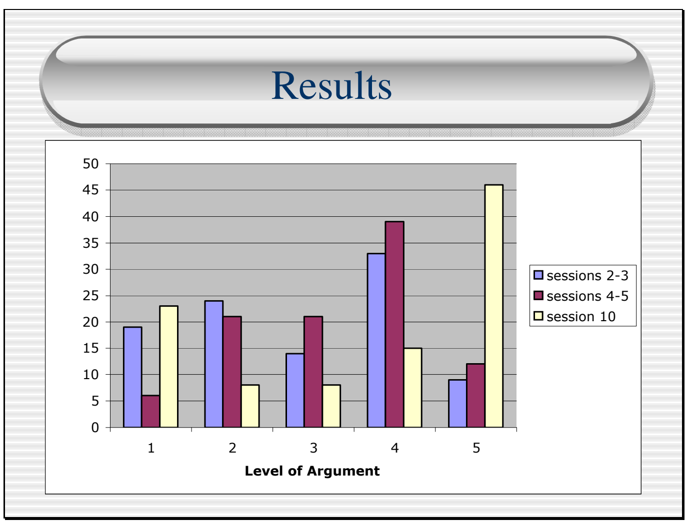


Slide 82



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Evolution of Argumentation Quality

- Both in the two first (2+3) and intermediate (4+5) sessions the category with the higher frequency (33 and 39 %, respectively) is level 4
- In session 10 the higher frequency, 46 % corresponds to level 5, followed by level 1 (23%)
- 67 arguments : 33 without rebuttals (levels 1, 2 and 3) and 34 with rebuttals (levels 4 & 5)
- The evolution points to a refinement of the arguments (the number of arguments is relatively small so from the comparison we cannot infer strong conclusions)

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Study 5: Role of Subject Knowledge

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Breaking the law: promoting domain-specificity in chemical education in the context of arguing about the periodic law

Sibel Erduran

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Abstract In this paper, domain-specificity is presented as an understudied problem in chemical education. This argument is unpacked by drawing from two bodies of literature: learning of science and epistemology of science, both themes that have cognitive as well as philosophical undertones. The wider context is students' engagement in scientific inquiry, an important goal for science education and one that has not been well executed in everyday classrooms. The focus on science learning illustrates the role of domain specificity in scientific reasoning. The discussion on epistemology of science presents ideas from the emerging field of philosophy of chemistry to highlight the much neglected area of epistemology in chemical education. Domain-specificity is exemplified in the context of chemical laws, in particular the Periodic Law. The applications of the discussion for chemical education are explored in relation to argumentation, itself an epistemologically grounded discourse pattern in science. The overall implications include the need for reconceptualization of the nature of teaching and learning in chemistry to include more particular epistemological aspects of chemistry.

Keywords Domain-specificity · Argumentation · Chemical laws · Periodicity

Introduction

In The Same and Not the Same, the Nobel Prize winning chemist, Hoffmann (1995) argues for restructuring schooling such that all students acquire an understanding of ''what it is that chemists do'' (p. 228). As a chemist who has reflected extensively on interdisciplinary aspects of chemistry, Hoffmann is an exceptional scientist who recognizes the significance of fostering students' meaningful learning. Through a vast set of analyses (e.g. Hoffmann

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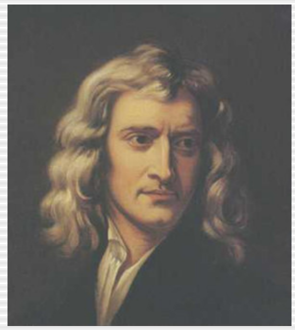
Periodic Law vs Law of Gravitation



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Competing Theories

- **Theory 1**: The periodic law and the law of gravitation are similar in nature
- **Theory 2**: The periodic law and the law of gravitation are different in nature

Evidence

to support Theory 1 and/or Theory 2

- A law is a generalization
- The periodic law cannot be expressed in an algebraic form while the law of gravitation can be. etc…

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Conclusions

- Mixed methodologies (e.g. quantitative measure of quality of argumentation; case studies of teaching; longitudinal study of argumentation)
- Short term training of pre-service teachers resulted in attainment of intended pedagogical and learning goals
- Primary school children are capable of being engaged in authentic scientific enquiries involving the development of complex arguments

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Implications

- Conceptualisation of argumentation
  - Sociological (e.g. power and gender issues)
- Definition of learning
  - Emphasis switched from conceptual understanding to argumentation skills?
- Teacher development
  - Trace the developmental stages in the learning to teach argumentation - from preservice to expertise
- Contribution of argumentation to other aspects of science education
  - Situate argumentation in science teaching and long term professional development

RESEARCH SESSIONS

Mathematics

Teaching practices in middle school algebra classrooms in France and Lebanon: Interactions and knowledge used during correction phases

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Abstract

Our study concerns the characterization of professional practices of mathematics teachers during phases of correction related to algebraic expressions at grade 7 in Lebanon and grade 8 in France. Our research focused on the ways teachers organize these correction phases, notably mathematics knowledge and interactions with students. We also elaborated and analyzed two questionnaires which aim to analyze the students' validation procedures and the teachers' analysis of students mistakes. We also videotaped two classes in each country during the whole number of sessions concerning the calculation of "algebraic expressions". In this paper, we show some results concerning these questionnaires and we indicate regularities in practices, for only one teacher, among the four teachers, in his organization of the knowledge to be taught and the management of validity of answers and students interactions.

Introduction

During last years, researches in didactics of mathematics have showed more and more interest to the practices of classes. More specifically, after 1990, researchers began to focus on class practices in France and in other countries. The results obtained from these researches were used to train teachers.

Our center of interest will be studying relations between the learning processes of students and teachers' practices during correction phases. In the classroom, these phases seem particularly favorable to the process of learning, notably during the confrontation between the student's answer and the teacher's expectations. We consider that these moments allow us to observe and analyze students' errors and verification procedures, as well as their treatment by the teacher. We also look for regularities of a teacher's practice, especially the way he/she organizes the knowledge to be taught, the interactions with the students and the management of the validity (or not) of answers.

We chose the topic "manipulating algebraic expressions" for two reasons. Firstly, studies in didactics of algebra are numerous and various. For years, researchers were interested in the analysis of this mathematical subject, notably the relationship (in terms of cuts and continuity) between arithmetic and algebra (Vergnaud, 1988, 1989 ; Chevallard, 1985, 1989, 1990 ; Gascon, 1994). Some studies (Kieran, 1991 ; Bednarz & al., 1996) were carried out on the statutes of different objects (letters, equal sign, operation signs, etc), and other studies described and analyzed errors (Behr & al., 1980 ; Booth, 1988 ; Drouhard, 1992 ; Grugeon, 1995 ; Kirshner & al., 2004). In contrast, few recent studies have taken into account the class and the teacher's practice (Schmidt & al., 1996 ; Tirosh & al., 1998 ; Coulange, 2000 ; Lenfant, 2002 ; Robert 2001).

A second reason, is that during teaching "algebraic expressions", lesson, there is an important number of correction phases.

Our theoretical framework is based on the Anthropological theory of didactics (Chevallard, 1999). In this theory we analyze any human activity, in terms of *practical-block* (*praxis*), which constitutes the practice, formed of a *type of tasks* and the *techniques* used to solve these tasks, and in terms of *knowledge-block* (*logos : technological-theoretical bloc*) that provides the mathematical discourse necessary to justify and explain the practical block.

A task is a coordination of several simple operations (for example multiply 2×3) in order to reach a more complicated purpose (develop the expression 2(3+x)). Thus two tasks are of same type when the operations to be done lead to the same purpose (for example reduce 2x+4x and reduce 5x+6x are two tasks of the same type : reduce a polynomial of degree one). In contrast, "developing an algebraic expression" and "reducing an algebraic expression" are two types of tasks. The main types of tasks, discussed in this paper, mainly correspond to "reducing algebraic expressions". We limit our research to grades 7 and 8, in Lebanon and France, respectively

Besides, Chevallard defines six moments of study, among which, one of them is the practice of techniques and the other is the evaluation practice. Correction phases are part of these two moments.

We are situated in a comparative analysis between two countries : France and Lebanon. Hence, by considering the differences and similarities concerning the education characteristics, between both countries, such as the organization of lessons, teachers' practice, teacher– student interactions, and students' acquisitions during correction phases, the research questions are the following :

How does the teacher organize the phases of correction taking into consideration the mathematical knowledge (type of tasks, techniques, technological-theoretical bloc) and the interactions with the students ?

What are the techniques which the students implement in order to validate a given answer ?

What does the teacher know about students' errors relative to different types of tasks and how does he deal with these errors ?

Method

We collected several types of data : analysis of official curricula and mathematical manuals ; statistical data with two questionnaires one for students and the other for teachers ; video analysis based on real class data.

We began our study analyzing the knowledge related to calculating algebraic expressions in both countries. We studied the middle-school official curricula. After that, we decided to limit our study to grade 7 classes in Lebanon and grade 8 in France where there is a "chapter" concerning this theme in mathematics books at these levels. "Develop and/or reduce an algebraic" are the basic types of tasks being studied in this theme. We analyzed the chapter related to "Algebraic expressions" in four grade 8-level French textbooks and four grade 7-level Lebanese textbooks.

In this article, we will talk about "reduce an algebraic expression" because most of the exercises in the studied manuals are formed of this type of tasks (and of "develop and reduce an algebraic expression").

- After categorizing the classical errors, we elaborated two questionnaires, one dedicated to teachers and the other to students.

Finally, we filmed the lesson “algebraic expressions” in four classes (2 grade 8 classes in France and 2 grade 7 classes in Lebanon).

Questionnaires for students

- A questionnaire was distributed to students in France (grades 8 and 9, 186 students) and in Lebanon (grades 7 and 8, 164 students). With this questionnaire, we aimed to determine the techniques of validation being established by students. Hence, we proposed exercises that were already solved by fictitious students. The provided answers, to these solved exercises, contained classical errors. We asked the real students whether the answers are correct or not, and to justify their validation (for example : reduce the algebraic expression : 7-2x+4x. Louis has written 7-6x. Do you consider it is right or wrong. Justify). Some tasks were familiar[2], and others were less known. We wanted to determine also the percentages of success, failure and types of errors by offering unsolved exercises.

In order to specify the different techniques of validation that can be implemented by students, we defined the following five categories :

- Call to resolution: the student works out the exercise and then compares his answer with the one provided by the fictitious student. This procedure allows him to decide whether or not the response is valid.

- Locating of the error: the student indicates that the provided solution is wrong, by pointing out the error. The arguments used can be definite (explicit indication of error) or less definite (for example, "false, the student forgot some steps during the application of the distributive law of multiplication over addition").

- Use of a numerical example: the student tests the validity of the response by replacing the variable(s) with a (different) number(s).

- Reference to a general rule: the student explicitly states or refers to a mathematical property or a rule, which can be correct or not. In the case where it is correct, the mathematical property can be appropriate or not for the situation.

- Reference to a general argument or absence of justification: the student uses words from the exercise instructions. For example, he/she answers "he developed well / he didn’t develop well", "he calculated well", etc.. In this case we are unable to know if the student really verified the answer or if he/she answers without checking.

Questionnaire for teachers

A similar questionnaire (most of the exercises were similar to those introduced in the student’s questionnaire) was offered to 33 middle-school teachers (16 French and 17 Lebanese). We wanted

[2] What we mean by "familiar" is that the resolution process corresponds to an algebraically simple technique and to a direct application of basic knowledge.

to study the teachers' knowledge of students' errors, notably in terms of description and interpretation. Meanwhile, because of difficulties to find volunteers, we didn't choose the teachers, who responded to the questionnaires, so our sample of teachers is not representative :

More than half of the French (10) and the Lebanese teachers (9) have more than 10 years of experience in teaching at the middle-school level, 2 French and 3 Lebanese teachers have more than 5 years of experience, the others have less experience.

5 French and 2 Lebanese teachers had more than 10 training courses, 5 French and 3 Lebanese teachers have between 5 and 10 training courses, 4 French and 5 Lebanese teachers have less than 5 training courses and finally 2 French teachers and 6 Lebanese ones have never participated to training sessions.

To analyze the teachers' answers concerning their interpretations of students' errors, we used categories identified by DeBlois in 2006. She defines five learning environments to which the teachers refer:

- In-class teaching (E1): teachers compare between what they do in their class and what is done by the student.
- Acquaintance of students with the task (E2): teachers compare the task with other tasks of a similar type on which the student is accustomed.
- Students' understanding (E3): teachers evaluate textual indications written by the student.
- Characteristics of the task offered to students (E4): teachers identify certain characteristics of the task (for example, the importance of the vocabulary or the order of presentation of the data of a problem).
- Knowledge related to the programs (E5): teachers limit themselves to identifying operations done by the student without any further analysis of what he has done or of the evoked error. Moreover, they may relate the error to describing student's attitude.

Practices of teachers in real-classes

We filmed all sessions concerning teaching the chapter related to calculating "algebraic expressions" in four classes in the two countries (two in each country). We also interviewed the four teachers before they began teaching this subject and we asked them about the difficulties and errors of students. The interviews were tape-recorded then transcribed for later analysis.

***Choice of classes**

Although the four teachers had professional experience but they were volunteers with no particular profile. We chose experienced teachers because we think that they have already stabilized practices (Le Boterf, 2007). Meanwhile, filming all the sessions will enable us to specify different regularities in teachers' practices.

*Conditions of recording

We used two cameras while filming in classes. One of them was located in a corner, at the back of the class, some times centered at the teacher, when he/she explains or intervenes during correction phases and other times centered at the student who is providing the solution. Besides, several students were always in the field of the camera. We also filmed the solution which is written on the board. The other camera, focused on several students, was fixed and located behind the desk of the teacher.

For this paper, we have chosen to talk about the teacher in class 2 in France where we filmed 11 sessions (February-mars 2006) .

***Class 2 in France**

Class 2 is in a private school located near the city (Lyon). The majority of students (720) belong to intermediate social-economical families. There are 28 students in class2. The level of the is good class according to the teacher and according to their grades in mathematics. The teacher has a master's degree in physics and 15 years of experience.

*Errors relative to the type of task "reduce an algebraic expression"

Students, according to the teacher, commit many errors when reducing algebraic expressions. She thinks that the non-mastering, by the students, of priority of operations causes these errors. Moreover, students have tendency to adjoin terms in a response thus obtaining one term, which is a habit acquired from previous practices, notably while treating arithmetic subjects.

***Video analysis**

After observing the sessions, and in order to simplify our analysis, we have reconstructed each period thus obtaining a synopsis[3] which is a representation of the lesson. It corresponds to the analysis that a researcher may begin with when observing a session (Tiberghien & al. 2007). We will present the basic structure of the synopsis and explain how this reconstruction of sessions has helped us in further analysis.

*Synopsis (Table of analysis) : at the beginning, we indicate the date, session number with respect to the chapter, length of the session, number of students, level of class, textbooks used, and types of tasks carried out during the session. This overall view is a table including seven columns and permits to have a global idea of what has happened in a session :

- The time code (1st column) : The scale of time is marked each two minutes. This scale serves as an indicator of time for the descriptions in the different columns.
- Organization of the class (2nd column) : In this column we distinguish 3 cases. The different sessions are characterized as being individual (each student working on his own with or without the teacher), whole class (the teacher working with all students), or group-work (groups are working with or without the presence of the teacher).
- The mathematical tasks (3rd column) : In this column we indicate the exercises and their location in the manual.

[3] "an intermediate representation of each lessons that can serve as a guide as someone tries to understand the lesson and that can be coded itself" (Stigler & al., 1999)

- Teaching phases (4th column) : We have located the different phases and moments of each session : introduction of a session, course contents and recalling of the previous course's subject matter, resolution of exercises, correction, institutionalization, synthesis, assessment, end of a session. We didn't limit ourselves to the six moments defined by Chevallard,1999, because we are looking for more precise units to be able to spot the phases of correction.

- Actions of the teacher and students (5th column) : Visible actions, of the teacher and students, are specified by verbs (for example the teacher writes, asks question, answers a question, etc.). We divide this column into two : one for the teacher and the other for the students (we identify the student when necessary, when he offers a solution for example). In order to differentiate between the student who is providing the solution and other students, the column corresponding to students' actions is divided into two or more columns corresponding to the number of students writing on the board.

- Mathematical content of the lesson (6th column) : In this column we mark in green the mathematical content which is written on the board and we present, synthetically, the principal phrases uttered by the teacher or the students. Hence, all the repetitions or reformulations of phrases are omitted. In contrast, when the questions and responses are short, we transcribe what is said.

- Types of errors (7th column) : In this column we categorize the errors that appear during the correction of exercises. We specify these errors according to the type of task being treated.

-

The figure below is an example of a Synopsis :

We have used the synopsis to locate correction phases which interest us and which are mainly characterized by types of tasks and of errors. These criteria will facilitate further studies and deeper analysis. For this purpose we use Transana, a qualitative analysis software for video and audio data, developed at the University of Wisconsin-Madison Center for Education Research

*Transana: is a software for analyzing and managing data in very sophisticated ways video data. It helps researchers transcribe and analyze, video and audio, data. It provides a way to view video or play audio recordings, transcribe it, and link transcript to frames in the video. It provides tools for identifying and organizing analytically interesting portions of video or audio files – called clips – , as well as assigning keywords to those, video or audio, clips. It allows arranging and rearranging clips, creating complex collections of interrelated clips, exploring relationships between applied keywords. It also features database and file manipulation tools that facilitate the storage, organization and management of large collections of digitized video.

Here is an example of a Synopsis :

Time	Org.	Mathematical tasks	Teaching phases	Actions		Mathematical content	Type of error
				Teacher	Students		
0-2	Whole class						
			introduction of the session	takes attendance			
2-4							
		Reduce, when possible the following expressions. $P=-5x^2-7x^2+3x^2$	correction exercise p. 107 n°1, part c	instructs		*We will begin with P*	
					Wal. reads and provides the solution	P is equal to 9 x square	
4-6		$O=7-2x+4x$	(revision)		student asks Q	What is the reduced expression of O I didn't correct the answer	
				respond		We have found 7 plus 2 x	
		$Q=3x+5+4x^2$			Ess. reads and provides the solution	I leave it as it is	
				explains		there are no similar terms	
		$R=-10x-3x-4x$				R is equal to minus 17 x	
		$S=5x+3+2x+6$			student reads and provides a R	S equals 7x plus 9	
		$T=-5x^2+3+8x^2-9$			student reads		
				asks Q		which terms are similar	
					student responds	minus 9 and minus 5 x square	errors related to the type of task reduce an expression
				writes while asking Q		$T=-5x^2+3+8x^2-9$ similar terms	
					student responds	5 x square plus 8 x square	
				asks Q		what is the answer	
6-8				writes the R	student responds	3 x square minus 6	
			(summary)	explains		it is a reduced expression here you cannot calculate no more because this term contains x square and the other term has no x	
		$U=-4x-2-8x-3$			student reads and provides a R	U is equal to minus 12 x minus 5	
		$V=2x^2-7x+4x$			Mad. reads and provides a R	2 x square minus 3 x	

Figure 1 : Synopsis corresponding to the first 8 minutes in session 1 ; class 2 in France

When we start Transana, we see four linked sub-windows : "data window", "video window", "transcript window", and "sound visualization window". In the "data window", we can view, organize, and manipulate Transana data objects. It is made up of four tabs :

- "Series" : are containers where we can attach video files called "Episodes" with corresponding transcription(s) ;

- "Collections" and "Nested collections" packaging clips : are parts of analytically interesting episodes and are theoretically-related. The structure of "Collections" and "Nested collections", which we constructed, are theoretically related within the framework of the Anthropological Theory of Didactics, specifically types of tasks. This structure ended up as a visual representation of the list of types of tasks that we had already shown.

- "Keyword Group" : a collection of related keywords which are analytically significant and used to describe a clip. The "Keyword Groups" that we constructed correspond to types of tasks, moments of interventions of a teacher, types of interactions teacher- students, types of errors, form of algebraic expression, the order of a session, etc.

- "Search" to perform a simple research or a data mining based on keywords, which will lead us to complete the process of inductive analysis of video data.

Here is a copy of the four-windows in Transana

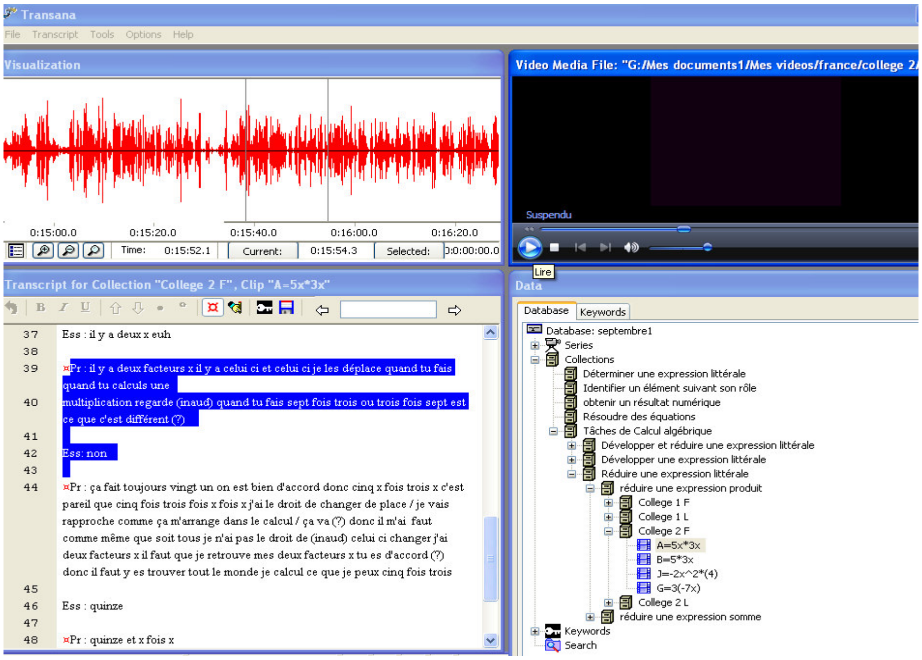

Figure 2: The four windows in Transana : video (upper right) ; database (lower right) ; audio (upper left) ; transcript linked to video (lower left)

We plan to use Transana as an instrument to identify and access analytically significant portions – clips – of video data ; to organize video clips into meaningful categories – collections –, to apply searchable analytic keywords to video clips ; to engage in data mining and hypothesis testing across large video collections. After finishing indexation of clips by key words we can export data to Excel by the function "clip data export" – tool in Transana –, as 1 or 0 format (1 indicates that the key word exists while the 0 means absence of keyword). Finally, this tool will allow us to reveal the regularities in the profile of the teacher during the correction phases.

*Categories of analysis : We present in this paragraph collections and nested collections (sub-collections). Then, we introduce the categories related to possible interventions of a teacher during correction phases.

Parallel collections : are the principal collections and correspond to the types of tasks : tasks related to manipulating algebraic expressions (for example : develop, and/or reduce algebraic expressions) ; obtain a numerical result ; translate from one representation into another or associate different expressions corresponding to different representations ; or point out one or more characteristic elements ; identify and use an algebraic expression ; solve equations.

We are interested in the first principal collection "manipulating algebraic expressions" where we can find nested collections corresponding to develop, and/or reduce algebraic expressions.

Main collections/nested collections : this hierarchy show us the different types of tasks as well as the form of algebraic expressions and the different classes where we have filmed. Clips exist in the nested collections.

Categories of intervention of a teacher : The interventions, we are looking for, correspond to organizing interactions with students and to managing the mathematical content. There are two types of interventions : either the teacher validates the response and tells if it is correct or not without interacting with the students ; or the teacher interacts with students (the student proposing the solution or with the class).

We are mainly interested in the techniques of validation and correction of errors. These categories are transformed later on into keywords in Transana in order to classify different clips.

Results, discussion and implications for practice

We will introduce, at the beginning, general results concerning different types of tasks (develop and/or reduce algebraic expressions) as well as teaching the lesson "algebraic expressions" in class 2 and France. Then we will present teacher's regularities in this class. Later, we will discuss in details results, from the questionnaires, concerning a classical error – conjoining algebraic expressions –. Finally, we will show a study case in class 2 in France where the teacher tries to provide a feedback to a student who committed an error similar to the one treated in the questionnaires.

*** Analysis of official curricula of middle school**

Analysis of official curricula of the intermediate classes in both countries has showed that the knowledge related to algebraic expressions is progressively introduced in time : the distributive law of multiplication over addition, which is the basic knowledge in calculating algebraic expressions, is introduced separately from developing and/or reducing algebraic expressions which appear in the following years. Besides, the development and factorization, in France, are not introduced in the same year (factorizing an algebraic expression is introduced in grade 9, while developing an algebraic expression appears in previous classes). In Lebanon, this is not the case. Factorization and developing algebraic expressions are taught in grade 7, but there is a use of theoretical elements based on "algebra of polynomials" to reduce an algebraic expression, which is not taught at schools.

***Mathematical textbooks**

Analysis of textbooks of grade 7 in Lebanon and of grade 8 in France has showed that the chapter related to "calculating algebraic expressions" is separate from that related to "equations". Moreover, the majority of tasks are "developing and/or reducing algebraic expressions". Most of the time and in contradiction to the recommendation of French official curricula, these tasks are introduced to students for practice and not for other purposes, For us these tasks are tools which should, for instance, serve for showing the equivalence of two expressions or to solve equations or inequalities.

Different formulations concerning the "distributive property of multiplication over addition or subtraction" exist in various status : definition, rule, properties. We believe that this variety may lead students to believe that there are no theorems in algebra. In addition, different terms such as "develop", "reduce", "simplify" and "remove parentheses" are used, in the instruction of an exercise, according to the form of the algebraic expression. For example, we often find "remove parentheses" or "reduce" with expressions of form $(a\pm b)-(c\pm d)$ while we use "develop" with expressions of type $(a\pm b)(c\pm d)$. It seems that this segmentation of knowledge may lead to an inability of recognizing or understanding the relationship between "develop", "factorize" and "reduce algebraic expressions" and to an unawareness that the distributive property of multiplication over addition or subtraction is the basic technological and theoretical element for these types of tasks. Hence, we believe that the acquired knowledge, by the students, will be divided into separate units. Thus, errors and misconceptions might generate.

***Questionnaire for teachers**

- The analysis of the questionnaire has showed that the teachers' answers are mainly classified in the learning environments E1, E2 and E5.

- Less than one fourth of the teachers compared the solution and techniques used to those expected from their own students (E1). For example, in the question "point out the reduced form of the expression $2x^2+3x+1-2x^2+4$, 50 % of the students of the class answered 8x. How do you interpret this error ?", teachers who use the vocabulary "adding similar terms" pointed out the error considering only statements used in the class to identify "reduce algebraic expressions". They stated "3x+1=4x and 3x and 1 are not similar".

- About half to two third of the teachers tried to specify the source of error by connecting it to mathematical properties (E2). For example, some teachers related the error to improper application of order of operations:

  "the students do not take into account the product 3x, of priority of operations and of the rules of reduction".

- In this case the teachers went farther than only a description of procedure.

- Finally, other teachers limited themselves to identifying operations in the steps followed by the student while solving a task (E5). For example, they wrote:

"the students think of reducing 3x+1+4 and add terms in x with other terms without x", "they add variables with numbers".

- Between one fourth and half of the teachers limited themselves to describing the attitudes of students (E5) without analyzing the error.

  "the student doesn't understand" or, "the student doesn't know."

- They consider that the source of error is due to an incomprehension of the concept or to lack of attention.

- In conclusion, about a third of the teachers who answered the questionnaire did not analyze the error when it appeared in an answer. Hence, we believe that these teachers don't analyze errors when it appears during the correction of similar tasks in the class. In consequence, their correction is limited at providing the correct answer only.

***Questionnaire dedicated to students**

The students used different validation techniques, such as "solving the exercise and then comparing the answer with the indicated one" ; "locating the error" ; and "referring to a general

rule". As for "test by a numerical value", non of the students used it to justify that two algebraic expressions are not equal which may be a consequence of teachers' practices but it may also result from the form of the algebraic expressions which we had introduced in the questionnaire (simple expressions of degree less than three and with two to four terms) an answer is not correct.
For those who referred to general rules, they relied mostly on ostensive elements[4] (Bosch & al., 1999). The majority of students didn't refer to the distributive property of multiplication over addition or subtraction. On the other hand, we noticed that two particular errors appeared in the responses of a high percentage of students : conjoining algebraic expressions where the percentage of Lebanese students in committing this error is higher than that for the French students ; about 50% of students committed the error $(a+b)^2=a^2+b^2$.

***General results concerning teaching "algebraic expressions" in class 2 in France**

Almost all the corrected exercises or those being performed in the class belong to the mathematical textbook used in this class[5]. The majority of exercises contain tasks of same type. In the first two sessions, the majority of tasks (29 tasks) are of type "verify the equality of two algebraic expressions". In sessions 2, 3 and 4 the majority of corrected and performed exercises contain tasks of type "reduce an algebraic expression". Later, sessions 4 till 9 the majority of tasks are of type "develop and/or reduce an algebraic expressions". In the last 2 sessions there are tasks of type "calculate the numerical value of an algebraic expression" and "write an algebraic expression". During all sessions, there are corrections phases (121 task for the whole number of sessions).

Meanwhile, students write on copybooks the definitions, theorems and properties of the lesson. The teacher identify "reduce an algebraic expression" as adding similar terms without referring to the knowledge bloc, specifically the distributive property of multiplication over addition or subtraction.

There is no group work, and sometimes the teacher invites more than one student to the board to do correction, notably when the algebraic expressions are short (formed of two to 4 terms) and the students are accustomed to the task. This strategy is used to gain time. Finally, the teacher don't link between the variety of exercises which are related to different tasks and don't refer to previous sessions so that she can build on what the students already know. In contrast, there is a strong use of ostensive elements.

*** Regularities in the behavior of the teacher in class 2 in France**

In the following table, we represent some regularities during the correction phases, concerning the validation procedure, the interactions with the students, and the moment of intervention, of the teacher in class 2 in France. In the first column we selected some tasks which were corrected in sessions 2, 3, 4, 5 and 6. The next two columns correspond to the response, if it is correct or false. The 3rd, 4th and 5th columns concern the moments of intervention of the teacher, if she intervenes during the process of writing the solution or after the student writes the solution. The 6th, 7th and 8th

[4] All kinds of symbolisms, graphical representations, and even gestures are ostensive objects which we distinguish from concepts, ideas, etc. (non-ostensive entities)

[5] The used book is Triangle, grade 8, HATIER, 2002, where the two themes "algebraic expressions" "equations" are treated separately in two different chapters.

columns reveal the type of interactions between the teacher and her students. The last two columns reveal if the teacher is the one who locates the error, corrects the error, or validates the response.

	Response		Moments of intervention of teacher			Interaction of teacher with the students			Correcting errors and validating	
	false	correct	when an error appears	after the student performs an operation	after the student provides the solution	The teacher asks the student to explain the solution	The teacher guides the student	The teacher asks the class to validate the response	The teacher validates the response or step	The teacher locates the error
session 2										
$A=5x+3x$	0	1	0	0	1	0	0	1	0	0
$J=5x^2-3x$	0	1	0	0	1	0	0	0	1	0
$K=-2x^2-5x^2$/error:$7x^2$	0/1	1	0	0	1	0	0	1	0	0
$L=4+6x^2$	0	1	0	0	1	0	0	0	1	0
$M =4x-8x+5$	0	1	0	0	1	0	0	0	1	0
$N=-3x+7x+10x$	0	1	0	0	1	0	0	0	1	0
$O=7-2x+4x$/ error:$7-6x$	1	0	0	0	1	0	0	1	0	0
session 3										
$H=7x-x$	0	1	0	0	1	0	0	0	1	0
$T=-5x^2+3+8x^2-9$	0	1	0	1	0	0	1	0	1	0
$W=-3x^2-7x^2+2x^2$/ error : $10x^2+2x^2$	1	0	0	0	1	1	1	0	1	1
$Y=-5x+3-1x-2$ / error: $-6x-1$	1	0	0	0	1	0	0	0	1	1

$Z=6x^2+2x-x+x^2+0x^2-4x^2$	1	0	1	1	0	1	1	0	1	1
session 4										
B=5x*2+4*3x / error : 5x*3x+2*4	1	0	1	0	0	0	1	0	1	1
$N=-3x*2x+4(-2x^2)$/ errors :x*x→2x/ $4(-2x^2) \rightarrow 4x^2$	1	0	1	1	0	0	1	0	1	1
P=5(-4x)+2(3x)	0	1	0	0	1	0	0	0	1	0
M=2*3x-5*2x	0	1	0	0	1	0	0	0	1	0
D=-4*5x-2*6x/ errors :4*5→21 / 5x*6x	1	0	1	1	0	0	1	0	1	1
F=-8*4x+2*8x-4*2x errors:-32x+16x→ 24x-8x	1	0	1	1	0	1	1	0	1	1
session 5										
I=3(2x+4)+4x	0	1	0	0	1	0	0	1	0	0
J=4(2x+5)+3(4x+2)	0	1	0	0	1	0	0	1	1	0
I=5(x+4)+2(3+x)	0	1	0	0	1	0	0	1	0	0
J=3(x-5)-4(5+x)	0	1	0	1	0	0	0	0	1	0

K=4(x+6)-1(4-x)	0	1	0	0	1	0	0	0	1	0
N=-x(5+4x)-3(-2x+5)	1	0	1	1	0	0	1	0	1	1
session 6										
A=(5x+2)-(6x+4)	0	1	0	0	1	0	0	1	0	0
C=(-3x-4)-(-8x+3)	0	1	0	0	1	0	0	0	1	0

Table 1 : interventions of the teacher in class 2, in France

F2 asks for the whole solution and not only the response. She intervenes frequently after the student offers the solution, as we see in the table, and handles the responsibility of validating the response of the student. She rarely asks the student to explain what he/she has done.

When the response is correct, the validation procedure is limited to either reading the solution (by the teacher), or, praising the student (for example : telling him/her "very good"). In contrast, when the response is false, the teacher guides the student and decomposes the task into micro-tasks thus asking closed questions to the student providing the solution. Moreover, the correction of an error is done with the help of the teacher, locating it. The technique "testing by a number" to verify if two algebraic expressions are not equal is never used as a validation procedure although during the first two sessions there are exercises where the instruction is to replace by a number and show that the algebraic expressions are not equal. This result correspond to that in the questionnaire dedicated to students, where no student has used this technique to validate that two algebraic expressions are not equal, as we have already mentioned.

Finally, the interactions appear more between the teacher and the student on the board while the rest of the class remains for long moments observing the correction and validation procedure without interfering.

From our experience as a middle school teacher and from the mathematics education literature, we know that students tend to conjoin algebraic expressions(for example, writing 4x+2 as 6x). For this reason, in the following paragraphs we will analyze this type of classical errors, related to the type of task "reduce an algebraic expression", taking into account the various elements introduced in the methodology.

***Students tendency to conjoin algebraic expressions**

The tendency of students to conjoin algebraic expressions is documented in the mathematics education literature. Payne & al., 1990, underlines that the source of this error is that some students perform meaningless symbolic manipulation. Other studies explain that this tendency is caused by difficulties associated with the order of operations (i.e. usually students carry out operations from left to right, in the order of reading, and therefore obtain wrong answers when the expression is of the form $a \pm b \times c$). Researchers, as Sfard, 1991, indicate that students grasp algebraic expressions with a sign "+" or "–", (for example 4n+3) as a process to be performed and not as an answer – a mathematical object –, hence, they transform it to 7n. Furthermore, students think of the "=" sign as a unidirectional concept which precedes a numerical answer (Kieran, 1981). This is reinforced by a conception of the "+" sign which is associated with the idea of physical conjoining.

Moreover, Booth, 1988 underlines that the "2 apples plus 5 bananas" approach chosen by some teachers to represent 2x+5y may not be helpful. Not only does it encourage an erroneous view of the meaning of letters, but it can also be used by students to justify their simplification of 7ab : 2 apples plus 5 bananas is 7 apples-and-bananas.

Finally, we add to this list of analysis the idea that the technique of factorization may not be emphasized and that the technological elements based on the property of distributive law of multiplication over addition are not used.

***Opinion of teachers about this error.**

In the teacher's questionnaire, we asked the following question :

In the following exercise, "Point out the reduced form of the expression $2x^2+3x+1-2x^2+4$," 50 % of the students gave the answer 8x. How do you interpret this error?

Eleven teachers limited themselves to locating and to describing the error without going farther :

> "$2x^2-2x^2=0$; 3+1+4=8 ; 3x+1+4=8x"; "they added variables with numbers".

Among them, four teachers indicated a definite description, operation by operation, of the students' method, often in terms of what was lacking :

> "it is necessary to pay attention to the priority of multiplication over addition. Here they did the contrary" ; " we can only reduce like terms. Two like terms are monomials which have same variable and same exponent. For example $2x^2$ and $-2x^2$ are like terms while +3x, 4 and 1 are not like terms. Hence, we cannot reduce them" ; "here is an example which explains this error : 2 tables+3 chairs+1 watch– 2 bottles+ 4 watches = 8 chairs."

- These results confirm those of Tirosh & al., 1998, in which they explore teachers' awareness of students' tendency to conjoin algebraic expressions. According to these researchers, this error is attribute to actual classroom teaching methods.

Only two thirds of the teachers (11 French and 11 Lebanese) tried to analyze this error :

- Half of the teachers indicate that there is a confusion between terms with x and terms without x, or that they don't differentiate between x and x^2.

- Five teachers specify that students don’t take into account neither the role of parentheses nor the order and properties of operations (specifically, the distributive law of multiplication over addition and rules of reduction).

- Only one teacher is aware of students’ tendency to conjoin algebraic expressions: "students want to reduce as much as possible to give a result which resembles a number".

Once again, we confirm that the theoretical elements are not always evoked. This leads us to think that teachers may also have difficulties in identifying the mathematical procedures implemented by their students and, furthermore, in analyzing their errors in an appropriate manner

During the interview, the filmed teacher in class 2 in France attributes students’ errors and difficulties related to reducing an algebraic expression to order of operations and to the tendency of students to conjoin algebraic expressions.

Inspired by an error found in a real lesson, we asked the following question in the questionnaire dedicated to students :

Reduce the expression : 7-2x+4x. Louis wrote : 7-2x+4x =7-6x

❑ true, explain why

❑ false explain why

We are going to successively analyze answers to the questionnaire and the extract of the real lesson.

***Analysis of students’ questionnaire concerning the error : 7-2x+4x=7-6x**

The majority of students answered this question, but in contrary to what we had supposed, half of them considered Louis's answer as a correct one. The highest percentage of students (32%) stated general arguments:

> "the answer is correct, he reduced as much as he could" ; "the answer is correct because his calculation is correct and he doesn’t have any mistake concerning signs" ; "I say that his response is correct by intuition"

19% of students wrote general rules among which the majority are correct mathematical properties but not adapted to the situation : "the answer is correct, he had added similar terms" ; "the answer is correct, when adding we can begin anywhere".

23% of students located the error : "false, because he added –2x+4x without considering the "–" sign in front of 2x" ; "false, because –2x+4x=2x" ; "false, because -2+4=2".

Finally, we certify that this classical task "reduce 7-4x-2x" was not successfully completed and students found it difficult to detect the error. This is because of the used procedure of validation which is limited to ostensive elements. The students paid more attention to terms with x and to constant terms, neglecting other facts (they verify the presence of a term that has an x and the term that doesn’t have an x). This is reinforced by the common idea of the word "reduce" which means "having fewest terms" (the fact that the form of the final expression includes fewer terms than the initial expression corresponds to).

Now we will analyze a case-study in a real class where the same error appears.

***Case-study related to correcting the error 7-2x+4x=7-6x in class 2 in France**

In the second session concerning the chapter "algebraic expressions", in class 2 in France, the teacher introduces the following exercise to students : "Reduce A=7-2x+4x". So we are going to study the corresponding episode.

Students work individually. The teacher stands next to Adrian and sees that he wrote "A=5x". A discussion occurs between them and Adrian thinks that his answer is wrong. Intervention 3, mentioned below, encourages us to think that Adrian intends to "finish" the expression (i.e. to conjoin algebraic expressions) and that his answer, 5x, is an intermediate result of 7-2x. Whereas, the teacher's interventions show that he indeed thinks that this error is a result of calculating -2x+4x. Here is the dialogue which is established between them :

1. Adrian : two x plus four x

2. Teacher : do you have two x plus four x

3. Adrian : no, in fact it is seven minus two x

4. Teacher : is there is there two x

5. Adrian : well yes

6. Teacher : yes there is only two x what did I mark on the board which small arrows what goes with two x what is there in front of it

7. Adrian : minus two

Here we see definitely that the teacher takes into account only a part of the expression (where the error occurred) while the student gives his whole answer again since he did not locate any error. In the 4th intervention, the teacher restrains her question by asking if there is two x, then, in the 6th intervention, she recalls the arrows which she must have drawn on the board to show the distributive property of multiplication over addition. Therefore we see in this short exchange an example of strong use of the ostensive objects which make sense to the teacher but not for the student. In effect, Adrian can definitely think that the teacher's insistence about the existence of two x corresponds well to what he had written.

The following extract shows that the teacher is going to take a part of the expression (-2x+4x) in order to calculate it in an independent manner by the student, and this is what Adrian succeeds in doing after some trials.

8. Teacher : it is minus two x plus four x so minus two x plus four x

9. Adrian : minus two x.

10. Teacher : minus two x plus four x

11. Adrian : minus four x

12. Teacher : think

13. Adrian : minus four x

14. Teacher : how do you do in order to obtain minus four x with minus two x plus four x if I say to you

15. Adrian : no, no it is equal minus two x

Finally, in the following interventions from 16 to 19, the teacher is going to calculate -2x+4x again by considering only the numerical values. We can, thus, say that she factorizes this expression but without explicitly declaring it to the student. From this moment the dialogue between them becomes a question/answer dialogue, managed by the teacher and based on ostensive objects detached from the whole expression and therefore from any sense. We also remark that the student's answers are short. Finally, we note that intervention 30 certifies our hypothesis concerning the interpretation of the error as a result of difficulties when calculating relative numbers.

16. Teacher : if I tell you minus two plus four what is the result of minus two plus four

17. Adrian : well two

18. Teacher : so now minus two x plus four x

19. Adrian : the result is two x two x

20. Teacher : so the result is two x it is already regulated and then this can we calculate it

21. Adrian : no

22. Teacher : so what are we going to write

23. Adrian : seven minus two x

24. Teacher : why minus two x you told me two x two x what which sign is in front

25. Adrian : minus

26. Teacher : when you write two x it is simplification at least two x they have the right to make this that they under hear when they write two x which is the sign which is in front of

27. Adrian : plus

28. Teacher : it is plus two x

29. Adrian : seven plus two x

30. Teacher : therefore seven plus two x pay attention to relative numbers

Using this example, we wanted to show that, on one hand, from the beginning of the discussion this teacher hypothesizes about the student's error which leads her, in this case, to ask questions related to the technique of addition of relative numbers by asking him short and closed questions which the student answers correctly. This gives the teacher the illusion that the student understands and rectifies his error, while the calculation of the whole expression is, at the same time, ignored. On the other hand, we note that the teacher does not ask the student how he got his answer. Therefore, the teacher loses information which would have been helpful in order to validate her hypothesis. In addition, the distributive property is not mentioned. This confirms one of our research hypotheses indicating that there is an absence of theoretical elements to justify calculation concerning algebraic expressions. Finally, the teacher's speech is based on ostensive objects having different significations for her, on one hand, and for the student on the other hand.

Conclusion

We conclude that students, when validating a solution, don't depend mainly on theoretical and technological elements, notably the distributive property of multiplication over addition or subtraction on the set of real numbers which was not emphasized enough in textbooks and in teachers' practices.

We gave an example of a complete analysis about an error related to the type of task "reduce an algebraic expression". For the time being, we analyzed an episode in a single class. It is therefore meaningless to produce general results. However, this case highlights an approach to teaching, in which the student is asked to perform fragmentary and individual tasks, which makes no sense for the student. We think, as teacher-trainers, that this approach in correcting errors is classical.

This study will allow us to formulate new hypothesis which will serve for later studies corresponding to a representative sample. Finally, in order to accomplish these goals, the classification built in Transana should be an important help.

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The Difficulties Facing Technology Integration into Mathematics Education in Lebanon

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Introduction

One of the major responsibilities of the math education community is to prepare students for the work place and provide them with the necessary expertise to effectively use the different technologies dominating it. The educational systems of many developing countries face difficulties in realizing this goal because technological advances in the twenty first century are taking place at a quicker pace than educational reform. In Lebanon, mathematics education has not fully benefited from the surrounding electronic technology rich environment due to the following reasons:

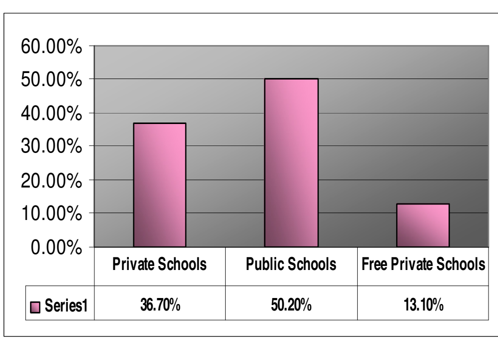
- Access to technology
- Lebanese mathematics curriculum
- Teachers' qualifications, beliefs and professional development.

*In all what follows, the word **technology** will refer to technology associated to **computers**. Any other type of technology will be specified.*

Access to Technology

Integration of technology in math education requires access to computers, educational software and internet. Such an access is not guaranteed in all the Lebanese schools. In Lebanon, there are schools that are well prepared to integrate technology into math education and they are doing that successfully, while there are schools that don't have computers yet. Financial matters play an important role in that respect. According to the statistics accomplished by the Center for Education and Research Development during the year 2006 (CERD 2006), the 2788 Lebanese schools were divided in three categories: 1025 private schools, 1399 public schools and 364 free private schools .In 2006, the Lebanese students were distributed over these schools is shown on the chart below.

Figure 1 **Partition of Lebanese Schools**
(CERD 2006)



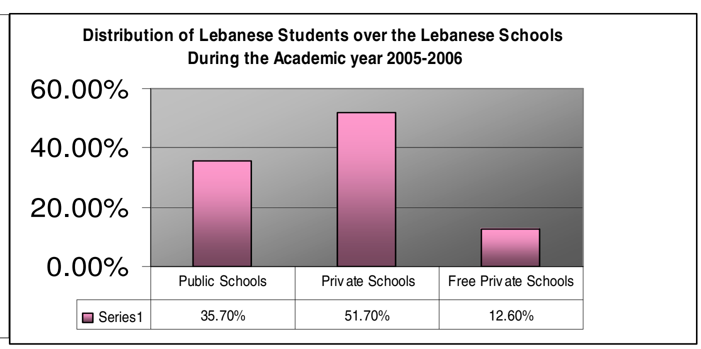


Figure 2

In the public schools, learning is open to every student with a tuition fee that does not exceed $70 per year and they have a full financial support from the government. Unfortunately, financial difficulties has deprived many public schools in Lebanon from getting computers, but the ministry of education is doing its best to overcome this problem and has distributed almost 8000 computers to the public schools last year. The situation in the private schools is different since students' tuition fees range from $300 to $10000 per year which insures a sufficient financial support for these schools (but not all of them). Consequently, many (but not all) of these private schools have financial abilities and they are integrating information technology into math education. There is not a study done on a nationwide scale that concerns the number of computers available at each school and whether these computers are used in mathematics education.

Usage of graphic calculators is also not accessible to all Lebanese students because graphic calculators are expensive.The provision of computers, software and graphic calculators does not really imply technology integration in math education if it was not accompanied by a curriculum reform.

Lebanese Mathematics Curriculum

The first reform in the Lebanese Mathematics Curriculum (LMC) took place after 25 years of war in Lebanon was in 1997. In this curriculum, recommendations to use a graphic calculator or an appropriate computer program took place twice: once in grade 11 for controlling the graph of the representative curve of a function (CERD 1997 p. 251) and the other time in grade 12 to help students visualize the parametric curves (CERD 1997 p.122). These two recommendations were not taken in consideration while applying the curriculum because not all the Lebanese students can afford to buy a graphic calculator and not all the schools had computers and computer programs to use them in teaching. Since 1997 and till now, the LMC was not updated. Mathematics in the LMC is still that topic dominated by abstract concepts, symbols and algebraic expressions. The different representations of concepts and especially the graphical ones are considered as principal goals of the curriculum and not as tools that facilitate learning as it is the case with the graphical representations of functions (CERD 1997, p.195). The numerical calculations of measures of dispersion and central tendency are still at the heart of the objectives of the statistics in the LMC while they can be performed by any simple scientific calculator nowadays. Such calculations are becoming a burden to the students who don't really appreciate to do what non sophisticated scientific calculators can perform if few seconds.

Few private Lebanese schools have the appropriate software to use in teaching, but they are unable to change the instructional objectives of the LMC because the Ministry of Education has the control over the structure and the content of the curriculum as well as over the official exams which every student attending grade 12 has to pass in order to graduate.

Teachers' Qualifications, Beliefs and Professional Development

"*Technology can improve teaching and learning, but just having technology doesn't automatically translate to better instructional outcomes"* (SIIA 2000).

The key to any successful reform in mathematics teaching and in particular with respect to technology integration in teaching are the teachers themselves (Kaput 1992, NCTM 1989, 2000). They are the ones who effectively decide when and how to implement any change in the curriculum and what technologies to use.

To be able to implement technology, teachers must have a mastery of the mathematics content, of the pedagogical skills and the technology used. Some Lebanese math teachers are highly qualified content, pedagogical and technology wise, but many as well are not.

The main problems facing teacher professional development are: financial problems, time constraints, teachers' own beliefs about technology integration in math education and the type of workshops designed for technology integration in math teaching.

The financial issues are not only reflected on equipping school with the necessary number of computers and the convenient software, but on the schools' budgets assigned to teachers' professional development. Concerning the private sector, there is only few schools in Lebanon that fully support their in-service teachers' professional development, while the others partially support or don't support it at all. Concerning the public sector, the ministry of education organizes free workshops for teachers in the public sector that range from teaching the teachers the basics needed for using the computer to developing a project based learning using computers. However, not all teachers in the public sector have the chance to participate in such workshops. In brief, most of the in- service teachers who seek professional development have to financially support the offered workshops themselves. The economical difficulties in Lebanon prevent them from participating in these workshops. In addition, if these teachers learn how to use a certain soft ware, they won't have the chance to practice using and applying it because the software is not available at their schools.

Time constraint is a real problem that prevents teachers from participating in workshops and integrating technology into math teaching. Being bounded to official exams exerts a pressure on math teachers who have to cover large amounts of content in a limited period shorter than the usual academic year. This time constraint prevents them from integrating technology because it will be time consuming especially for those who have a lack of expertise with using computers and software. Another aspect related to time constraint is the timing of the professional development workshops. The majority of such workshops take place in the afternoon. Most of the Lebanese teachers have a full teaching load and they can't leave their schools early. Also, most of the workshops take place in the capital Beirut and teachers must have a whole free afternoon to be able to attend a certain workshop.

Among the difficulties facing math teachers' professional development concerning technology integration is the type of workshops they receive and the availability of necessary software. Many of the workshops teach about the technology itself rather than how to apply the technology in class. Such workshops are necessary for those who don't know how to use certain software and they should be followed by practice to succeed. These teachers don't have the opportunity to practice the skills they have learned in these workshops and to find ways that help integrate technology in their teaching because it is not available at their schools. Only few workshops taking place in Lebanon address an expert audience in using technology. In such workshops, the main goal is usually the application of such technologies in class.

The most important factor that helps technology integration in class is teachers' beliefs about that. Many teachers still believe that their explanations are sufficient for students to learn and understand concepts and that technology is time consuming.

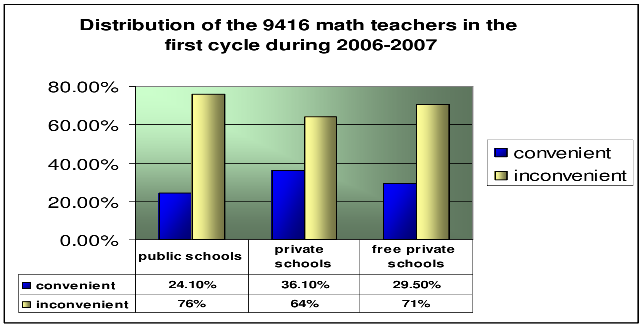


Figure 3

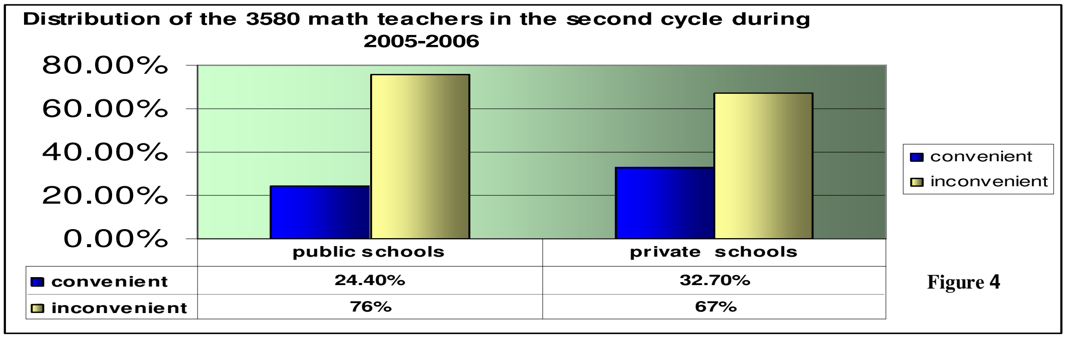


Figure 4

These teachers still don't believe in the effect of technology on students' learning. This is related to their education about technology, to their proficiency in applying technology and the way they have learned math. The majority of the teachers who teach mathematics have learned math in the traditional manner without having technology incorporated into their learning. The Strategic Educational Document developed by the Center for Research and Development 2006 have shown the following results concerning teachers' convenience (the term convenient in this study refers to **"holds a university degree in the domain of mathematics or has graduated from faculty of education"**) to teach mathematics:

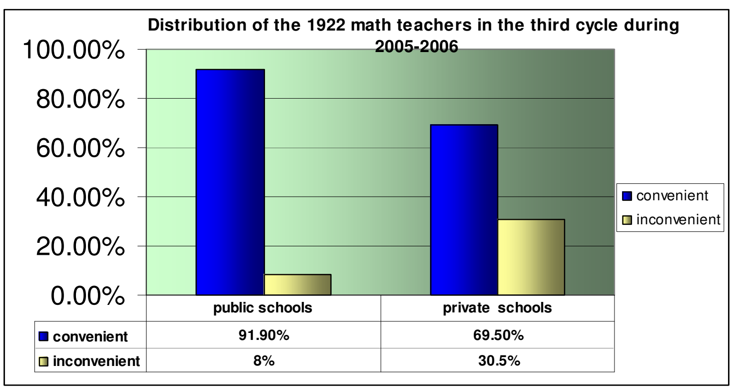


Fig5

According to the results presented here before, almost 70% of the mathematics teachers in the elementary and middle school are considered as inconvenient to teach mathematics, while this percentage decreases in the secondary school. Such an inconvenience prevents technology integration in mathematics teaching. Most of the teachers who don't hold a degree in mathematics haven't learned mathematics with technology tools and haven't received training to integrate technology in their teaching. A direct consequence of that is feeling uncomfortable with the use of technology in math teaching which leads to avoidance of technology integration in math teaching due to the lack of knowledge about the technology itself and about the important role it plays in math teaching. The results of a study by Arouni (Arouni 2005) on 100 mathematics teachers that hold a B.S. or a higher degree in mathematics showed that lack of training is also one of the causes that prevent these teachers from learning about new technologies and integrating them into their teaching.

Suggestions That Help Technology Integration in Mathematics Teaching

The National Council Of teachers of Mathematics (NCTM) has recognized technology as one of the Principles for School Mathematics:

"Technology is essential in teaching and learning mathematics; it influences the mathematics that is taught and enhances students' learning"

(NCTM 2000. p.24)

Technology changes the way mathematics is done today as it allows the visualization of abstract concepts and ideas. It brings certain utility and functionality that can not be achieved without it. It allows a differentiated instruction (Schneiderman , M. 2004) as it caters for different learning styles. The influence of technology is not limited to the mathematics that is taught, but it is also extended to what is taught and when a topic should appear in the curriculum (NCTM 2000, p.26). Consequently, when technology is going to be integrated in any curriculum, it should be accompanied by a curriculum reform aiming at enhancing mathematics learning and teaching with technology rather than teaching about technology (Garofalo J.et al. 2000, Kaput, J.J. 1992).

Before proceeding in any future reform in mathematics that integrates technology into math teaching in Lebanon, access to resources and technology should be feasible and easy. For that purpose, schools should be well equipped to apply this reform and technology implementation in math teaching should be one of the major items on any school's agenda. A part of any school budget should be devoted for buying computers and software or updating their computers. Another part of schools' budgets should be consecrated for teachers' professional development. To guarantee an easy teachers' and students' access to computers, this issue should be considered when schools time tables are prepared. If it is not possible to have all schools supplied with computers and software, then the other option would be the usage of graphic calculators which will be cheaper than school preparation for integration of technology, but still too expensive for many students to buy. In this case, schools should consider buying several calculators and renting them to students who can't afford buying them.

One of the challenges that the Lebanese Ministry of Education will face in case technology is integrated in math education is to ensure that all schools have the necessary and convenient software to use. It is recommended to decide on the types of software to be used and supply schools with these software with a reasonable price or for free. Once technology is integrated in the curriculum, assessment methods will change. Lebanese official exams, in particular, will be affected by that and this guarantees that all the schools will apply the changes to meet the requirements of the official exams.

Technology and Curriculum Reform

Integrating technology in math education in Lebanon will create a crucial change in the learning objectives of the curriculum. Once different representations of the same concept are not treated as objectives, but as tools to facilitate learning and the tedious calculations are minimized, content will change from focusing on procedural and algorithmic skills to a content that emphasizes a deep understanding of concepts and students will have the ability to make decisions in mathematics and apply the math they learn to real life situations. Any work on curriculum reform aiming at integrating technology in math teaching can benefit from the work of Garofalo et al. for promoting appropriate uses of technology in mathematics. They had devised a set of guidelines to shape the development of mathematics activities and materials. These guidelines are:

- introduce technology in context
- address worthwhile mathematics with appropriate pedagogy
- take advantage of technology
- connect mathematics topics
- Incorporate multiple representations. (Garofalo, Shockey, Harper, & Drier, 1999) .

Technology should be introduced and illustrated in the context of meaningful content-based activities that address worthwhile mathematics concepts, procedures, and strategies and interconnect mathematics topics and connect mathematics to real-world phenomena. These activities should take advantage of the capabilities of technology, and hence should extend beyond or significantly enhance what could be done without technology. Multiple representations of mathematical topics should be incorporated in these activities to help students translate among the different representations of the same concept and acquire a better conceptual understanding of the topic (Garofalo, Shockey, Harper, & Drier, 1999) .

Teachers' Development

The main goal of any reform in mathematics is the improvement of the quality of teaching and learning. Reviewing the math curriculum and providing schools by computers and software is not sufficient to successfully integrate technology into math teaching and improving the quality of learning. The mathematics teachers' beliefs about the integration of technology which is reflected in their teaching practices and the way they adopt technology play an important role in the success of a reform that integrates technology in teaching.

Changing Lebanese mathematics teachers' beliefs and attitudes towards technology needs time and it should start by teacher development. Teacher development has to be an ongoing process that focuses on: the affect of technology integration on the quality student learning and understanding, and on teacher training to use technology.

To change their beliefs about technology integration, teacher development must: provide teachers with opportunities to reflect on their own beliefs (Borko & Putnam, 1995, 1996; Bransford & Schwartz, 1999), allow teachers to experience the value of technology integration in math teaching by having an access to others practices and beliefs that are reflective of their subject and grade level, and observe the positive impact these practices have on students' learning (Richardson & Placier, 2001; Sandholtz, Ringstaff, & Dwyer, 1997) and that will lead to reform over time.

To use technology efficiently in math teaching, teachers should be well trained to use technology in teaching so that they will have confidence in their abilities while using technology in class. A priority in this teacher training should be: the connections between subject matter and pedagogical content, and the emphasis on learning about technology in the context of subject matter and pedagogy. This will help teachers to understand conceptually the potential for technology in their daily professional lives. When teachers learn isolated technology skills, they tend to forget them with time. When they learn technological skills that are related to the curriculum they teach and to the technological tools they have access to, teachers can practice what they have learned and that will increase their use of technology to support instruction and student teaching (Hughes, 2004). To get the maximum benefit from teacher training, they should be complemented by mentoring sessions inside the classes.

Prospective teachers' professional development and preparation are also important issues that have a significant impact on technology integration in math teaching, but such issues will not be discussed in this paper.

Finally, teachers themselves must take initiatives in their professional development. According to the NCTM :

Mathematics teachers must develop and maintain the mathematical and pedagogical knowledge they need to teach their students well. One way to do this is to collaborate with their colleagues and to create their own learning opportunities where none exist. They should also seek out high-quality professional development opportunities that fit their learning needs. By pursuing sources of information, building communities of colleagues, and participating in professional development, teachers can continue to grow as professionals. (NCTM ,2000, p. 373)

Conclusion

"*Education technology is neither inherently effective nor inherently ineffective; instead, its degree of effectiveness depends upon the congruence among the goals of instruction, characteristics of the learners, design of the software, and educator training and decision-making, among other factors"*

(Schneider M., SIIA, 2000)

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Science

The Effect of Reflective Discussions following Inquiry-based Laboratory Activities on Students' Views of Nature of Science

Hagop Yacoubian and Saouma BouJaoude-American University of Beirut

Abstract

This research investigated the effect of reflective discussions following inquiry-based laboratory activities on students' views of the tentative, empirical, subjective, and social aspects of nature of science (NOS). Thirty eight grade six students from a Lebanese school participated in the study. The study used a pretest-posttest control-group design and focused on collecting mainly qualitative data. During each laboratory session, students worked in groups of two. Later, experimental group students answered open-ended questions about NOS then engaged in reflective discussions about NOS. Control group students answered open-ended questions about the content of the laboratory activities then participated in discussions of results of these activities. Data sources included an open-ended questionnaire used as pre- and post-test, answers to the open-ended questions that experimental group students answered individually during every session, transcribed videotapes of the reflective discussions of the experimental group, and semi-structured interviews. Results indicated that explicit and reflective discussions following inquiry-based laboratory activities enhanced students' views of the target NOS aspects more than implicit inquiry-based instruction. Moreover, implicit inquiry-based instruction did not substantially enhance the students' target NOS views. This study also identified five major challenges that students faced in their attempts to change their NOS views.

Introduction

Science as a way of knowing involves teaching nature of science (NOS) which includes understanding, appreciation, and reflection of the nature of construction and validation of scientific knowledge, the work of scientists, and processes of science (Aikenhead & Ryan, 1992; BouJaoude, 2002). Science educators (e.g. Abd-El-Khalick 2005; Lederman, 1999) have abstracted universal aspects of NOS on which there is some consensus, with the purpose of integrating them in the K-12 science curricula.

There are at least two approaches to teach NOS. Explicit approaches consider NOS understandings cognitive instructional outcomes which can be acquired through careful instructional planning. Alternatively, implicit approaches consider the engagement in inquiry activities sufficient for improving students' NOS understandings (Khishfe & Abd-El-Khalick, 2002). However, the explicit approach has received empirical support in recent science education literature (e.g., Carey, Evans, Honda, Jay & Unger, 1989; Khishfe & Abd-El-Khalick, 2002; Lederman, 1999; Sandoval & Morrison, 2003). In addition, many science education researchers have incorporated reflective elements in their attempts to teach NOS explicitly to middle school students (Khishfe & Abd-El-Khalick, 2002) and found these elements effective in enhancing students' views. Reflective group discussions contribute to students' learning from each other, thus making NOS instruction even more explicit.

The science laboratory presents a suitable context for teaching NOS by creating an authentic learning environment that resembles a real research workplace. Hofstein and Lunetta (2003) suggest that inquiry-based laboratory experiences can help students develop ideas about the nature of a scientific community and NOS. To them, well-designed laboratory activities that focus on inquiry can help students develop concepts, frameworks of concepts, communication skills, and an appreciation of the construction of scientific assertions.

Nonetheless, inquiry-based laboratory instruction alone is not sufficient for students to construct complex conceptual understanding about NOS (Hofstein & Lunetta, 2003). The science curricula of the 1960s in the United States provided many opportunities for students to be involved in inquiry, problem solving, and critical thinking (Bybee & DeBoer, 1994) with the assumption that student involvement in inquiry would result in the enhancement of their NOS views. However, this was not the case. Research indicated that students still had naïve views about the scientific enterprise even after being involved in inquiry activities (Carey et al., 1989; Khishfe & Abd-El-Khalick, 2002). Understanding NOS seems to be a cognitive learning outcome that needs to be planned and explicit (Khishfe & Abd-El-Khalick, 2002).

Reflective discussions following inquiry-based laboratory activities have the potential to be more effective in enhancing students' views of target NOS aspects. Khishfe and Abd-El-Khalick (2002) found that "explicit and reflective inquiry-oriented instruction is more effective than an implicit inquiry-oriented approach" (p. 573) in enhancing students' views of target NOS aspects. Moreover, Hofstein and Lunetta (2003) recommended the exploration of the effect of reflective discourse after an inquiry-based laboratory on student learning. Incorporating reflective elements in teaching NOS has two important features. First, metacognition and reflective thinking are often associated with meaningful and effective learning (Baird, 1988; Kuhn & Pearsall, 2000). Second, reflection in a group context contributes to students' learning from each other, thus making NOS instruction even more explicit. Consequently, the study addressed the following question: Do explicit and reflective discussions following inquiry-based laboratory activities enhance students' views of (a) tentative NOS, (b) empirical NOS, (c) subjective NOS, and (d) social NOS more than implicit inquiry-based instruction?

Method

Thirty eight students enrolled in grade six of a Lebanese school that offers an international program participated in the study. The school policy requires assigning students to different sections of the same grade randomly. Moreover, the two sections were assigned to the control and experimental groups randomly.

The study used a pretest-posttest control-group design and focused on collecting mainly qualitative data. The posttest was a delayed one, conducted almost a month after the intervention. Two sets of laboratory activities together with teacher lesson plans specially prepared for the purposes of this research, one set for the experimental group and the other for the control group, were used in the study. The two sets of laboratory activities consisted of the same eight activities which corresponded to level 1 on the Herron Scale (Herron, 1971) in which the problem and procedure were provided and the students were expected to come up with the solution. Students worked in groups of two during each laboratory session under the guidance of their teacher who was trained by one of the researchers. Following each laboratory activity, students in the experimental group answered open-ended questions about NOS and then engaged in a reflective discussion about NOS . Students in the control group answered open-ended questions about the content of the laboratory and then participated in a discussion of the results of the laboratory activities. The teacher guided all the discussions.

Data sources for the study included an open-ended questionnaire entitled “Perspectives on Scientific Epistemology Questionnaire (POSE)” (Abd-El-Khalick, 2002) which was used as a pre- and post-test to gauge changes in students’ views of NOS. Three other sources of data were used: 1) responses of individual students in the experimental group to the open-ended questions that they answered individually after engaging in inquiry-based laboratory activities; 2) videotapes of all class sessions in the experimental and control groups; and 3) semi-structured interviews with a number of students from the experimental group. The interviewed students were selected to represent the three categories that resulted for data analysis. The interviews and videotapes were transcribed for future analysis.

A framework developed and used by Abd-El-Khalick, Bell, and Lederman (1998), BouJaoude, Sowwan, and Abd-El-Khalick (2005), and Khishfe and Abd-El-Khalick (2002) was used, with some modifications, to analyze data from the POSE questionnaire. Accordingly, students’ responses were categorized into one of the three categories: adequate, partially adequate, and inadequate. Percentages of responses in each category and for the four aspects of NOS was calculated in the pretest and posttest and compared to each other.

Data from the videotapes, open-ended questions, and interviews were analyzed qualitatively. One of the researchers was a participant observer during the sessions which enabled him to become familiar with the students and the setting. This researcher started developing some constructs while attending the reflective discussions and observing the behavior of certain students in class. During the data analysis those constructs were further developed, supported by evidence and emerging patterns were identified. Then students’ responses were analyzed using the developed constructs. The analysis was later checked by the other researcher. The disagreements were solved by consensus upon further referring to the data sources. Finally, the patterns were grouped with the aim of generating meaningful themes.

Results

Students’ performance on the POSE questionnaire prior to the study in the experimental and control groups did not differ significantly[6] with respect to the percentages of students’ views of the target aspects of NOS. Inadequate views were evident in the four target aspects of NOS in most students, and particularly in the subjective and social aspects (Table 1). At the end of the study, results showed that most students in the control group maintained inadequate NOS views while a substantial number of students in the experimental group possessed ones that were more adequate. The section below presents the results for each aspect of NOS investigated.

Tentative NOS

Analysis of the responses on the pretest indicated that 55% of the students in each of the experimental and the control groups had inadequate views of the tentative aspect of NOS (Table 1). To them scientific knowledge was certain, although new knowledge could be added as evidenced by the following excerpt:

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[6] All chi-square tests were not significant at the 0.01 level.

I think that it [scientific knowledge in the textbooks] will change because the world is still open for more new stuff. Till now some stuff are discovered but there are still so many stuff (E17[7], pre[8]).

Thirty percent of the students in the experimental group and 39% in the control group had partially adequate views of the tentative NOS at the beginning as evidenced by analysis of the pretest. They viewed the scientific enterprise as subject to change in the sense of improving already existing claims:

The scientists will discover new things and will develop the theories into better ones (E13, pre).

Finally, results indicated that only 15% of the students in the experimental group and 6% in the control group considered change to include abandoning of certain scientific claims and replacing them by others:

Technology is developing in the world. Scientists' facts, laws and theories are going to change because technology is developing. They would find more knowledge and information and they would conclude them in their facts and etc, or they would change the facts, laws, etc. I mean scientists maybe would change them because maybe they will look at the old things in new way (C11[9], pre).

Table 1

Frequency distribution and percentages of students' views of target NOS aspects (N=38)

	Tentative		Empirical		Subjective		Social	
	Pre	post	pre	post	pre	post	pre	post
Experimental Group (N=20)								
Adequate	3 (15%)	3 (15%)	0 (0%)	9 (45%)	0 (0%)	5 (25%)	0 (0%)	6 (30%)
Partially ad.	6 (30%)	15 (75%)	5 (25%)	5 (25%)	0 (0%)	7 (35%)	2 (10%)	12 (60%)
Inadequate	11 (55%)	2 (10%)	15 (75%)	6 (30%)	20 (100%)	8 (40%)	18 (90%)	2 (10%)
Control Group (N=18)								
Adequate	1 (6%)	2 (11%)	0 (0%)	1 (6%)	0 (0%)	0 (0%)	1 (6%)	0 (0%)
Partially ad.	7 (39%)	5 (28%)	6 (33%)	6 (33%)	2 (11%)	3 (17%)	0 (0%)	3 (17%)
Inadequate	10 (55%)	11 (61%)	12 (67%)	11 (61%)	16 (89%)	15 (83%)	17 (94%)	15 (83%)

After the second session, 70% of the students in the experimental group thought that scientists change their mind and claimed that science changes over time but the reason why this happens was associated to acquiring new knowledge and improving already existing scientific claims. From the justifications that those students gave in their responses to the open-ended questions, it could be inferred that most of them believed that there was an absolute truth and that scientists were trying to reach that truth.

Science changes because scientists will get the best answer (E5, oeq[10], 2).

[7] E = Experimental group, number following E represents student number

[8] pre = pretest

[9] C = Control group, number following C represents student number

[10] oeq = open-ended questions, number following oeq represents session number

A number of students in the experimental group believed that scientists could change their explanations because they are human beings and humans are always prone to error:

Scientists do change their explanations because there are always human errors in an experiment (E20, oeq, 2).

Still others argued that scientific claims change because of new discoveries:

Scientists do change their explanations because they might discover something else (E14, oeq, 2).

These different perspectives did not seem to change much over time. In the answers to the open-ended questions in the subsequent sessions many students in the experimental group came up with different scenarios of scientists changing their mind or scientific knowledge changing; nevertheless, change was mostly limited to improvements of the old claims where scientists would see something from a new perspective as a result of growth (learning):

Science changes when scientists get a better perspective (E12, oeq, 5).

Most students in the experimental group were not able to see the fact that certain scientific claims could be abandoned and replaced by others. Only two students gave an adequate view of the tentative NOS after the fifth teaching session, and these students were able to view science as a relative enterprise as shown in the following dialogue between the teacher and the student that took place during the reflective discussion (E9, vid[11], 5):

Student (E9): Science changes because everyday new scientific laws, theories and facts are being created which might cause scientists to add details to their ideas and sometimes change their explanations because they might turn wrong

Teacher: What do you think scientists are trying to do by doing science?

Student: Trying to explain new things. Its like a puzzle, they keep on trying.

Teacher: Do they know how this puzzle will look like?"

Student: No one knows

During the interview this student (E9), who was also classified as having an adequate view of the tentative NOS on the posttest, claimed that:

We need to know more and sometimes see if what we know or scientists know is correct or not so that to change it (E9, int[12]).

Nevertheless, students in the experimental group who had partially adequate or inadequate views believed in an absolute truth:

The goal of science is to have more knowledge. If scientists don't do experiments they will have small amount of knowledge and they will not know all the facts (E16, int).

The goal of science is to find the right answer… The right answer is hidden and the scientists find it (E5, int).

Analysis of posttest results of the experimental group indicated that 82% (Table 1) of those who had inadequate views about the tentative NOS moved towards more adequate ones; however, limiting change to improving already existing claims. One student moved from a partially adequate view to an adequate one and one student who had an adequate view, ended up with a partially adequate one. For the control group, percentage of students with inadequate views of the tentative NOS in the posttest was 6% more than that in the pretest (Table 1).

Empirical NOS

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[11] vid = videotape, number following vid represents session number

[12] int = interview

Most students (75% in the experimental group and 67% in the control group) held inadequate views of the empirical NOS in the pretest. To them, the only valuable evidence was direct:

They [scientists] determine the representation of the atom by powerful microscopes (and they disagree about their beliefs regarding the representation of the atom) because some scientists did not have powerful microscopes to observe it [the atom] (E6, pre).

Analysis of the pretest also indicated that many students did not seem to differentiate between scientific knowledge and opinion.

Scientific knowledge is how smart the idea is and scientific opinion is what scientists think about this idea (C6, pre).

Only 25% of the students in the experimental group and 33% in the control group had more adequate views of the empirical NOS in the pretest, but none of them appreciated the role of evidence in modifying or rejecting scientific knowledge:

Scientists know that dinosaurs really existed from the fossils they found. They could tell how these animals looked like by examining the fossil's shape or features and a bit imagining (E8, pre).

During the first two sessions when the students were asked how they came up with their conclusions, most students in the experimental group claimed that their conclusions were based on the experiments rather than the evidence that results from the experiments. There was also a trend evident in the responses to open-ended questions and videotapes that most students had a naïve mental scheme of experiments. Experiments, for many of them, involved a wide range of activities that scientists perform when they work with materials, including designing an experimental procedure, technical work, data collection, data presentation, and data analysis. When E20 (vid 2) was asked how scientists perform their work, he said,

they predict, experiment and then share their conclusions just like what we did.

Moreover, when he was asked about the bases for conclusions, his answer was "*experiment*s". Finally, sharing was important for teaching and learning "*because if someone has a wrong and different idea he/she will realize the mistake…*"

Two conclusions could be drawn from the above: First, E20 has not differentiated the different actions (designing an experimental procedure, data collection, data analysis, etc.) into distinct entities and that he seems to have a naïve mental category called "performing experiments". Second, conclusion, to him, is analogous to learning. The challenge for the student, then, was to differentiate those actions into distinct categories and realize that the evidence derived directly or indirectly from the data collected accounts for the conclusion.

During the following sessions E20 was successful. He said: "*I came up with the conclusion based on the observations I made in the lab*" (E20, oeq, 6), "*I came up with my conclusions depending on the results and observations that me and my friends made…*" (E20, oeq, 8). During the interview the following discussion took place:

Researcher: What do you mean by experiments?

E20: Experiments are things that scientists do in the lab

Researcher: Can you elaborate on that?

E20: They have a hypothesis, they try to answer that so they collect data and conclude and explain.

Researcher: What are their conclusions based on?

E20: They are based on the data that they find. (E20, int)

Although no student in the pretest appreciated the role of evidence in modifying or rejecting scientific knowledge, as time passed more students saw a relation between evidence and the tentative NOS. After the seventh session, analysis of the responses to open-ended questions showed that 40% of the students in the experimental group had developed a connection between evidence and changing of scientific claims.

I think scientists sometimes change their minds after experimenting and then finally find the answer (E10, oeq, 7).

Analysis of posttest results of the experimental group indicated that 60% of the students who initially possessed inadequate views of the empirical NOS had formed more adequate ones, thus emphasizing the role of evidence as the basis of scientific research (Table 1). Forty five percent of the total number of students considered evidence important in modifying or rejecting scientific knowledge.

Scientists produce facts and theories by experimenting and discussing their conclusions. Time by time their conclusion might change from evidence and data…(E19, post[13]).

Alternatively, the posttest results of the control group indicated that only one student (6%) had moved from the initial inadequate view to a more adequate one (Table 1).

Subjective NOS

Analysis of the pretest showed that all students (100%) in the experimental group and most students (89%) in the control group had inadequate views of the subjective NOS (Table 1). To them, different explanations of data were because:

Scientists have different opinions (E10, pre)

They [scientists] did not do enough experiments (C5, pre)

Each one [scientist] has different point of view and could get different conclusions (E18, pre).

Many of the inquiry-based laboratory activities were designed to have students explain their findings in different ways and then come up with a common explanation following group discussions guided by the teacher. Analysis of the open-ended questions showed that although the students in the experimental group explained their findings in different ways during the first two laboratory sessions and although all students (except one) claimed that they did explain their findings in different ways, when they were asked whether scientists formulate the same explanations to observed phenomena, half of the students (50%) claimed that scientists do that. There were explanations offered by the students. First, some of them considered science as an objective enterprise:

[When the scientists] do the same experiment, they observe the same details (E19, oeq).

Second, the rest claimed that differences in scientists' explanations resulted from the use of language:

Scientists have the same explanations, but different words (E16, oeq, 2).

Students who claimed that scientists could explain observed phenomena in different ways constituted the remaining 50% of the experimental group. They attributed those differences to different points of view that scientists hold (2 students), different ways of thinking (3 students),

[13] post = posttest

different background information that scientists possess (2 students), and different ways of experimenting (2 students).

After the fifth session analysis of the responses to open-ended questions and reflective discussions of the experimental group showed that 35% of the students still thought that explanations needed to be the same when scientists did the same experiments or they ascribed variation to scientists' differing views or opinions. They had a very robust view that science is objective even though they were conducting experiments about this aspect during every laboratory session and many students were raising this issue during the reflective discussions. The following discussion took place during the reflective discussion of the sixth session:

E16: I came up with my explanation after I predicted, experimented, and found my results.
Teacher: Did you and your friends come up with the same explanations?
E16: Not really
Teacher: Why?
E16: Because everyone explains differently. We are human beings.
Teacher: What about scientists?
E16: Scientists are humans and explain things differently because they have different points of view but in science when they do the same experiments they explain in the same way because they observe the same details (vid, 6).

During the interview that took place after the posttest E16 claimed:

Scientists experiment, then communicate their answers and then explain them… Anyone can explain the answers. Scientists have different points of view… but these explanations will not change anything (E16, int).

Alternatively, views of a few students in the experimental group fluctuated during the sessions. E1 claimed that "*different information possessed by people leads to different explanations*" (E1, oeq, 2, 3; vid, 2,3) following the second and the third sessions. Nevertheless, two sessions later, he claimed that scientists "*explain in the same way because they observe the same thing*". During that session this student did not experience different explanations. "*I'm not sure if we formed different explanations*" (vid, 5). Following the last session, E1 confidently argued that "*scientists think in different ways … they explain in different ways*" (vid, 8).

Similarly, E5 argued several times (E5, oeq, 2, 3, 6) that "*everyone explains in his way*"; however, following the last session he claimed that scientists know the same facts about the bird flu, so if they do new experiments they will explain things in the same way. Obviously, E5 was not able to transfer his experiences in the previous laboratories to a new, more abstract context.

Analysis of the posttest indicated that 60% of the students in the experimental group had changed their initial views of the subjective NOS (Table 1). Fifty nine percent of those who changed their views had partially adequate views at the end:

They [scientists] get different conclusions because every scientist has a way of thinking…. It is not surprising that scientists disagree on the cause of the extinction of the dinosaurs because they didn't live at that age… and each one has different experience according to what he has read in books (E14, post).

Forty one percent of the experimental group students who changed their initial views ended up with adequate views. They were able to see the influence of scientists' theoretical knowledge in shaping scientific knowledge.

…All scientists have different amounts of knowledge on the subject which causes them to have different ways of seeing and analyzing the data (E9, post).

Analysis of the posttest also indicated that there were minor changes in the views of students in the control group. Only one student in the control group changed her initial inadequate view of the subjective aspect of NOS into a partially adequate one (Table 1).

Social NOS

Data from the pretest showed that 90% of the experimental and 94% of the control group students gave no room for social construction in science (Table 1). Ten percent of the experimental group students and none of the control group ones had partially adequate views; accordingly, communication among scientists was limited to sharing information:

They [scientists] might compare their results to other facts, laws, and theories found by other scientists… (E9, pre).

Only one student in the control group had an adequate view of this aspect in the pretest:

Scientists discover something by agreeing and disagreeing so that they can have open minds and prove something is right. When everybody agrees it becomes scientific knowledge (C16, pre).

A major finding after the second session was that students in the experimental group had a very naïve mental construction of the function of experiments in science. Data from the responses to open-ended questions of the second session showed that 70% of the students thought that performing experiments was the primary purpose of science. Experimentation was seen as a priority that led into several outcomes: Discussions, negotiations, learning, and new scientific knowledge.

Scientists work by experimenting. Science is all about experiments (E18, oeq, 2).

The job of a scientist is to perform experiments (E4, oeq, 2).

Moreover, following the second session, 60% of the students in the experimental group recognized the role of communication in science. Half of them thought that communication had collective significance:

[Communication and negotiation] are important in real scientific societies because it shows results from different points of view (E8, oeq, 2).

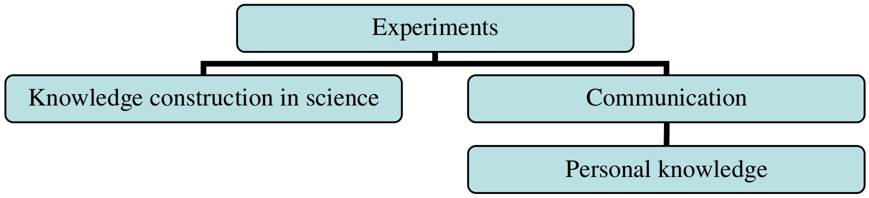
The other half believed that communication had personal significance, mainly for personal learning.

[Communication and negotiation] are important because… they (scientists) would learn from each other" (E19, oeq, 2).

Furthermore, data from the responses to open-ended questions and the reflective discussions indicated that many students viewed scientific knowledge construction different from developing personal knowledge. Many students in the experimental group thought that scientific experiments lead to two different outcomes: Construction of scientific knowledge on the one hand and personal knowledge gained through communication of the results of experiments on the other (Figure 1).

I think it (communication) is important because we know other people's ideas. It is important for scientists because they must discuss their ideas together… Scientists negotiate their ideas so that they can learn more (E17, oeq, 2).

Figure 1. Model of experimental group students' views, of how science works following the second session



During the reflective discussion E17 said,

Scientists discover new things by doing experiments…No one can say it is wrong because he discovered it (E17, vid, 2).

Only two students (10%) initially said that "experimentation" and "communication" are equally important.

[Communication and negotiation are important] because they (scientists) all have to agree about the same thing (E12, oeq, 2).

Some students did not change these views with time. E3 claimed after the third session that "*the goal of scientists is to do experiments*" (E3, vid, 3). During the interview, she said: "*Science works by experiments…The goal of the scientists is to make experiments so that they can prove things*" (E3, int). The following excerpt is taken from the final interview with E16:

Researcher: Why is doing experiments in science important?

E16: because it proves something for the scientists. It is also important because it helps us to have more knowledge.

Researcher: OK. What do you mean by knowledge?

E16: What you study. When you study you get knowledge.

Data from the responses to open-ended questions and reflective questions showed that many students in the experimental group were able to see that knowledge construction was an aim, while experimentation and communication were tools to reach that goal:

Science is based on scientific laws, facts, and theories. Experimenting, observing, interpreting and communicating are important parts of science as well (E9, oeq, 5).

The following discussion illustrates how E10 changed his view about communication:

Teacher: Was communication of findings important in today's laboratory?

E10: It was very important because in my way of thinking hearing how other people think might be good.

Teacher: Why was that important?

E10: To learn from them. (vid, 3)

Two weeks later, he said:

E10: Today I found communication important because the other classmates might know more than you, so you should hear them out to find out new things.

Teacher: What do you mean by finding out new things?

E10: ah…. I think… I don't know but maybe they have interesting way to explain which I did not have

Teacher: does this happen in real scientific societies?

E10: Yes (vid, 5)

Communication and experimental work became equally important for most students in the experimental group with time. Analysis of the responses to open-ended questions showed that after the sixth session most students viewed communication as important as doing experiments.

Scientific knowledge is not only the result of experimental work but also the result of communication and negotiation.

[Communication and negotiation] help in understanding and proving a point (E8, oeq, 5).

During the last session, students in the experimental group realized that communication in science is not limited to sharing information:

My answer was invalid and if we didn't (communicate) I would have thought my answers were valid. This goes for scientists as well (E18, oeq, 8).

They (scientists) publish the most important one (E5, oeq, 8).

Concerning the views that personal learning of science is isolated from scientific knowledge many students were able to change this view. E11 had claimed several times (E11, oeq, 2, 3, 6, 7) that communication is important for learning and getting information from others. During the reflective discussion of the seventh session the following discussion took place:

E11: Scientists discover things and add to what is there... Also they teach what they find to the world (E11, vid, 7).

E12 jumped into the discussion and said: Scientists need to communicate because other scientists need to find out if their ideas were valid or invalid. Otherwise they will stuck with their inaccurate or different ideas (E12, vid, 7).

Teacher: So what. Let them get stuck with their different ideas.

E12: No. If they don't agree on one thing they cannot teach people.

Teacher: What do you think Yara [E11]?

E11: (confused a bit). It could be. (vid, 7)

Posttest results indicated that 10% of the experimental group students had inadequate views of the social NOS, 60% had partially adequate views, whereas 30% considered negotiation and talk important in the construction of scientific knowledge (Table 1).

Scientists produce scientific knowledge by exploring and gathering information and experimenting to check their predictions. If it is correct the scientists who came up with it will publish it in textbook. But before he publishes he should negotiate his explanations with other scientists because others may explain the same answers differently. If he is able to convince them it is correct he publishes it, if the others find it wrong and they are not convinced the scientists will not publish it in the textbook (E20, post).

Alternatively, 83% of control group students held inadequate views of the social NOS (Table 1).

During the interviews that took place after the posttest, students were asked to discuss the relation between evidence, scientific knowledge, scientific experiments, explanations, and communication. They were encouraged to draw a graphic representation (like a concept map) to show the relationships by using arrows. Figure 3 shows typical maps. The first student was classified in the posttest as having adequate views in all aspects except for the social NOS, which was partially adequate (Figure 3a). The second was classified as having adequate views in all except for the tentative NOS, which was partially adequate (Figure $3a^1$). The third and fourth students had partially adequate views in all the four aspects (Figures 3b, $3b^1$). The fifth student had inadequate views in all except the social NOS, which was partially adequate (Figure 3c), while the sixth student had inadequate views in all except the tentative NOS which was partially adequate (Figure $3c^1$). Two observations can be made regarding the maps. First, students with more adequate views produced more complex maps. Second, the maps summarize the descriptions of students' views presented above, making it easier to understand their profile.

Figure 2. Students' construction of concept maps showing how science works.

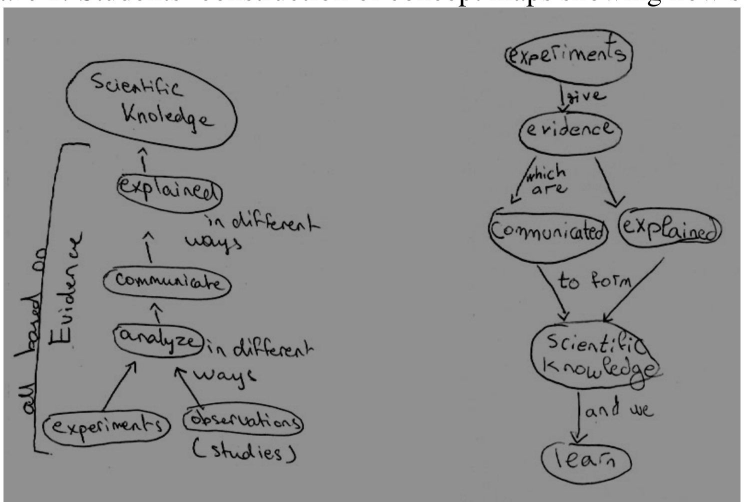


Figure 2a Figure 2a[1]

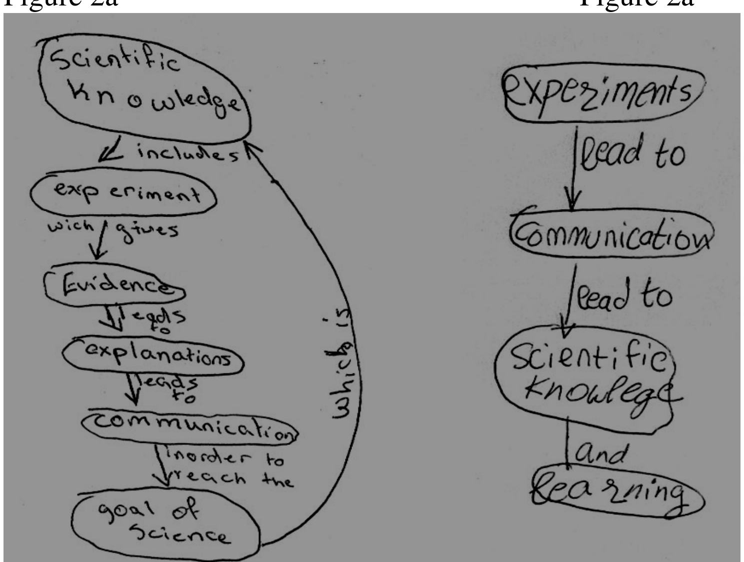


Figure 2b Figure 2b[1]

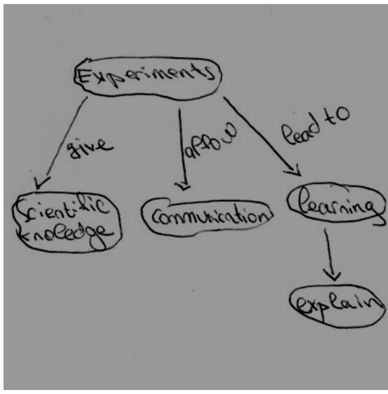


Figure 2c

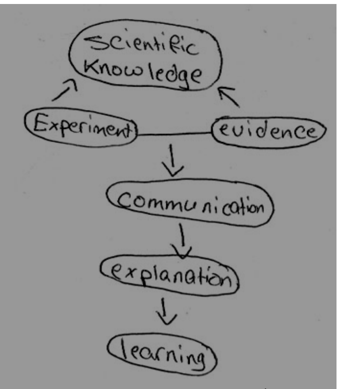


Figure 2c[1]

In sum, at the end of the study, results showed that most students in the control group maintained inadequate NOS views while a substantial number of students in the experimental group possessed ones that were more adequate. In their attempts to change their NOS views, the students in the experimental group seemed to face five main challenges:

1. The challenge of viewing science as a relative enterprise.
2. The challenge of differentiating among the components of inquiry.
3. The challenge of realizing the possibility of different explanations for the same phenomenon.
4. The challenge of viewing scientific experiments as tools rather than the goal of science and viewing communication as a tool similar to experimentation in the construction of scientific knowledge.
5. The challenge of understanding the relation between personal learning of science and construction of scientific knowledge.

Discussion and Conclusion

Initially, the majority of the students held inadequate views of the four aspects of NOS. These results are consistent with previous studies conducted with middle and high school students in Canada (e.g., Griffiths & Barry, 1993), Lebanon (e.g., Khishfe & Abd-El-Khalick, 2002), and the United States (e.g., Carey et al., 1989). Furthermore, results indicate that explicit and reflective discussions following inquiry-based laboratory activities enhanced students' views of the tentative, empirical, subjective, and social NOS; results that are similar to those reported by Carey et al (1989) and Khishfe & Abd-El-Khalick (2002).

However, results indicate that not all students in the experimental group ended up forming adequate views of the target aspects of NOS even though there was an improvement over their initial ones. There could be more than one explanation for these results. First, although all students in the experimental group had the opportunities to reflect on their experiences through answering open-ended questions after every laboratory session, analysis of the videotapes shows that a number of students did not participate in the reflective discussions and express their ideas. This apparent lack of involvement might have resulted in these students having less adequate NOS conceptions. In addition, time constraints might have deprived students from extended and profound discussions on NOS aspects; leading them to have partially adequate understandings.

A second possible explanation for the lack of complete change from inadequate to adequate conceptions could be the difficulty that students face in changing well entrenched views, analogous to misconceptions, formed as a result of their prior formal and informal learning experiences (Strike & Posner, 1992). These misconceptions along with all knowledge and beliefs that a learner possesses such as new knowledge about the misconceptions, other prior knowledge/existing conceptions, relationships among various concepts, and epistemological beliefs comprise what is identified as the student's conceptual ecology. According to Hewson, Beeth, & Thorley (1998, p. 200), the interaction of the beliefs and knowledge in the conceptual ecology determines the status of specific conceptions, such as conceptions of NOS. That is, these interactions "support some ideas (raise their status) and discourage others (reduce their status)" (Hewson et al., 1998, p. 200). Seemingly, the reflective discussions that took place in class did not convince students to change their conceptions. At least two issues emerge as a result of this situation, a research and a practical issue. In terms of research the issue there is a need to understand the factors in learners' conceptual ecologies that generate and maintain misconceptions. These factors should not be limited to epistemological ones; they should include motivational variables (Pintrich, Marx, & Boyle; 1993; Strike & Posner, 1992) and views of the nature and value of a subject matter as well (Strike & Posner, 1992). At the practical level there is a need to understand the factors that should be considered when planning and implementing reflective discussions in order to encourage all students to participate and be convinced to change their inadequate conceptions.

In addition to the concerns of lack of time and the difficulty of changing misconceptions, this study showed that there seemed to be five major challenges that students faced in their attempts to change their NOS views: Viewing science as a relative enterprise, differentiating among the components of inquiry, realizing the possibility of different explanations for the same phenomenon , viewing scientific experiments as tools rather than goals of science and viewing communication as a tool in the construction of scientific knowledge, and understanding the relation between personal learning of science and construction of scientific knowledge.

Challenge 1: Viewing Science as a Relative Enterprise

An obstacle that may have hindered the change in students' NOS conceptions seems to be the fact that many students had a view that there was an absolute truth and that the responsibility of the scientists was to find this truth, a finding consistent with those of Carey et al. (1989). The tentativeness would not have been an issue had the students understood that science is a relative enterprise. To them, tentativeness was not a significant issue because whatever scientists do, their goal is to reach the truth. The present study did not focus on the relativistic NOS. Future research needs to consider this and try to investigate the relationship between understanding the relative nature of the scientific enterprise and understanding and appreciating the tentative NOS.

Challenge 2: Differentiating among the Components of Inquiry

Initially many students had a naïve mental category called "performing experiments". This category included many activities that could be performed when doing science (Designing an experimental procedure, collecting and analyzing data, etc.). They had not differentiated these components into distinct entities. The challenge for these students was to differentiate the components into distinct entities whose sum constitutes the inquiry process. Results show that with time many students were able to accomplish this task, probably because of being involved in and reflecting on inquiry. Furthermore, students needed to realize that evidence derived directly or indirectly from the data accounted for the conclusion. Again, this became relatively straightforward once students differentiated the activities into distinct entities. This challenge might have influenced students' conceptions of the empirical NOS, especially when determining the relationships between evidence and conclusions.

Challenge 3: Realizing the Possibility of Different Explanations for the Same Phenomenon.

Many students in the experimental group had robust views that science was an objective enterprise. The students experienced the subjective aspect throughout the laboratory sessions and claimed during the reflective discussions that they constructed different explanations based on the data. However, many of them were not successful in transferring this experience to the context of professional science. Moreover, many students' ideas regarding the subjective NOS fluctuated throughout the sessions. These fluctuations were apparently based on how they constructed their views that day. They were not able to transfer what they learned in the previous laboratories to new contexts. It seems that the students had difficulty in developing abstract knowledge that could help them to transfer knowledge between different contexts. This is consistent with BouJaoude's (1991) finding that grade eight students' understandings of the concept of burning depended on the type of task conducted and the concrete and observable changes that took place during burning. Evidently, many middle school students base their explanations on concrete experiences and the context in which they are placed and have difficulty abstracting explanations and transferring them into new situations. Future research needs to take this issue into consideration.

Challenge 4: Viewing Scientific Experiments as Tools rather than Goals of Science and Viewing Communication as a Tool Similar to Experimentation in the Construction of Scientific Knowledge

Initially many students considered performing experiments as the goal of science. They did not appreciate the role of experimentation in the construction of scientific knowledge. Similar findings were reported by Carey et al. (1989). Experimentation to participants in this study was simply trying things out. Students did not realize that systematic experimentation had a purpose. In addition, many students considered communication a means for scientists to learn from each others' experiments. They did not acknowledge the importance of communication activities that lead to what eventually becomes as accepted scientific knowledge (Sutton, 1998). The challenge for the students was to see that knowledge construction was the goal of science and that experimentation and communication were tools to reach this goal. Gradually, and possibly because they engaged in authentic experiences and reflective discussions, students realized that experimentation was a tool rather than a goal of science and that communication involved not only sharing of ideas but persuasion. Consequently, many students changed their models of how science works; the new model was more complex and included network of connections.

Challenge 5. Understanding the Relation between Personal Learning of Science and Construction of Scientific Knowledge.

Many students had the view that personal learning of science is unrelated to scientific knowledge construction. Communication was considered a means for scientists to learn from others. Moreover, for them scientific knowledge construction was an outcome of experiments independent of communication and personal learning. Students were not able to see that both were guided by similar mechanisms and that they were complimentary rather than separate entities. From this perspective students needed to realize that personal learning in science and the construction of scientific knowledge share similar features. Posner, Strike, Hewson, and Gertzog (1982) regarded conceptual change in science and that in learning somehow analogous in that two similar phases exist in both: Agreement or disagreement between existing concepts and new phenomena. Results indicate that there seems to be a relation between having inadequate views of some or all the target NOS aspects and misunderstanding the relation between scientific and personal knowledge. Carey et al. (1989) claimed that most grade 7 students who participated in their research had a “copy theory of knowledge” (p. 526) and because knowledge directly reflected reality, students did not differentiate between the goal of understanding a phenomenon and the goal of producing a phenomenon. The present study revealed that reflective discussions after inquiry-based activities were successful in changing such views to a certain extent; however, future research needs to investigate the factors that allowed some students to understand the relation between personal learning and knowledge construction.

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Students' Alternative Conceptions in Photosynthesis and Respiration

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Science education researchers have shown considerable interest in diagnosing and addressing students' alternative conceptions in a variety of science topics. This interest comes from research findings that suggest that students come to the science classroom with firmly held beliefs about natural phenomena. Moreover, researchers have used a variety of methods to identify alternative conceptions, including multiple choice tests, interviews, open-ended questionnaires, and two tier tests. Two tier tests have the advantage of allowing the researcher to identify students' alternative conceptions as well as the reasons for these conceptions. Consequently, the purpose of this project is to diagnose middle and high school students' alternative conceptions of photosynthesis and respiration in plants by using an adapted version of a two-tier multiple choice diagnostic test designed by Treagust, and Haslem (1987) to investigate the effect of gender on these conceptions. Subjects for this study were 663 students in grades 7, 8, 9, 10, 11, and 12 in five schools in Aley, three private and two public. The test was administered during regular class periods in the second half of the academic year after students had covered the two topics. The test is made of 13 items. The first tier of each item requires students to respond to a multiple choice question that addresses content related to photosynthesis and respiration. The second tier requires students to select a reason for the answer they selected in the first tier. The reasons presented in the second tier include alternative conceptions about photosynthesis and respiration identified in the science education research literature. Space was provided for students to provide their own reasons if the ones presented were not acceptable to them. Students' responses were analyzed to identify alternative conceptions and possible effects of grade and gender on these conceptions. Results showed that students did not comprehend the nature and function of respiration in plants, did not comprehend that respiration in plants was an energy conversion process, did not understand photosynthesis as a chemical process, considered respiration to be synonymous with breathing; and had minimal comprehension of the relationship between photosynthesis and respiration in plants.

By the time children start school, they will have constructed a number of intuitive ideas and alternatives conceptions about how the world around them works (Pine, Messer, & John, 2001). Students acquire this knowledge through their observation of the environment and their interaction with it, constructing and reconstructing that knowledge in response to new experiences. In addition to alternative conceptions that children develop from the world around them, overgeneralizations, science textbooks, and teachers are other possible sources of alternative conceptions in science. These alternative conceptions can be influenced, at least in part, by students' gender, age, attitude toward the topic, and prior experiences related to the topic (Sencar, & Erylimaz, 2003**).**

According to Ausubel (1968) "the most important single factor influencing learning is what the learner already knows. Ascertain this and teach him accordingly." Therefore, to be effective, a science teacher should determine the nature of knowledge students possess and what concepts they have formulated, and work accordingly to change the alternative concepts and introduce new ones. New concepts are only learned and retained if they fit already existing knowledge. Otherwise, they will be rejected and thus no learning will occur (Sewell, 2002).

Studies aimed at determining students' understanding and alternative conceptions of biology concepts have revealed many misconceptions in the topics of photosynthesis, respiration, diffusion, genetics, amino acids and translations, natural selection, digestive system, and circulatory system (Çakir, Geban, & Yürük, 2002). Anderson, Sheldon, and Dubay (1990, cited in Ozay and Ostaz 2003) have demonstrated that students of all ages show strikingly similar alternative conceptions about photosynthesis. Most students know that during photosynthesis plants take in carbon dioxide and release oxygen, yet the fact that this exchange is the reverse of plant respiration is not recognized by many students. In addition, the concept that photosynthesis provides food for plants contradicts students' prior knowledge about nourishment coming from an external rather than an internal source. Similarly, it has been shown that students have some difficulties understanding that plants manufacture organic substances from inorganic ones such as water and mineral salts taken from the soil.

A variety of research approaches have sought to investigate students' alternative conceptions about photosynthesis and respiration in plants. Wandersee (1983, cited in Griffard 2001) has conducted a nationwide cross-age survey using multiple choice and open-ended questions. This study revealed an alternative conception common from elementary to university levels, specifically that plants obtain their nutrition from the soil. Eisen and Stavy (1988) conducted and study using an instrument consisting of 14 open-ended questions about oxygen release, respiration, autotrophic feeding, and sunlight energy to high school and college students. Results of this study showed that students' alternative conceptions about photosynthesis were correlated with other learning activities or concepts. For example, students who did not study advanced courses in biology, either in high school or at the university, showed very little understanding of the essential role of photosynthesis in the ecosystem. Most students understood that plants release oxygen and animals absorb it. Yet there is no awareness of the mechanism involved in these processes. Many of them are not aware that plants absorb carbon dioxide and water to produce organic materials which are used in the respiration process. The most difficult problem was the energy aspect of photosynthesis. Both photosynthesis and respiration are perceived only in terms gas exchange.

Methodology

The purpose of this study was to diagnose middle and high school students' alternative conceptions of photosynthesis and respiration in plants. Specifically, this study investigated the following questions:

1. What are the Lebanese students' alternative conceptions in the two topics photosynthesis and respiration in plants?
2. Do students' conceptions change with increasing exposures to formal science instruction?

Context

The study was conducted in five schools in Aley. Three of the schools were private (one complementary, and two complementary and secondary) and the other two were public (one complementary and the other secondary). The schools follow the Lebanese national curriculum and prepare their students to sit for the country's official exams at the Grades 9 and 12 levels. Math and science are both taught in English. Biology, the field of interest in this study, is taught at all grade levels beginning with Grade 7. The concepts of photosynthesis and respiration in plants are taught in grades 7 and 10 only.

Sample

The sample consisted of 663 students in grades 7-12 (Table 1). Three hundred and fifty two were females and 311 were males with ages ranging from 11 to 20 years with an average of 15.1 years. Student numbers in grade levels is presented in Table 1.

Table1

Number of Participating Students at Each Grade Level (n=663).

Grade	Number of students
7	106
8	110
9	72
10	181
11	147
12	47

Instruments

According to Treagust & Haslam (1987), the usual means for obtaining information about students' alternative conceptions have been through individual student interviews and /or open-ended response questions on specific science topics. However, a convenient yet valid approach to identify altercative conceptions is using of two-tier multiple-choice diagnostic tests In this study, an adapted version of a two-tier multiple choice diagnostic test designed by Treagust, and Haslem (1987) was used. The first tier of each item requires students to respond to a multiple-choice question that addresses content related to photosynthesis and respiration. The second tier requires students to select a reason for the answer they selected in the first tier. The reasons presented in the second tier include alternative conceptions about photosynthesis and respiration identified in the science education research literature. Once misconceptions are identified, a science teacher will be more inclined to remedy the problem by developing and utilizing alternative teaching approaches which address students' misconceptions (Treagust, 1988).

Two examples of the two-tier multiple choice diagnostic test used in this study are:

1. Which gas is given off by green plants in large amounts when there is no light energy at all?
   1-carbon dioxide gas
   2-oxygen gas

The reason for my answer is because:

a- Green plants stop photosynthesizing when there is no light energy at all so they continue to respire and therefore they give off this gas.

a- This gas is given off by the green plant during photosynthesis which takes place when there is no light energy.
b- Since green plants respire only when there is no light energy they give off this gas.
c- ____

2. Which of the following is the most accurate statement about respiration in green plants?
   1- It is a chemical process by which plants manufacture food from water and carbon dioxide.
   2- It is a chemical process in which energy stored in food is released using oxygen.
   3- It is the exchange of carbon dioxide and oxygen gases through plant stomata.
   4- It is a process that does not take place in green plants when photosynthesis is taking place.

The reason for my answer is because:

a- Green plants never respire they only photosynthesize.
b- Green plants take in carbon dioxide and give off oxygen when they respire.
c- Respiration provides the green plant with energy to live.
d- Respiration only occurs in green plants when there is no light energy.
e- ____

Data analysis

Students' responses were analyzed for the possible combination of correct choice and reason. The percentage of responses is shown for the combination of correct choice and possible reasons. To get a clearer idea about students' alternative conceptions, attention was given to those responses selected by more than 10 percent of students.

RESULTS

Research Question 1: What are Lebanese Students' Alternative Conceptions in Photosynthesis and Respiration in Plants?

Students' responses were analyzed for the possible combination of correct choice and reason. The percentage of responses is shown for the combination of correct choice and possible reasons. To get a clearer idea about students' alternative conceptions, attention was given to those responses selected by more than 10 percent of students.
Table 2 presents the alternative conceptions uncovered in students' reasons for their responses to all the questions in which more than 10% of the students selected an incorrect response.

Table 2
Alternative Conceptions Uncovered in Students' Responses

Question and Reason Selected by Students.	Reason (%)	Alternative Conceptions
1b	17.9	1. Oxygen gas is given off by the green plant because green plants only photosynthesize and do not respire in the presence of light energy.
1d	15.5	2. Oxygen gas is a waste product given off by green plants after they photosynthesize.
2c	45.2	3. Oxygen gas is used in respiration which only occurs in green plants when there is no light energy to photosynthesize.
5b	61.7	4. Only leaves have special pores (stomata) to exchange gas.
7b	23.7	5. Green plants take in carbon dioxide and give off oxygen when they respire.
8a	31.1	6. Cells of green plants can photosynthesize during the day when there is light energy, and therefore, they respire only at night when there is no light energy.
9a	14.6	7. During respiration green plants take in carbon dioxide and water in the presence of light energy to form glucose.
9b	26.1	8. Carbon dioxide and water are used by the green plant to produce energy during which time glucose and oxygen waste are produced.
9c	21.6	9. During respiration green plants take in oxygen and give off carbon dioxide and water.
12a	30.0	10. Photosynthesis provides energy for plant growth.
12c	41.2	11. Carbon dioxide is taken in by the leaf through the stomata during photosynthesis.

Research Question 2: What are the Effects of Gender on Students' Alternative Conceptions in Photosynthesis and Respiration?

Students' responses on each question were analyzed by gender for the possible combination of correct choice and reason. Based on the total number of correct answers for both parts of each question, there were no significant gender differences.

Research Question 3: Do students' conceptions change with increasing exposure to formal science instruction?

Since students exposure to biology increase with grade level, their responses to each question were analyzed by grade level to investigate how concepts changed with more exposure to biology. The percentage of responses is shown for each combination of correct choice and possible reasons for each grade level. As stated above, for the purposes of this study attention was given to those responses selected by more than 10% of student groups. Some items proved to be less effective in soliciting alternative conceptions in that many alternative responses were selected by less than 10 per cent of students. Nevertheless consistency of alternative conceptions was identified throughout years 7, 8, 9, 10, 11, and 12. It is worth noting that a number of students formulated their own reasons rather than use the alternatives provided.

Table 3 presents the alternative conceptions by grade level for Question 1. The alternative conception (reason b), that is oxygen gas is given off by the green plant because green plants only photosynthesize and do not respire in the presence of light energy, has been detected by 40.3% of the students in Grade 9. The fact that the concept of photosynthesis and respiration in plants is taught in grades 7 and 10 in the Lebanese curriculum explains the pattern of correct reasons provided by students: 40.6% in Grade 7, decreased to 20.0% in Grade 8 and 13.9% in Grade 9, then increased to 55.8% in Grade 10, and 66.0% in Grades 11 and 12. It seems that students reverted to their alternative conceptions in Grades 8 and 9 possibly due to forgetting.

Table 3

Percentage of Correct Choices with that of Possible Reasons by Grade Level

Q1- Which gas is given out in the largest amounts by green plants in the presence of sunlight?

1. carbon dioxide gas
2. oxygen gas *

The reason for my answer is because:

1. This gas is given off in the presence of light energy because green plants only respire during the day.
2. This gas is given off by the green plant because green plants only photosynthesize and do not respire in the presence of light energy.
3. There is more of this gas produced by the green plant during photosynthesis than is required by the green plant for respiration and other processes, so the excess gas is given off. *
4. ____

This gas is a waste product given off by green plants after they photosynthesize Grade level	No. of students	Correct choice (%)	Reason (%)				
			a	b	c	d	e
7	106	84.0	4.7	10.4	40.6*	26.4	16.0
8	110	79.1	20.0	20.9	20.0*	13.6	23.6
9	72	91.7	11.1	40.3**	13.9*	23.6	8.3
10	181	89.0	9.9	19.3	55.8*	8.8	5.0
11	147	97.3	5.4	8.2	66.0*	14.3	6.1
12	47	87.2	2.1	19.1	66.0*	12.8	.0

*: correct choice and correct reason.
**: high % of incorrect reason.

Table 4

Percentage of Correct Choices with that of Possible Reasons by Grade Level

Q2- Which gas is taken in by green plants in large amounts when there is no light energy at all?

1- carbon dioxide gas

2-oxygen gas*

The reason for my answer is because:

a- This gas is used in photosynthesis which occurs in green plants all the time.

b- This gas is used in photosynthesis which occurs in green plants when there is no light energy at all.

c- This gas is used in respiration which only occurs in green plants when there is no light energy to photosynthesize.

d- *This gas is used in respiration which takes place continuously in green plants.

e- ____

Grade level	No. of students	Correct choice (%)	Reason (%)				
			a	b	c	d	e
7	106	84.0	0.9	17.9	47.2**	29.2*	3.8
8	110	66.4	7.3	18.2	60.0**	6.4*	6.4
9	72	83.3	8.3	19.4	52.8**	13.9*	5.6
10	181	78.9	7.7	12.7	34.8	39.2*	5.0
11	147	85.7	2.0	4.1	35.4	53.1*	5.4
12	47	91.5	0.0	2.1	66.0**	29.8*	2.1

*: correct choice and correct reason

**: high % of incorrect reason.

Table 4 identifies an alternative conception (reason c), that is respiration only occurs in green plants when there is no light energy to photosynthesize, with a high percentage of incorrect reasons throughout grade levels: 47.2% in Grade 7, 60.0% in Grade 8, 52.8% in Grade 9, 34.8% in Grade 10, 35.4% in Grade 11 and 66.0% in Grade 12.

Table 5 identifies an alternative conception (reason b), that is respiration in plants takes place in the cells of the leaves only since only leaves have special pores to exchange gases, with high percentages across grade levels: 76.4% in Grade 7, 69.1% in Grade 8, 55.6% in Grade 9, 58.6% in Grade 10, 50.3% in Grade 11, and 68.1% in Grade 12.

Table 5

Percentage of Correct Choices and Possible Reasons by Grade Level

Q5- Respiration in plants takes place in:

1- the cells of the roots only.
2-in every plant cell.*
3- in the cells of the leaves only.

The reason for my answer is because:

a- All living cells need energy to live.*
b- Only leaves have special pores (stomata) to exchange gas.
c- Only roots have small pores to breathe.
d- Only roots need energy to absorb water.
e- ________________________________

Grade level	No. of students	Correct choice (%)	Reason (%)				
			a	b	c	d	e
7	106	14.2	17.9*	76.4**	0.9	1.9	0.9
8	110	32.7	25.5*	69.1**	0.0	2.7	0.9
9	72	32.4	30.6*	55.6**	1.4	6.9	2.8
10	181	33.3	32.6*	58.6**	2.8	2.8	3.3
11	147	49.7	34.0*	50.3**	0.0	15.6	0.0
12	47	29.8	29.8*	68.1**	2.1	0.0	0.0

*: correct choice and correct reason.
**: Incorrect reason

Table 6 (question 8) reveals an alternative conception (reason a), that is cells of green plants can photosynthesize during the day when there is light energy, and therefore, they respire only at night when there is no light energy, with a high percentage in grades 8 (40.9%) and 9 (62.5%). The percentages of correct reason across grades are found to be as follows: 61.3% in Grade 7, 32.7% in Grade 8, 26.4% in Grade 9, 59.7% in Grade 10, 68.7% in Grade 11, and 59.6% in Grade 12.

Three alternative conceptions (reasons a, b, and c) were revealed across grade levels in Table 7. They are: During respiration green plants take in carbon dioxide and water in the presence of light energy to form glucose; in the process of respiration carbon dioxide and water are used by the green plant to produce energy during which time glucose and oxygen waste are produced; and during respiration green plants take in oxygen and give off carbon dioxide and water. The percentages are as follows: Reason a: 22.6% in Grade 7; Reason b: 30.2% in Grade 7, 37.3% in Grade 8, 27.8% in Grade 9, 20.4% in Grade 10, and 26.5% in Grade 11; and Reason c: 21.7% in Grade 7, 29.3% in Grade 10, 23.1% in Grade 11, and 23.4% in Grade 12.

Table 6
Percentage of Correct Choices with that of Possible Reasons by Grade Level

Q8- When do green plants respire?
1-Only at night (when there is no light energy).
2- Only during daylight (when there is light energy).
3- *All the time (whether there is light energy or when there is no light energy).

The reason for my answer is because:
a- Cells of green plants can photosynthesize during the day when there is light energy, and therefore, they respire only at night when there is no light energy.
b- *Green plants need energy to live and respiration provides energy.
c- Green plants do not respire they only photosynthesize, and photosynthesis provides energy for the plant.
d- ____

Grade level	No. of students	Correct choice (%)	Reason (%)			
			a	b	c	d
7	106	74.5	29.2	61.3*	1.9	6.6
8	110	58.7	40.9**	32.7*	2.7	16.4
9	72	40.3	62.5**	26.4*	0.0	9.7
10	181	76.2	28.2	59.7*	3.3	7.2
11	147	85.7	18.4	68.7*	0.0	11.6
12	47	83.0	14.9	59.6*	2.1	23.4

*: correct choice and correct reason.
**: high % of incorrect reason.

Two apparent alternative conceptions, (reasons a, and c), detected with high percentages in Table 8 (a-The most important benefit to green plants when they photosynthesize is the production of energy for plant growth and c-The most important benefit to green plants when they photosynthesize is the removal of carbon dioxide from the air through the leaf's stomata). The pattern of responses for these alternative conceptions was as follows: Reason a 58.3% in Grade 9, and 44.7% in Grade 12; Reason c 50.9% in Grade 7, has decreased to 45.5% in Grade 8 and 29.2% in Grade 9, then increased in Grade 10 to 49.7% and decreased in Grade 11 to 33.3% and 19.1% in Grade 12.

Table 7

Percentage of Correct Choices with that of Possible Reasons by Grade Level

Q9- Which of the following equations best represents the process of respiration in plants?

1- Glucose + Oxygen -------------> Energy + Carbon dioxide + Water.*

2- Carbon dioxide + Water ------------> Energy + Glucose + Oxygen.

light energy

3- Carbon dioxide + Water ----------------------> Glucose + Oxygen.

chlorophyll

4- Glucose + Oxygen ------------> Carbon dioxide + Water.

The reason for my answer is because:

a- During respiration green plants take in carbon dioxide and water in the presence of light energy to form glucose.

b- Carbon dioxide and water are used by the green plant to produce energy during which time glucose and oxygen waste are produced.

c- During respiration green plants take in oxygen and give off carbon dioxide and water.

d- *During respiration, green plants derive energy from glucose using oxygen.

e- ____

Grade level	No. of students	Correct choice (%)	Reason (%)				
			a	b	c	d	e
7	106	21.0	22.6**	30.2**	21.7**	18.9*	—
8	110	16.7	18.2	37.3**	10.0	26.4*	—
9	72	25.0	9.7	27.8**	15.3	37.5*	—
10	181	50.8	14.4	20.4**	29.3**	31.5*	—
11	147	45.6	11.6	26.5**	23.1**	34.7*	—
12	47	68.1	6.4	8.5	23.4**	53.2*	—

*: correct choice and correct reason.

**: high % of incorrect reason.

—: no answer

Table 8

Percentage of Correct Choices with that of Possible Reasons by Grade Level

Q12- The most important benefit to green plants when they photosynthesize is:

1- Removal of carbon dioxide from the air.

2-Conversion of light energy to chemical energy.*

3- Production of energy.

The reason for my answer is because:

a- Photosynthesis provides energy for plant growth.

b- *During photosynthesis energy from the sun is converted and stored in glucose molecules.

c- Carbon dioxide is taken in by the leaf through the stomata during photosynthesis.

d- ____

Grade level	No. of students	Correct choice (%)	Reason (%)			
			a	b	c	d
7	106	8.6	29.2	8.5*	50.9**	6.6
8	110	18.3	15.5	25.5*	45.5**	7.3
9	72	9.7	58.3**	9.7*	29.2	2.8
10	181	18.4	26.5	18.2*	49.7**	2.8
11	147	32.4	27.2	32.0*	33.3**	5.4
12	47	14.9	44.7**	12.8*	19.1	23.4

*: correct choice and correct reason.
**: high % of incorrect reason.

Table 9 reveals one alternative conception (reason d), that respiration takes place in all plants only when there is no light energy and in all animals all the time. This alternative conception is prominent in Grade 9 with 45.8% of the students selecting it. The pattern of this alternative conception across the grade levels was as follows: Grade 7: 29.2%, Grade 8: 23.6%, Grade 9: 45.8%, Grade: 10 13.3%, Grade 11: 8.2% and Grade 12: 21.3%. In addition, more than 10% of the students in three grade levels selected reason a (Green plants photosynthesize and do not respire at all).

Table 9
Percentage of Correct Choices with that of Possible Reasons by Grade Level

Q13- Which of the following comparisons between the processes of photosynthesis and respiration in green plants is correct?

Photosynthesis	Respiration
1. Takes place in green plants only.	-Takes place in animals only.
2. Takes place in all plants.	-Takes place only in all animals.
3. * Takes place in green plants in presence of light energy.	-Takes place in all plants and in all animals at all times.
4. Takes place in green plants in presence of light energy	-Takes place in all plants only when there is no light energy and all the time in all animals.

The reason for my answer is because:

a- Green plants photosynthesize and do not respire at all.
b- Green plants photosynthesize during the day and respire at night (When there is no light energy at all)
c- *Because respiration is continuous in all living things. Photosynthesis occurs only when light energy is available
d- Plants respire when they cannot obtain enough energy from photosynthesis (e.g. at night) and animals respire continuously because they cannot photosynthesize.
e- ____

Grade level	No. of students	Correct choice (%)	Reason (%)				
			a	b	c	d	e
7	106	81.1	1.9	3.8	59.4*	29.2	4.7
8	110	64.5	2.7	15.5	49.1*	23.6	4.5
9	72	32.4	4.2	8.3	34.7*	45.8**	4.2
10	181	56.3	6.1	23.2	51.4*	13.3	3.3
11	147	73.1	1.4	11.6	70.7*	8.2	4.8
12	47	80.9	4.3	2.1	48.9*	21.3	21.3

*: correct choice and correct reason.
**: high % of incorrect reason.

Table 10

Alternative Conceptions Uncovered in Students' Response with High Percentages at all Grade Levels

Grade level	Alternative conceptions
7	1- Oxygen gas is used in respiration which only occurs in green plants when there is no light energy to photosynthesize. 2- Only leaves have special pores (stomata) to exchange gas. 3- During respiration green plants take in carbon dioxide and water in the presence of light energy to form glucose. 4- Carbon dioxide and water are used by the green plant to produce energy during which time glucose and oxygen waste are produced. 5- During respiration green plants take in oxygen and give off carbon dioxide and water. 6- Carbon dioxide is taken in by the leaf through the stomata during photosynthesis
8	1- Oxygen gas is used in respiration which only occurs in green plants when there is no light energy to photosynthesize. 2- Only leaves have special pores (stomata) to exchange gas. 3- Cells of green plants can photosynthesize during the day when there is light energy, and therefore, they respire only at night when there is no light energy. 4- Carbon dioxide and water are used by the green plant to produce energy during which time glucose and oxygen waste are produced. 5- Carbon dioxide is taken in by the leaf through the stomata during photosynthesis
9	1- Oxygen gas is used in respiration which only occurs in green plants when there is no light energy to photosynthesize. 2- Oxygen gas is given off by the green plant because green plants only photosynthesize and do not respire in the presence of light energy.

3- Only leaves have special pores (stomata) to exchange gas.
4- Cells of green plants can photosynthesize during the day when there is light energy, and therefore, they respire only at night when there is no light energy.
5- Carbon dioxide and water are used by the green plant to produce energy during which time glucose and oxygen waste are produced.
6- Photosynthesis provides energy for plant growth.
7- Plants respire when they cannot obtain enough energy from photosynthesis (e.g. at night) and animals respire continuously because they cannot photosynthesize.

10

1- Only leaves have special pores (stomata) to exchange gas.
2- Carbon dioxide and water are used by the green plant to produce energy during which time glucose and oxygen waste are produced.
3- During respiration green plants take in oxygen and give off carbon dioxide and water.
4- Carbon dioxide is taken in by the leaf through the stomata during photosynthesis

11

1- Only leaves have special pores (stomata) to exchange gas.
2- Carbon dioxide and water are used by the green plant to produce energy during which time glucose and oxygen waste are produced.
3- During respiration green plants take in oxygen and give off carbon dioxide and water.
4- Carbon dioxide is taken in by the leaf through the stomata during photosynthesis

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1- Oxygen gas is used in respiration which only occurs in green plants when there is no light energy to photosynthesize.
2- Only leaves have special pores (stomata) to exchange gas.
3- During respiration green plants take in oxygen and give off carbon dioxide and water.
4- Photosynthesis provides energy for plant growth.

Continuity of knowledge: an aspect of classroom practices to interpret students' performances

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Abstract:

This paper presents a study concerning the relations between evolution of students' performances and physics teaching sequences in three 10^{th} grade classrooms dealing with the same part of mechanics. Analysis is focused on knowledge considered as a joint production of the teacher and the students in the classroom. The methodology is based on the reconstruction of taught knowledge in the classroom from video recordings. This reconstruction is mainly done at three scales: macroscopic, based on knowledge's conceptual structure, mesoscopic, based on a thematic approach, and microscopic, based on units of knowledge called facets that are statements of sentence size. Two notions, continuity and density of knowledge, defined from facets, contribute to characterizing dynamics of the taught knowledge. Our results show a narrow link in many cases between taught knowledge's continuity and students' performances.

Introduction

Several research studies are currently studying teaching practices and trying to relate them to learning. Some of them are large scale studies (Hiebert & al., 2003; Fisher & al., 2005) and others are case studies (Sensevy & Mercier, 2007; Tiberghien & Malkoun, 2007). As we know, hypotheses allowing to anticipate effects of teaching in classroom on students' performances are still subject to debates.

Our research, which is a case study, concerns relations between the teaching activity and the evolution of the students' performances related to conceptual acquisitions between the beginning and end of a teaching sequence.

Theoretical framework

Our perspective is that of the works developed in a comparative approach in didactics. In these works, the choice made is that of studying the "didactical action", which means "what the individuals do in the places (institutions) where we teach and where we learn" (translated by us), considering that this action is jointly realized by the teacher and the students (Sensevy, 2007, p.14). These works are also based on the hypothesis of the predominant role of knowledge in the classroom. In fact, classroom is a place to teach and learn. This leads us to consider teaching and learning practices from the point of view of what is taught and learned, what we call knowledge. "Convinced that knowledge gives their form to teaching and learning practices, we want to consider, more generally, that the contents of the practices determine their structure. […]

Understanding the action is first understanding how the content of this action specifies it" (translated by us) (Sensevy, 2007, p.9).

We make then the choice to focus on the knowledge taught in the classroom in order to approach the classroom practices. This knowledge is not in text, it is involved in the whole oral, gesture, and written productions of the classroom. To study it, the researcher is led to reconstruct it (Tiberghien & Buty, 2007). Different points of view can be considered in this reconstruction, the point of view of the discipline, of the teacher, of a student, or of a group of students. We made the choice to reconstruct the taught knowledge using the conventional meaning of physics, since this is the "official" meaning that the school institution wants to transmit to the students by means of the teacher in the classroom.

Research studies on the evolution of students' knowledge in the course of a teaching sequence lead us to emphasize the difference between knowledge acquired by the students and taught knowledge (Niedderer & al. 2005). As several researchers have shown (Dykstra, 1992; Niedderer & al., 2005; Küzuközer, 2005; Mercier & al., 2005), the progression of the student in learning is different from that of the taught knowledge. We assume that understanding develops due to new relations constructed by the learner and that these new relations or incorporations are most often built from rather small elements of knowledge (Küçüközer, 2005). We consider that if the taught knowledge gives the opportunity of resumptions or repetitions of the knowledge newly introduced then it favors its acquisition by the students. This hypothesis, rather obvious for the researchers in didactics, does not drive directly to a methodology allowing testing it in a systematic way. The methodology which we worked out consists of rebuilding the taught knowledge at three scales, the macro, the meso and the micro scales (Tiberghien & Malkoun, 2007). We also consider that the variety of elements of knowledge involved together in a situation can affect learning. An important number of elements of knowledge introduced together might for example constitute a load for the students who might not be able to integrate them in the network of knowledge elements they already have.

Methodology:

Collecting data

To assess the evolution of students' performances we passed a questionnaire before (Pre-test) and after (Post-test) the teaching sequence on mechanics. This questionnaire was worked out from a study on evaluation in classroom concerning the mechanics in 10^{th} grade (Coulaud, 2005). It was passed in one classroom in Lebanon and twenty in France. Nine of the French classrooms followed the sequence constructed by their teacher (group 1) and eleven followed a sequence conceived by the research and development group SESAMES (group 2). To analyze the taught knowledge in classroom we gathered data, particularly video recordings, in three classrooms of 10^{th} grade, one in Lebanon (class 3) and two in France: one belonging to the group 1 (class 1) and the other to the group 2 (class 2). The French teachers have more than 10 years of experience while the Lebanese one has less than five years. The socio economic status of the three classes is good and their level is fair according to their teachers. The recordings were made during the mechanics part, while teaching "forces and interactions" and "introduction of the inertia principle", and lasted for about seven sessions in each classroom. Two cameras were used, one was fixed in the front part of the classroom in order to have the largest number of students in its field, and the other at the back of the classroom in order to follow the teacher and capture the writings on the board.

Analyzing data

The complexity of classroom situation leads us to use several scales. We follow Lemke (2002) on the idea that a very detailed analysis at micro scale does not allow researchers to structure analysis at a higher scale: "Activities at higher levels of organization are emergent, their functions cannot be defined at lower scales, but only in relation to still higher ones. […] Going "up" we know the units, but we know *neither the patterns of organization nor the properties of the emergent higher level phenomena*" (p. 25).
We take three scales, macroscopic, mesoscopic and microscopic which include both time and granularity of knowledge.

At the macro scale, the whole teaching sequence is concerned. The macro analysis gives the conceptual structure of the sequence in a chronological order but without duration.
At the meso scale, due to our knowledge perspective, we have chosen a thematic analysis in order to keep knowledge's meaning (Fillietaz, 2001). Structuring in themes is based on a thematic coherence *and* on a discourse analysis; most of the time there are discourse markers of introduction and conclusion. Theme is the mesoscopic unit of analysis; it is relevant to investigate the students' and teacher's responsibility of knowledge. This unit has several characteristics: it is at a mesoscopic scale of time and knowledge in the sense that its duration is between some minutes to a quarter of or half of an hour and the granularity of knowledge is lower than the knowledge included in the whole sequence and bigger than an element of knowledge given in a sentence; its delimitation depends both *on knowledge and on communication*.

At the micro scale, we choose two types of analysis: facets and epistemic tasks (we only present facets in this paper). The analysis in terms of facets corresponds to the decomposition into small elements of knowledge in relation to the learning hypothesis presented in the theoretical part. To designate these elements we use the term introduced by Minstrell (1992) and reused by Galili & Hazan (2000). These authors identify and catalog elements of knowledge or reasoning that students seem to apply in different situations. These elements have the size of a sentence. In our study, an effective utterance (or several utterances in the case of verbal interactions) is associated to a facet to the extent that the researcher considers they have the same meaning. The meaning can be either the conventional one or the speaker's one (student's meaning). We made the choice to reconstruct the conventional meaning of physics since our aim is to reconstruct the taught knowledge and compare it in the three classrooms.
A first list of facets was constructed by Küçüközer (2005) in order to analyze the evolution of several students during a teaching sequence in mechanics in grade 11. This list was adapted in order to analyze the discourse of a classroom during a teaching sequence in mechanics in grade 10 and reconstruct the taught knowledge from the conventional meaning's perspective. Many facets were added *a posteriori* during the observation of the video recordings. A catalog of facets was finally constructed where the facets were grouped according to their nature. The groups are: concepts, symbolic representations, language, procedures, functioning of physics as a science and phenomenon. The classroom production is coded in facets by themes. Each utterance is coded as corresponding to a "new facet" if it is introduced for the first time in the observed teaching

sequence or as a "re-used facet" if it was already introduced and is used again. The coding was done using Excel which made easy the quantitative treatment of facets.

The extract below shows the analysis of discourse in terms of facets. In this extract, the teacher begins the correction of a task worked out by the students in small groups. The task consists of answering the following questions: "Throw the ball vertically upwards and catch it. Note the moments when you exert an action on the ball. Indicate each time the direction of the action you exert on the ball."

1. T	Well let us correct (?) first question note the moments where you exert [….] Student A when do you exert an action on the medicine ball (?)
2. A	when we throw it and when we catch it
3. T	when we throw it and when we catch it when you throw the medicine ball the action of your hands or your action on the medicine ball how is it oriented (?)
4. X	upwards
5. T	student A please answer
6. A	upwards
7. T	upwards, does everybody agree (?)

Table 1. Extract of transcription taken from the 2nd session of class 2; T replaces "Teacher"; A and X replace the effective nouns of two students.

These are the facets that, from our point of view, have the same meaning as the utterances presented in the table above; for each facet we give the number of the utterances having the same meaning:

- "When an object A is in contact with an object B it acts on it" (utterances 1 to 3)
- "Action has a direction" (utterances 3 to 7)

The first facet is more distant from the effective utterances than the second one. In fact the word "contact" does not appear in the discourse but the utterances 2 and 3 entail verbs of action, "throw" and "catch". We consider that these verbs are descriptors of the situation of two objects in contact. In the utterance 3, the expression "the action of your hands" reinforces this idea of contact action.

We remind the hypothesis that if elements of knowledge newly introduced are often re-used during instruction, they have a bigger chance to be acquired by the students; these elements can be re-used in a new application field or directly recalled. The analysis in terms of facets which identifies the use of a facet by theme, allows reporting the re-use of every facet. Therefore, we introduce the notion of "continuity" of knowledge (Tiberghien & Malkoun, 2007) which expresses, generally, the rate of number of re-uses by the number of introductions. Three types of continuity can be calculated for a given duration, the duration can be that of a session, of many sessions or of the whole teaching sequence; in our case, we consider the whole teaching sequence. The three types of continuity are (Malkoun, 2007):

- continuity of a facet: number of re-uses of a facet during the whole teaching sequence.
- continuity of a group of facets: sum of re-uses of all the facets of a group / the number of facets introduced belonging to this group.
- continuity of all the catalogue's facets: sum of re-uses of all the catalogue's facets / the number of facets introduced belonging to this catalogue.
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This notion of continuity establishes links between the micro level (facets) and the macro level (teaching sequence) in our case. Different kinds of conclusions concerning the taught knowledge can be made according to the three types of continuity: continuity of a facet leads to conclusions concerning the way an element of knowledge lives in the classroom; continuity of a group of facets leads to conclusions concerning the conceptual organization of knowledge and the dynamic of the conceptual groups (or these of representations, language, etc.); and continuity of the whole catalogue's facets leads to conclusions concerning the general dynamic of taught knowledge in a classroom.

Another hypothesis made, is that the variety of elements of knowledge involved together in a situation can affect learning. To account for this hypothesis, we introduced another notion, "density" of knowledge (Tiberghien & Malkoun, 2007), which expresses the number of facets in relation to a given duration, the duration can be that of a theme, several themes, or a teaching sequence; in our case, the duration of a theme is the base to calculate density. Two types of density can be calculated (Malkoun, 2007):

- density of new knowledge: number of new facets introduced in a theme / duration of the theme (in minutes)
- density of re-used knowledge: number of re-used facets in a theme / duration of the theme (in minutes)
-
- This notion of density establishes links between the micro level (facets) on one hand and the meso (themes) and macro level (teaching sequence) on the other. The two types of density show how knowledge is introduced, regularly or not. They also show the variety of facets involved together in a given duration and lead to questions concerning the links between different elements of knowledge (this analysis that we do not present in this paper, is carried out at the meso level of the themes); if the density is high and the links are not made explicit, this might be an overload for the students. It is important to note that the quantitative treatment concerning density does not lead to direct links with students' performances.

Results

The analysis in terms of facets shows similarities and differences between the three classes in terms of continuity and density of knowledge. Some of these differences will be presented below as well as the students' performances on some questions and their interpretation in terms of continuity.

Classroom practices

-
- As we said before, three types of continuity can be calculated and each one leads to conclusions concerning knowledge according to its granularity.
- In table 2, the use of all the catalogue's facets in the three classes is presented, which shows the general dynamic of the taught knowledge in these classes. We can notice that class 3 introduces a lot of facets comparing to the two other classes. This is mainly due to the introduction in this class of the gravitational law, presented in the Lebanese curriculum, that was not introduced in the other classes and that leads to the addition of many facets to some already existing groups like action-interaction, force-interaction, representations, etc. This difference is not only due to a the curriculum constraints but also to a specific functioning of class 3 that makes reflections concerning the general functioning of physics as a science and refers to phenomenon interpreted by it, which leads to the introduction of facets related to this functioning.
- A difference can also be noticed between class 2 and class 1 concerning the introduction of new knowledge. In fact, the SESAMES sequence focuses on the concept of action before introducing the concept of force and introduces the representation of the diagram system-interactions before the representation of forces; this diagram is a simplified representation of interactions between objects, that does not account for the line of action, direction and intensity of these interactions. This leads to the introduction of many facets concerning actions and rules of representation in class 2.
-
- This table also shows that continuity of knowledge in class 3 is much lower than continuity in the two other classes. This is mainly due to the fact that this class introduces a lot of elements and rarely or never gives the possibility of repeating them during instruction. This leads us to the question of the relevance of this "supplementary" knowledge for the conceptual understanding in class 3: is it a help for students' understanding of the concepts or simply an overload for them?
-

All the catalogue's facets for the whole teaching sequence	Class 1	Class 2	Class 3
Newly introduced	54	71	138
Re-used	203	236	313
Continuity : Re-used / Newly introduced	3,7	3,3	2,3

Table 2. Continuity in the three classes for all the facets during the discourse shared by the whole classroom.

- In table 3, the most used facets in the three classes are presented. It is striking to see a resemblance in the use of the facets even if these facets are not the same. The most used facet in class 2 concerns the action between objects in contact (20 times) and has its equivalent in terms of force in classes 1 (12 times) and 3 (11 times). Also facets relative to the action or the force exerted by the Earth are part of the most used in the three classes.
- On the other hand, a difference appears concerning the much more frequent recall in class 1 of the rectilinear and\or uniform movement. Another very clear difference is the importance of facets concerning the symbolic representations in the class 2, related to the diagram system-interactions and to the vector force. Finally a difference appears in the frequent use of facets concerning the characteristics of vector force in class 3.

Group	Facets	Classe 1	Classe 2	Classe 3
Action - Interaction	When an object A is in contact with an object B it acts on it (there is a contact interaction between A and B).	2	**20**	2
	Earth always acts on (attracts) the objects.	1	**15**	2
Force - Interaction	When an object is in contact with others then it exerts a force on these objects.	**12**	1	**11**
	Earth always exerts a force on the other objects.	**13**	2	**10**
Vecteur Force	La force a direction	7	9	**14**
	La force has a line of action	6	7	**9**
Motion	The motion of an object is rectilinear when its trajectory is a straight line.	**14**	8	2
	When the value of the velocity of a point does not vary the motion is uniform.	**13**	7	5
Representation	Diagram system- interactions	0	**13**	0
	Force	6	**11**	5

Table 3. Continuity of the most re-used facets in the three classes during the discourse shared by the whole classroom.

Another notion characterizing the dynamic of the taught knowledge in the classes, density of new knowledge, is shown in figure 1.

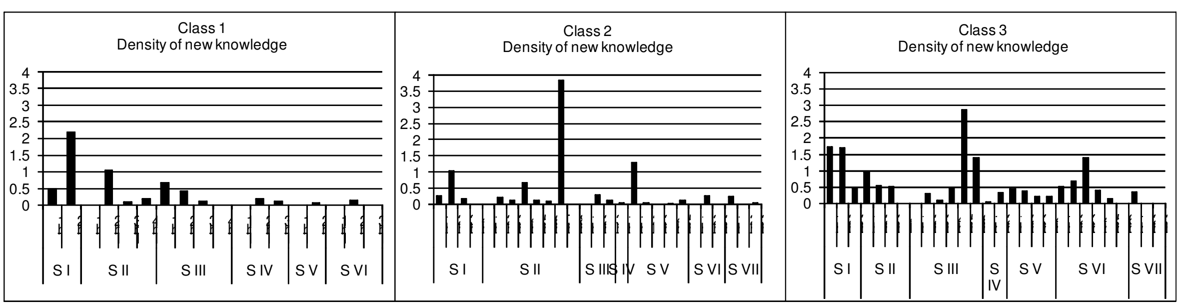

Figure 1. Density of new knowledge (vertical axis) introduced during the discourse shared by the whole classroom for the three classes respectively. The density is presented by theme and session (horizontal axis).

In class 1, the density of new knowledge is generally weak and decreases with the progress of the sequence; we just observe two small peaks which correspond to the presentation of the interactions (theme 2, session I) and the modeling of the action by a force and the representation of the force (theme 2, session II); the duration of these themes varies from 7 to 10 minutes.

In class 2, the density is also weak; we observe 3 peaks. These peaks correspond to the introduction of three models (each model is presented in a short text giving the theoretical components of mechanics) during the sequence, that of the interactions (theme 2, session I), that of the force and its representation (theme 7, session II) and that of Newton's laws (theme 1, session V). The new knowledge is thus introduced in blocks in this class, in the form of a model, at the three precise moments of the sequence; the duration of these themes varies from 4 to 6 minutes. Thus, in classes 1 and 2, there are several themes where very few or no new elements of knowledge are introduced.

In class 3, the density of new knowledge is more important than that of the two other classes and in almost every theme, we observe an introduction of new knowledge (fluctuation around the value 0,5) with 5 remarkable peaks corresponding to the introduction of the gravitational law (themes 1 and 2, session I), the modeling of the action by a force (subject 5, session III), the introduction of some contact forces (theme 6, session III) and finally the introduction of Newton's laws (theme 3, session VI). The duration of these themes varies from 8 to 12 minutes, except for themes 5 and 6 of the session III (about 3 minutes).
The high density of the new knowledge in certain themes of these classes can sometimes be an overload for the students who will maybe have difficulty in assimilating this new knowledge at one go.

This analysis at the microscopic level which involves calculations on facets can take sense only if it is restored at the superior levels. Our analyses show that the thematic analysis at the mesoscopic level plays a crucial role in the interpretation of the classroom practices; it allows to give meaning to the analysis in terms of facets by placing them in a theme, to precise the temporal situation of these facets and to understand how these facets are situated in the conceptual structure of the sequence at the macroscopic level.

Students' performances

We present, in the tables below, the results of the three classes on the questionnaires for the four questions (questions 3, 4, 6 and 7) concerning contact actions and forces. The numbers in the tables represent the percentages of students who gave the right answer to the item concerned.

Two of these questions (questions 3 and 6) are considered more difficult than the two others because they test a misconception considered difficult in the literature. In fact, these two questions present the situation of an object put in movement by a person and then released. Once released, this object continues to move on a support or in the air, then the only forces applied on this object are that of the Earth and those of the objects with which it remains in contact. So a ball, once thrown upwards, can continue to go up and the forces exerted on it will be the one exerted on it by the Earth (its weight) and, if we do not neglect it, the force exerted on it by the air. It moves upwards and the resultant of the forces applied on it is downwards. Many previous studies have shown that a non negligible part of students of all levels proposes a force in the direction of the object's motion.

Question 3 A player of ice hockey threw a puck. Once thrown, the puck slides on the ice with a uniform rectilinear motion. Among the forces below mark those exerted on the puck when it slides on the ice (a schema is given): Proposed Item: force in the direction of the motion. **Question 6** At the beginning of a basketball game, the arbitrator takes the ball and throws it upwards. In this question, we are interested at the ascent of the ball once the arbitrator has released it. Among the forces below, mark those exerted on the ball during this phase. Proposed item: a vertical force exerted upwards by the arbitrator's hand.									
	Pre-test			**Post-test**			**Difference**		
	Cl 1	**Cl 2**	**Cl 3**	**Cl 1**	**Cl 2**	**Cl 3**	**Cl 1**	**Cl 2**	**Cl 3**
Q3: force in the direction of the motion (Not marked)	32	26	22	61	74	39	29	48	17
Q6: a vertical force exerted upwards by the arbitrator's hand (Not marked)	11	13	5	7	42	13	-4	29	8
Crosstabs of the two items of Q3 and Q6				3	42	13			

Table 4. Percentages of the right answers to question 3 and 6 concerning the force in the direction of motion and their crosstabs for the post-test

The results show a progress for the three classes concerning question 3 and a progress only for class 2 concerning question 6. Therefore, we presume that a large number of students still have this misconception even after instruction; the situation presenting a vertical motion (question 6) seems to favor the use of this misconception more than the one presenting a horizontal motion (question 3). They also show that class 2 has better results on the two questions than the two other classes. The crosstabs show that when we cross the results of the two questions, the difference between class 2 and the two others becomes more important; we presume then that the students of this class have a more important conceptual stability concerning the contact actions and forces.

The two other questions (4 and 7) are considered less difficult than the two others since they do not test a misconception considered as difficult and present situations of objects in contact where students have to recognize that since there is contact between the objects then they exert a force on each other.

Question 7 We consider a ball of steel suspended by a cotton thread to a wooden support placed on a wooden table in a room (schema). We approach a magnet to the device that takes a new stable equilibrium position, the one who is represented in the schema. Tick the true proposition (N.B: all of the proposition are true except the first one)									
	Pre-test			**Post-test**			**Difference**		
	Cl 1	**Cl 2**	**Cl 3**	**Cl 1**	**Cl 2**	**Cl 3**	**Cl 1**	**Cl 2**	**Cl 3**
1. The magnet exerts a force on the hand	43	68	35	64	97	30	21	19	-5
2. The thread exerts a force on the support	82	77	83	79	84	70	-3	7	-13
3. The thread exerts a force on the ball	43	45	74	86	93	70	43	48	-4
4. The ball exerts a force on	89	94	83	100	97	61	11	3	-22

the thread									

Table 5. Percentages of the right answers to the items of question 7 involving the actions and forces of contact

Question 4 Are the following propositions true or false? (N.B: all of the proposition are true)									
	Pre-test			**Post-test**			**Difference**		
	Cl 1	**Cl 2**	**Cl 3**	**Cl 1**	**Cl 2**	**Cl 3**	**Cl 1**	**Cl 2**	**Cl 3**
1. The pen exerts a force on me when I push it	29	39	31	75	87	83	46	48	52
2. The pen exerts a force on me when I hold it	61	74	44	79	90	61	18	16	17
3. The pebble being on the roof of a truck exerts a force on this truck	68	87	96	96	90	87	28	3	-9
4. The suitcase exerts a force on me while I drag it	75	71	74	93	97	30	18	26	-44

Table 6. Percentages of the right answers to the items of question 4 involving the actions and forces of contact

Crosstabs for the post-test	**Cl 1**	**Cl 2**	**Cl 3**
Crosstabs of the 4 items of question 7	52	77	13
Crosstabs of the 4 items of question 4	62	77	22
Crosstabs of the all of the items of question 7 and question 4	38	65	9

Table 7. Percentages of the right answers given by the crosstabs of the items of question 7, question 4, and both of them, done for the post-test

The results show a progress and similar results for classes 1 and 2 concerning most of the items, and a regression concerning most of the items for class 3 (except for two items). The crosstabs show that the more we cross items, the more the difference between class 2 and the two other classes becomes important, although the results of this class are close to these of class 1 if we consider them item by item; we presume then that the students of this class have a more important conceptual stability concerning the contact actions and forces.

Relation between continuity of knowledge and students' performances

In order to relate students' performances to classroom practices, links at the different scales were made, especially at the meso and micro levels. At the micro level, the questions were analyzed in terms of facets that should be used by the students in order to answer them; the way these facets were used in the classrooms, by means of their continuity, was then related to students' performances on the questions. For the questions shown above, concerning contact actions and forces, three facets are relevant: one concerning the relation force-interaction: "when an object is in contact with the others then it exerts a force on these objects" and the two others concerning actions-interactions: "when an object A is in contact with an object B it acts on it (there is an interaction of contact between A and B)" and "when an object A is not anymore in contact with the object B it does not exert anymore an action on it". We can wonder why statements so simple cannot be used in these questions by a part of the students after the teaching sequence. The answer needs a detailed analysis of physics knowledge but also of the students' knowledge. This force in the direction of motion proposed by the students (and a big part of the not physicists) is a sign of the use of a causal relation: there is motion because there is a force in the direction of the motion (Viennot, 1996). The analysis of "the physicist" requires a decomposition of motion: the contact force exerted by the hands on the ball and that puts the ball in motion, does not exist anymore when the hands are not anymore in contact with the ball; the ball can continue its motion without any force in the direction of this motion. So, it is not enough to know the statement of the facets mentioned above, but it is necessary to be capable of applying them in coherence with an understanding of the material world.

Groups	**Facets**	**Class 1**	**Class 2**	**Class 3**
Action-Interaction	When an object A is in contact with an object B it acts on it (there is an interaction of contact between A and B)	3	21	3
	When an object A is not anymore in contact with the object B it does not exert anymore an action on it	2	3	1
Force-Interaction	When an object is in contact with others then it exerts a force on these objects	13	1	12
TOTAL		**18**	**25**	**16**

Table . Facets concerning actions and forces of contact and their continuity for the three classes during the discourse shared by the whole classroom.

The table below shows the continuity of these facets that should be used by the students to answer the questions concerning actions and forces of contact. The continuity is in favor of class 2, what can partly explain the better results of this class concerning this concept.

Conclusion

The analysis of the taught knowledge in terms of facets at the microscopic level and the general view of these facets for the whole sequence allowed us to introduce the notion of continuity. The continuity expresses the resumption, in the taught knowledge, of an already introduced element of knowledge. This notion is related to a learning hypothesis: if elements of knowledge newly introduced are often re-used during instruction, they have a bigger chance to be acquired by the students. However, certain elements of knowledge cannot be learned in the same way as the others. Some are related to misconceptions and recognized by the literature as presenting difficulties: we consider them as difficult to acquire; we give to the others the label of elements of knowledge not presenting a particular difficulty. According to its difficulty, the resumption of an element does not lead inevitably to its acquisition.

The analysis of the answers to questionnaires in terms of small elements of knowledge allowed us to compare the students' acquisitions with the knowledge taught in three classes. Our results tend to confirm the hypothesis that, for certain small elements of knowledge, there is a relation between a strong continuity in the taught knowledge and their acquisition. While for the others, especially those considered as difficult to acquire involving misconceptions (like the concepts that objects in motion are not necessarily subjected to a force in the direction of their motion), this relation is less evident: even with a strong continuity, these concepts or elements were not learnt well by the students. The continuity also allowed us to explain certain differences of performances between the classes: a strong continuity for a class was found related to better performances.

This notion of continuity which relates the microscopic scale with the scale of the whole sequence was very interesting to relate students' performances with the classroom practices but was not able to explain everything. The recall of the analysis made at the level of the themes was indispensable in certain cases and enriched these relations. For example, in the case of the concept of contact forces, continuity partially explained the differences of performances but was not able to explain why a class succeeded for certain items and not for the others and why class 2 has the biggest coherence in the good answers according to the crossings. It is the analysis made at the level of the themes that allowed us to see the way these contact forces were treated in the classes: finding these forces by considering the contact or by their effects, as well as the variety of the semiotic registers, the application fields and the work of the students in groups, widely influenced the performances in our opinion.

The notion of density did not lead to direct relations between classroom practices and students' performances; however it seems interesting to explore more largely this notion and study the links between the elements of knowledge introduced together in a theme.
These results can be useful for teachers to the extent that they can be starting points in the conception of any teaching sequence. Teacher can conceive a sequence: 1) that introduces a reasonable number of knowledge elements with explicit links between them; 2) that presents a variety of application fields that permits resumptions of these elements and enables the student to learn them more easily by putting them in a more general context than the one in which they were introduced.

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Polysémie de vocables en sciences : conséquences sur l'enseignement et l'apprentissage
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Abstract

La précision du vocabulaire est l'une des caractéristiques du langage scientifique. De nombreux termes polysémiques sont toutefois employés dans les manuels de sciences. La recherche vise à évaluer la compréhension du terme polysémique « Importance » par les enseignants et apprenants libanais, et à mettre en évidence les conséquences épistémologiques de son utilisation ainsi que son influence négative sur l'acquisition des concepts et sur la formation scientifique des apprenants. Dans ce but un questionnaire a été passé à 49 enseignants de Biologie du niveau secondaire, et à un échantillon d'apprenants de ce niveau, et une analyse des énoncés incluant ce mot a été effectuée. La recherche révèle son incompréhension par un grand nombre d'enseignants et une confusion des termes chez les apprenants. Les résultats suggèrent qu'une attention particulière soit portée au langage scientifique dans l'enseignement, ainsi que l'adoption d'un système d'évaluation plus valide dans les examens scolaires et officiels.

Introduction et problématique

La précision du vocabulaire constitue l'une des caractéristiques du langage en sciences et beaucoup d'auteurs insistent sur cet aspect. Ainsi, Gentilhomme (1982) soumet le discours scientifique au principe de monosémie lorsqu'il écrit : « Dans la mesure où il s'agit d'un texte à vocation scientifique, les termes possèdent donc un sens précis – principe de monosémie –». En 1991, Chevallard écrit : « Dans tout discours scientifique constitué, le lexique et la rhétorique sont à un moment donné fortement contraints, et on ne saurait guère y employer un mot pour un autre. Remarque souvent entendue comme signifiant que le propre du discours scientifique est de n'employer que des mots ayant un sens précis ». Toutefois, cet auteur fait remarquer que divers éléments peuvent conférer un sens précis aux mots d'un discours scientifique, soit qu'on en aurait donné une définition précise, soit que ce sens découle du fait que ces mots n'apparaissent que dans des situations d'emploi précises, soit encore parce que ces mots sont utilisés dans un petit nombre de situations d'emploi très « codées ». Schneeberger (1993) adopte la même position lorsqu'elle écrit : « A la différence du langage commun, la monosémie est de rigueur dans le discours scientifique ».

En dépit de ces exigences de précision, de nombreux auteurs attirent l'attention sur l'ambiguïté du discours scientifique. Ainsi, Gentilhomme (1982) souligne que « tout texte scientifique est *a priori* ambigu », car, selon lui, « tout texte scientifique se présente comme un système lacunaire : sous-entendus, présupposés, évidences non mentionnées, etc. ». Selon Chomsky (1980), de nombreux énoncés du langage courant sont ambigus et il cite plusieurs exemples dont il dit qu'ils peuvent être compris de différentes manières. Bachelard (1977) introduit la notion d'« obstacle verbal » lorsqu'il étudie « le pauvre mot d'éponge » (selon ses propres termes) dans les écrits des savants du $18^{ème}$ siècle (Réaumur, Franklin, etc.) et il montre que ce mot, employé pour expliquer divers processus physiques ou biologiques (l'air, le fluide électrique, le sang, etc.) a constitué pour une longue période un « obstacle verbal » qui a empêché l'esprit humain de progresser dans l'explication de ces processus. En ce sens, il écrit : « Ces phénomènes, on les exprime : on croit donc les expliquer. On les reconnaît : on croit donc les connaître ».

Si la précision du vocabulaire est exigée dans les textes des savants et des scientifiques en général, qu'en est-il de cette exigence dans l'enseignement scientifique ? La réflexion sur le langage dans l'enseignement des sciences qui a débuté dans les années 70 du siècle dernier a porté sur 2 aspects principaux: le premier concerne **la place** occupée par le langage dans l'enseignement des sciences. En ce sens, Wellington et Osborne (2001) citent Postman et Weingartner (1971) qui disent que ce que nous appelons « le savoir », est du langage, ce qui veut dire que la clé pour comprendre un sujet est de comprendre son langage. Ce point de vue a pour conséquence l'idée que tout enseignant est un enseignant de langue. En effet, Wellington et Osborne estiment que toute leçon de science est une leçon de langue, et que tout enseignant de science est un enseignant de langue, et ils ajoutent : « Apprendre les sciences revient à apprendre une nouvelle langue». Dans cette optique, on considère qu'apprendre le langage scientifique est fondamental dans l'apprentissage des sciences, et que le développement conceptuel et celui du langage sont inextricablement liés. De même, on estime que la pensée met en jeu le langage, et réciproquement le langage met en jeu la pensée. A l'opposé, des difficultés de langage entraînent des difficultés de raisonnement. Selon Piaget (1989), « la logique et le langage sont évidemment interdépendants ».

L'autre aspect concerne **la nature** du langage à utiliser dans l'enseignement scientifique, et deux courants s'opposent dans le débat sur la nature de ce langage. Il consiste à se demander s'il est préférable d'utiliser des termes scientifiques dans la classe et dans la rédaction des manuels de sciences ou bien d'utiliser autant que possible les mots du langage courant, tendances qui présentent chacune des avantages et des inconvénients. Ce débat sur la nature du langage dans l'enseignement des sciences ainsi que les résultats des recherches ont mis en évidence que le langage scientifique présente plus de difficultés que le langage courant du fait que certains mots qui représentent des concepts de la science, tels que par exemple, énergie, travail, force – ont un sens précis en science et parfois une définition exacte, mais possèdent un sens très différent dans la langue de la vie quotidienne. Ainsi, la rédaction des manuels de sciences pose le problème de la nature du langage à utiliser pour faire acquérir les concepts et notions de la science et de nombreux auteurs et même des linguistes, suggèrent d'utiliser les termes du langage courant là où cela est possible. Wellington et Osborne (2001) citent des auteurs qui considèrent que, du fait que les idées de la science sont très difficiles pour la majorité des élèves, le langage doit être aussi simple que possible. De même, dans le but de rendre les manuels scolaires plus lisibles, il a été suggéré de supprimer les connecteurs logiques de ces manuels et, par suite, des questions d'examen. A l'opposé, Sutton (1992) estime que le problème du langage dans l'enseignement scientifique n'est pas résolu de manière convenable en abaissant le niveau de lisibilité des textes et des énoncés, ou bien en essayant d'éviter les termes techniques, et il recommande d'encourager la flexibilité du langage en exprimant une même idée de différentes manières. De même, il suggère aux enseignants d'utiliser à la fois des phrases techniques et d'autres moins techniques pour une même idée.

Toutefois, l'utilisation du vocabulaire scientifique dans les manuels scolaires ne constitue pas une garantie contre la polysémie de ce vocabulaire : dans une recherche effectuée sur le vocabulaire de manuels français de biologie, Schneeberger (1993) note que « Les textes des manuels scolaires ne répondent pas toujours à cette exigence (de monosémie) et cela peut mettre les élèves en difficulté », et cet auteur montre que, bien que des termes du langage scientifique soient employés dans ces manuels, ils « sont utilisés dans des sens différents à l'intérieur d'un même manuel. Le contexte ne permet pas toujours de choisir et des confusions peuvent avoir lieu », et elle attribue l'emploi des significations différentes d'un même mot à l'intérieur d'un manuel au fait que les auteurs « utilisent un vocabulaire correspondant à leurs conceptions personnelles des concepts envisagés ».

Les manuels libanais se placent dans leur majorité dans le camp de l'utilisation du langage courant dans l'enseignement des sciences. En effet, les recherches menées sur ces manuels dont l'une portait sur la présence ou non des articulateurs du raisonnement dans un manuel de Biologie avaient montré l'absence des articulateurs de causalité explicite (parce que, puisque, car) (Piaget, 1993) qui étaient remplacés par des expressions indiquant une causalité implicite (est dû à, grâce à, par, etc.) et l'auteur avait constaté que ces articulateurs de causalité implicite n'étaient pas perçus par environ 50% des élèves de classe de 5ème (11-12ans) comme des articulateurs de causalité (Hajj, 1997). Ces résultats ont été confirmés par une recherche menée sur un autre manuel qui a également montré l'absence de ces articulateurs (Saliba, 1997).

De plus, de nombreux termes polysémiques sont employés dans les manuels de Sciences et dans la classe, entraînant des difficultés et des échecs dans la formation, à la fois chez les enseignants et chez les apprenants. A titre d'exemple, le mot « Expliquer » suscite des difficultés, particulièrement pour les enseignants de sciences. En effet, ceux-ci expliquent les leçons à leurs élèves, c'est-à-dire qu'ils leur fournissent un supplément d'information en vue d'en faciliter l'acquisition. Par contre, lorsqu'il s'agit « d'expliquer » un phénomène en sciences – dans notre cas en Biologie - ce terme prend la signification de « trouver la cause » ou de « formuler une hypothèse explicative » de ce phénomène. Il en est de même d'autres mots relevant des méthodes des sciences tel que le mot « Interpréter ». En raison des multiples sens qu'il peut prendre selon les situations, celui-ci représente une difficulté pour les élèves, ce qui a conduit certains chercheurs en didactique à proposer d'en supprimer l'usage dans les classes qui précèdent l'enseignement secondaire (Astolfi et al., 1991). Cette situation est d'autant plus grave que, comme cela a été mentionné par Frayha (1999), le manuel scolaire reste au Liban l'outil didactique de base. De même en France, des études statistiques menées auprès des enseignants ont montré que dans 78% des cas, les enseignants font référence, dans la préparation de leur cours, uniquement au manuel scolaire de l'élève (Arsac et al., 1989).

Dans une recherche intitulée « Pour une surveillance épistémologique des manuels scolaires libanais » (Thoumy, 2007), nous avions signalé l'emploi imprécis et fréquent du mot « Importance » dans divers énoncés du manuel de Sciences de la Vie (Jammal et al., 1998) et cela dans différents contextes. Or, ce mot du langage courant est également polysémique, et nous avions signalé que l'usage d'un tel mot rendait l'énoncé vague du fait de l'élimination de la mise en relation du (ou des) facteur (s) cité (s) dans cet énoncé, avec le facteur sur lequel il avait un effet. En ce sens, Sutton (1992) souligne que les mots développent des significations particulières à partir de leur interaction avec d'autres mots, et que l'interdépendance des mots en ce qui concerne leur signification est une caractéristique générale du langage. Nous estimons aussi avec Rumelhard (1986) et Astolfi et al. (1997) que toute absence d'explicitation de l'origine des savoirs conduisait à leur dogmatisation.
Ce type d'énoncés devait donc nécessairement retentir de manière négative sur les enseignants et les apprenants au niveau des 2 aspects de compréhension du texte, et de l'acquisition et de la pratique des activités de mises en relation, d'autant plus qu'un grand nombre d'enseignants n'ont pas une formation suffisante à la démarche expérimentale et ne maîtrisent pas, par conséquent, le concept de causalité ou au moins le langage qui l'exprime. Dans une recherche antérieure, nous avions également montré la difficulté sinon l'incapacité des apprenants libanais à la mise en relation, activité mentale de base des sciences expérimentales (Thoumy, 1998). Etant polysémique, le terme « Importance » manque donc de précision et ne devrait pas, de ce fait, trouver sa place dans un manuel de sciences.

Or, la fréquence de son usage ainsi que son mode de présentation dans le manuel de Sciences de la vie du CNRDP (Jammal et al., 1998), conduisent à s'interroger sur son éventuelle présence dans d'autres manuels de sciences libanais utilisés dans l'enseignement secondaire (Moukarzel et al., 1998 ; Edition Le Pointier) et (Dakroub et al., 1999 ; Série Scientifica), ainsi que dans les textes correspondants d'un manuel scolaire français (Beaux et al., 1997, de l'Editeur Nathan) et sur les conséquences de cette utilisation sur la compréhension des textes des manuels par les enseignants et les apprenants de Biologie libanais, ainsi que sur la formation scientifique de ces groupes, et cela d'autant plus que Sutton (1992) estime qu'une partie non négligeable du temps de la classe devrait être consacrée à la comparaison des différentes compréhensions des énoncés par les élèves. Il est nécessaire de souligner que l'enseignement des sciences se fait, au Liban, en français, qui est une langue étrangère mal maîtrisée par les enseignants et les apprenants, ce qui aggrave encore les conséquences de l'usage de pareils mots dans les manuels.
Ce débat constitue la problématique générale de notre recherche qui vise essentiellement à évaluer la compréhension du mot « Importance » employé dans différents énoncés du manuel *Sciences de la Vie* (Jammal et al., 1998) par des enseignants de Biologie de l'enseignement secondaire public, et accessoirement par les apprenants de ce même niveau. Nous cherchons aussi à connaître l'impact de son utilisation sur la formation scientifique de ces 2 groupes. Enfin nous cherchons à mettre en évidence les conséquences épistémologiques de son utilisation. La recherche, qui se situe dans le cadre de l'interdisciplinarité, selon laquelle on estime qu'il n'existe pas de barrières strictes entre les diverses disciplines, devrait apporter des évidences qui appuient l'une ou l'autre des positions concernant la nature du langage à utiliser dans l'enseignement des sciences.

Définition des concepts et des termes

La polysémie est la propriété que possède un mot de présenter plusieurs sens. La polysémie est le contraire de la monosémie caractéristique du langage scientifique. Le terme « Vocable » est défini comme étant un mot d'une langue, considéré dans sa signification, sa valeur expressive (Le Micro-Robert, 1988). Le Robert (Dictionnaire de Synonymes et Contraires, 1996) donne du mot « Importance » les significations suivantes : au sens propre : conséquence, considération, étendue, grandeur, gravité, intérêt, nécessité, poids, portée, puissance, valeur. Par extension : Influence, orgueil, richesse. De même, dans le Larousse (2000) le mot « Importance » est défini comme le caractère d'une chose considérable, soit par elle-même, soit par les suites qu'elle peut avoir ; intérêt, conséquence, portée. Autorité, crédit, influence.
Il est à noter qu'aucune des définitions précédentes ni aucun des synonymes du mot « Importance » figurant dans les dictionnaires de langue, ne lui accorde un sens causal ou de relation.

Les questions de recherche

Nos questions de recherche qui portent sur les 2 aspects de compréhension par l'utilisateur du manuel et d'impact sur l'aspect épistémologique de la science sont les suivantes :
1- Les sujets ont-ils une compréhension exacte du mot « Importance » dans le contexte étudié ?
2- Quelle (s) autre (s) signification (s) les sujets examinés donnent-ils au mot « Importance » dans ces énoncés ?
3- Ces significations sont-elles différentes selon les sujets ?
4- Quelles sont les conséquences épistémologiques de l'utilisation de ce mot dans les manuels sur la pratique de la science par les enseignants et sur la formation scientifique des apprenants?

Les hypothèses

L'hypothèse générale du travail est qu'il est préférable d'utiliser, dans les manuels scolaires, le langage scientifique malgré sa difficulté, plutôt que les termes du langage courant parce que ceux-ci, étant le plus souvent polysémiques, seront vraisemblablement mal compris et différemment compris par les sujets. Sur cette base, nous faisons les hypothèses suivantes :
1- La signification exacte du mot « Importance », dans le contexte étudié, ne sera pas perçue par la majorité des sujets (enseignants et apprenants)
2- Les significations non pertinentes seront différentes selon les sujets
3- Les apprenants auront des résultats similaires ou inférieurs à ceux des enseignants.
4- L'utilisation de ce mot aura des conséquences épistémologiques défavorables à la pratique de la science par les enseignants et à la formation scientifique des apprenants se traduisant par une compréhension subjective de ce terme, et par l'élimination des mises en relation.

La méthode de travail

En vue de tester nos hypothèses un questionnaire a été soumis à un groupe d'enseignants et d'apprenants du niveau secondaire.
<u>Les échantillons</u>
Deux échantillons ont été engagés dans cette recherche : celui des enseignants, et celui des apprenants.
<u>L'échantillon des enseignants</u>
Il est constitué de 49 sujets dont 7 garçons et 42 filles qui suivent une formation en Didactique de la Biologie à la Faculté de Pédagogie de l'Université Libanaise. Ils enseignent dans les classes du niveau secondaire des écoles publiques, mais peuvent, dans le même temps, être chargés d'enseigner dans les classes du complémentaire qui correspond au 2ème cycle de l'Education de Base. Leur âge moyen est de 36 ans et ils ont en moyenne 12 ans d'expérience professionnelle. Ils sont titulaires soit d'une licence (20%) soit d'une maîtrise en Biologie (80%), ce dernier diplôme correspondant à la licence, à laquelle s'ajoutent des crédits supplémentaires, ce qui ne modifie pas le modèle de leur formation. Il est à signaler que ces sujets n'avaient jamais auparavant effectué ou participé à une recherche comme cela a été précisé lors d'un travail ultérieur, de sorte que leurs réponses peuvent parfois être inadéquates. Les caractéristiques de l'échantillon sont présentées dans le tableau 1.

Effectif	Sexe		Age	Expér. Profess.	Diplôme		Niveau de l'enseignement	
	♂	♀	μ	μ	Licence	Maîtrise	Complém.+Secondaire	
49	7	42	36	12	10	39	10	39

Tableau 1- Caractéristiques de l'échantillon des enseignants.

<u>L'échantillon des apprenants</u>
Il est moins défini que celui des enseignants. On peut toutefois dire qu'il est constitué par des élèves des classes de la première année secondaire (seconde), avec un âge moyen de 17 ans, étudiant dans des écoles privées ou publiques. Il est très vraisemblable que ces sujets n'ont jamais

participé à une recherche, et leurs réponses peuvent avoir été affectées par cette condition. Par ailleurs, les tests ont été passés aux élèves par les enseignants qui avaient eux-mêmes été soumis à ces mêmes tests. De ce fait, les réponses ont pu être biaisées par ces différentes conditions. Quoi qu'il en soit, les résultats sont davantage d'ordre qualitatif que quantitatif, et permettent malgré ces conditions défavorables de se faire une idée sur l'effet de l'utilisation du mot « Importance » sur leur apprentissage.

Le questionnaire

Trois énoncés incluant le mot « Importance » présentés en titre de paragraphe dans le manuel cité plus haut (*Sciences de la Vie*, 1998) ont été proposés aux enseignants, et il leur a été demandé de remplacer le mot « Importance » par un autre mot tel qu'ils le comprennent eux-mêmes. Les énoncés sont les suivants :

1- « Importance de l'eau et des ions minéraux » (Jammal et al., 1998, p 18)
2- « Importance de la lumière et de la chlorophylle » (idem, p 20)
3- « Importance de la production « à la chaîne » des végétaux » (idem, p 111)

Enfin, nous avons adopté, comme énoncé de référence, du fait qu'il répond aux normes du discours scientifique, l'énoncé suivant tiré du même manuel:

« Influence de l'éclairement et du dioxyde de carbone sur l'intensité photosynthétique » (Idem, p 122). Il servira pour la comparaison avec les énoncés du test. Il sera aussi utilisé en vue de mettre en évidence la structure de ces 2 types d'énoncés ainsi que les conséquences respectives de l'utilisation de chacun de ces types. Ce dernier énoncé n'a été discuté avec les enseignants qu'à la fin de la correction de leurs réponses au test.

Les conditions de la passation pour les enseignants

La passation du test a été effectuée le premier jour de la formation en vue de connaître leur condition initiale. Afin de s'assurer que les enseignants sont déjà familiarisés avec les énoncés du manuel qui font l'objet de cette analyse et qui seront utilisés pour le test, il leur a été demandé de préciser s'ils enseignent dans les classes de la $1^{\text{ère}}$ année de l'enseignement secondaire. La majorité des sujets ont donné une réponse affirmative.

Signification du terme selon les auteurs du manuel

La signification du mot « Importance » dans les énoncés du manuel a été identifiée, dans chaque cas, à partir du texte présenté au-dessous du titre. Cette identification permet, d'une part, de comparer la signification à celles que proposeront les enseignants, et d'autre part de mettre en évidence, par comparaison avec l'énoncé de référence du même manuel, rédigé en termes scientifiques, les conséquences épistémologiques de ces énoncés. Cette signification est présentée dans les résultats à côté de l'énoncé considéré.

Principe de comptage

Tout terme (ou l'un de ses synonymes), proposé par les enseignants en réponse à la question, et qui correspond à la signification dégagée du texte du manuel ou aux connaissances scientifiques admises, a été retenu comme une réponse exacte. Lorsque ce terme est accompagné d'un ou de plusieurs synonymes, il ne sera compté qu'une seule fois. Lorsque la réponse exacte est accompagnée d'une réponse fausse, c'est cette dernière qui sera retenue, ce qui permettra d'identifier le nombre de sujets ayant une compréhension sûre de ce terme.

Analyse du questionnaire : La signification du mot « Importance » dans les 3 cas cités

1- « Importance de l'eau et des ions minéraux » (p 18)
Ce titre est présenté dans le cadre de l'étude de la « Signification de l'autotrophie ». La lecture et l'analyse du titre indiquent que deux éléments (ou facteurs) ont de l'importance, sans qu'il soit possible de savoir quelle est, ici, la signification de ce mot, ni pour quel (s) autre (s) facteur (s) ces 2 éléments sont-ils « importants ». La photo du doc. a, dont la légende est la suivante : « Culture de laitue sur l'eau et sur un liquide nutritif » où ce dernier est une solution de sels minéraux (ions minéraux) ne lève pas l'ambiguïté du fait que le rôle de l'eau n'est pas mentionné. Ayant fait varier le facteur « ions minéraux » entre les 2 conditions de l'expérience, il est possible de déduire, d'une part que l'expérience étudie l'effet des ions minéraux sur les plants (croissance, etc.) et d'autre part que l'eau est considérée seulement comme un solvant dans le 2ème tube. Toutefois, en mentionnant, dans la légende, l'eau de manière explicite en tant que milieu de culture des plants, et parce que ces plants ne sont pas fanés, le titre suggère que celle-ci est nécessaire à la vie de la plante, de sorte qu'on peut dire que le mot « Importance » a ici le sens de « **nécessité** ».
Dans le doc. b, on lit : « Culture de blé…arrosé d'un liquide nutritif (liquide de Knop par exemple) ou carencé en ions, pour tester l'importance de ces derniers sur la croissance des plants ». Ici aussi, « l'importance » de l'eau n'apparaît pas dans le texte. Par contre, on peut noter « l'importance des ions minéraux sur la croissance des plants ». Dans ce dernier texte, le mot « importance » a donc pour signification « **rôle** » ou « **influence** » des ions minéraux. De plus, dans le corps du texte, le 2ème terme de la relation ou la variable dépendante est **la croissance des plants**. Par conséquent le titre élimine la mise en relation entre la présence des ions minéraux dans le milieu de culture et la croissance des plants.
Il découle de l'analyse de cet énoncé qui mêle l'eau et les ions minéraux, et sur la base des textes présentés au-dessous de ce titre, que le mot « Importance » correspondrait à « Nécessité » pour l'eau et à « Influence » pour les ions minéraux, de sorte que ce mot a, dans ce titre, 2 sens, ce qui confirme sa polysémie et ajoute une complication supplémentaire à sa polysémie initiale. Le texte manque donc de précision et ne permet pas l'acquisition d'un vocabulaire scientifique. En outre, l'acquisition de la capacité de mise en relation est éliminée par cet énoncé.

2- « Importance de la lumière et de la chlorophylle » (p 20)
Cet énoncé est présenté à l'intérieur de l'étude de « La photosynthèse : des conditions particulières ». Comme dans le cas précédent, deux éléments apparaissent dans le titre comme ayant de l'importance, sans toutefois permettre de savoir quelle est la signification de ce mot, ni pour quel (s) autre (s) facteur (s) ces 2 éléments sont-ils « importants ». Toutefois, dans l'exploitation de l'activité (p 21), on lit : « …dans le cadre de l'étude de l'influence de la lumière sur la photosynthèse », ce qui montre que dans ce texte, le mot « Importance » signifie « **rôle** » ou « **Influence** ». De plus, il apparaît que le facteur qui doit subir l'effet est la photosynthèse bien que ce processus comporte 3 manifestations : l'absorption de C02, le rejet de 02 et la formation de l'amidon et est susceptible de présenter des intensités différentes, et cela sans que soit précisée la manifestation qui sera étudiée. Il aurait donc été nécessaire d'associer, par une relation de cause à effet, le rôle de la lumière et de la chlorophylle à la fabrication de l'amidon, ce que les auteurs ont omis, conduisant de ce fait à un énoncé tronqué.

3- « Importance de la production « à la chaîne » des végétaux » (p 111)
Une 3ème signification du mot « Importance » apparaît dans ce titre dont on déduira, à la suite de la lecture du texte placé au-dessous du titre, qu'il signifie « Intérêt ». En effet, on retrouve ce mot dans le 2ème paragraphe où on lit : « Ces techniques intéressent les agriculteurs, les horticulteurs… », ainsi qu'au 5ème paragraphe, où on lit : « d'avoir un rendement économiquement intéressant » . Il apparaît, de surcroît, que l'usage de l'expression « à la chaîne » est erroné du fait qu'on ne retrouve pas cette expression dans les dictionnaires de langue. En effet, l'expression « à la chaîne » apparaît seulement dans « Travail à la chaîne » et dans « Chaîne de fabrication » (Larousse 2000). Il est nécessaire de signaler que cet énoncé n'étudie pas de manière explicite l'effet d'un facteur physique sur un autre facteur. Le texte indique que la production « à la chaîne » des végétaux présente un intérêt économique. Ce terme exprime donc l' « **intérêt** », l'« **avantage** », le « **bénéfice** » qu'il y a à pratiquer la production « à la chaîne » des végétaux. De ce fait, cet énoncé n'étudie pas une relation causale explicite entre 2 facteurs physiques de la situation, mais la relation entre un procédé physique et un concept abstrait (économique).
Il résulte de cette analyse que le mot « Importance », outre sa polysémie due au fait qu'il provient du langage courant, est polysémique à l'intérieur même du manuel où il présente 3 significations différentes: nécessité, rôle ou influence, et intérêt, entraînant une ambiguïté du sens chez les enseignants et apprenants et élimine les mises en relation ainsi que la familiarisation des sujets, engagés dans les sciences, avec ce type d'activités mentales.

Analyse de l'énoncé de référence : « Influence de l'éclairement et du dioxyde de carbone sur l'intensité photosynthétique » (p 122)

Dans cet énoncé, on constate la présence du mot « Influence » là où on rencontrait « Importance ». Ce terme entraîne, contrairement aux énoncés précédents, l'explicitation de la variable dépendante (intensité photosynthétique), contribuant au développement de la pensée causale et de la pratique des mises en relation chez les enseignants et les apprenants. En effet, les 2 facteurs causals sont précisés, en l'occurrence l'éclairement et le dioxyde de carbone, ainsi que le facteur qui subit l'effet, qui est l'intensité photosynthétique. Dans ce titre, outre l'utilisation du mot « influence », on constate que le facteur « lumière » est analysé en « éclairement » qui apparaît dans le titre et « chaleur » qui n'apparaît pas, et la photosynthèse est étudiée en terme d'intensité.
La comparaison entre l'énoncé 2 (à titre d'exemple) et l'énoncé de référence est montrée dans le tableau 2.

Importance	de la lumière	et de la chlorophylle		
Influence	de l'éclairement	et du CO2	sur	l'intensité photosynthétique

Tableau 2- Comparaison de l'énoncé 2 (incluant le mot « Importance ») et de l'énoncé de référence (incluant le mot « Influence »).

La lecture du tableau et la comparaison des 2 énoncés montre que le 1er énoncé est tronqué et constitue un jugement, les 2 éléments, lumière et chlorophylle perdant, de ce fait, leur rôle ou leur qualité de facteurs, le facteur étant un élément de la situation ou une caractéristique d'un objet, sujet ou objet d'une action. Ils apparaissent de ce fait statiques et exclus du réseau de la causalité qui recouvre les objets du monde physique. De même, le mot « Importance » apparaît isolé, et n'entre pas en interaction avec d'autres mots, car, comme le dit Sutton (1992), c'est à travers leur interaction avec les autres mots que les mots d'un énoncé acquièrent leur signification. A l'opposé, le second énoncé est centré sur la préposition « sur » qui marque une relation qui est ici une relation de causalité en ce sens que les 2 facteurs « d'éclairement et de CO2 » ont un effet sur le facteur « intensité photosynthétique » qui est une modalité du processus de la photosynthèse. Il montre également que dans le premier énoncé, la lumière n'est pas analysée en éclairement et chaleur, mais est considérée dans sa globalité, faisant perdre à la fois une information et la notion de facteur. Le premier énoncé élimine donc les notions d'analyse en facteurs, de facteur, de relation, de causalité, de facteur causal et de variable dépendante, sans parler de son ambiguïté en ce sens qu'il peut être compris différemment par les différents lecteurs.

Présence du mot « Importance » dans différents manuels scolaires libanais et étrangers

Nous venons de voir que le mot « Importance » apparaissait dans les titres de plusieurs situations différentes dans le manuel du CNRDP et nous en avions analysé 3. On se demande si ce même mot est également utilisé dans les titres d'autres manuels libanais du même niveau pour l'étude des mêmes situations, sinon quels termes y sont employés et quels termes sont utilisés dans des manuels étrangers. La recherche a porté sur 2 manuels libanais, le premier de la série Scientifica (Dakroub et al., 1999), et le deuxième est le manuel de l'éditeur Le Pointier (Moukarzel et al., 1998). Enfin, nous avons consulté le manuel français de l'éditeur Nathan (Beaux et al., 1997). A titre d'exemple nous présentons un tableau comparatif pour la situation **« Importance de la lumière et de la chlorophylle »** qui apparaît dans les 4 manuels :

C.N.R.D.P. 1998	Scientifica 1999	Le Pointier 1998	Nathan 1997
Importance de la lumière et de la chlorophylle (p 20).	Influence de la lumière sur la synthèse d'amidon (p 54). L'importance de la chlorophylle (p 54).	Sans titres	On cherche à établir une relation entre l'intensité photosynthétique et l'éclairement (p 70). Influence de l'éclairement sur l'intensité photosynthétique (p 70).

Tableau 3- Comparaison de l'utilisation du terme « Importance » dans 3 manuels libanais et un manuel français.

L'analyse des énoncés des 4 manuels montre qu'alors que le mot « Importance » est utilisé de manière exclusive dans le manuel du CNRDP, il apparaît dans les autres manuels libanais soit à côté du terme « Influence » comme c'est le cas du manuel de la série Scientifica, 1999, soit n'est ni utilisé ni remplacé par d'autres termes, comme c'est le cas du manuel de Le Pointier, où le terme est évité. Enfin, dans le manuel de Nathan, il est systématiquement remplacé par « Influence » ou par « Etablir une relation ». Il est à noter que dans le manuel de la série Scientifica, le terme « Importance » est utilisé de manière massive dans les pages consacrées à l'étude des facteurs déterminants de la productivité (pp 142 et 143) où il est utilisé 5 fois pour les 5 facteurs étudiés.

Les résultats

1- Compréhension du terme « Importance » par les enseignants

*« Importance de l'eau et des ions minéraux » = **Nécessité** de l'eau et **influence** des ions minéraux sur la vie et la croissance des plantes

Catégories	Nécessité Besoin Indispensable	Influence Effet Rôle Dépendance de	Utilité But d'utilisation Intérêt	S .R.	Total
Effectifs	21 +6 +4	4 +2+ 3+ 1	3 +2 +1	2	49
Total	31	10	6	2	49
%	63%	33%		4%	100%

Tableau 4- Distribution des significations du terme « Importance » dans la première situation (où les effectifs correspondent respectivement et successivement aux termes employés, et où S.R. représente la catégorie sans réponses).

En ce qui concerne cette situation, nous avons vu, lors de la recherche de la signification sous-entendue par les auteurs, mais non exprimée par eux, que le mot « Importance » correspondrait à « Nécessité » pour l'eau et à « Influence » pour les ions minéraux, double sens qu'aucun sujet n'a perçu, du fait qu'il n'y est fait mention dans aucune de leurs réponses. En effet, le tableau montre que 10 termes différents sont employés par les sujets pour exprimer leur compréhension personnelle du mot « Importance », et certains sujets ont utilisé 2 termes différents. Ces termes ont été regroupés en catégories de synonymes dont les effectifs correspondent respectivement et successivement au terme présenté. Ainsi, l'effectif 21 correspond au terme « Nécessité », l'effectif 6 à « Besoin », et l'effectif 4 à « Indispensable », et il est difficile de dire si les 3 termes utilisés se rapportent à l'eau ou aux ions minéraux du fait de l'existence des 2 termes dans le titre, et cette catégorie de synonymes est utilisée par 31 sujets, soit 63% du groupe, alors que, comme nous l'avons dit plus haut, ni le rôle de l'eau dans cette situation ni sa nécessité ne sont envisagés dans les textes du manuel qui se trouvent sous ce titre. Ces résultats montrent donc que cette interprétation a été effectuée grâce au recours à des connaissances personnelles antérieures des sujets et indiquent également leur difficulté à percevoir et à comprendre la variation des facteurs.
Dix sujets soit 20% envisagent le terme « Importance » comme synonyme de « Influence », « Effet », « Rôle », « Dépendance de », montrant qu'ils ont vraisemblablement perçu la variation d'un facteur, qui est ici la présence des ions minéraux, entre les 2 conditions de l'expérience. Ils utiliseraient donc ce terme pour les ions minéraux, alors que 6 autres le comprennent comme « Utilité », etc. La diversité des interprétations de ce terme indique une approche subjective de la situation et une incompréhension du sens précis de ce terme ainsi que la difficulté à envisager ses 2 significations possibles dans la situation considérée et à faire le choix pertinent de chacune d'elles pour l'associer à chacun des facteurs.
Au total, les résultats du tableau sont difficiles à interpréter. On peut cependant dire que l'effectif le plus élevé correspond à la première catégorie qui indique que les sujets ont vraisemblablement perçu le rôle de l'eau, comme étant indispensable à la vie de la plante, information commune qui provient de la vie quotidienne, alors que l'aspect de causalité ainsi que les termes qui lui sont relatifs (influence de, effet de, etc.) sont nettement moins élevés.

* « Importance de la lumière et de la chlorophylle » = **Influence** de la lumière et de la chlorophylle

Catégories	Influence Rôle Effet	Nécessité Besoin Indispensable	Intérêt	La synthèse But Spécificité	S.R.	Total
Effectifs	21 + 9+ 2	8 + 1+ 1	2	1+1+1	2	49
Total	32	10	2	3	2	49
%	65%	31%			4%	100%

Tableau 5- Distribution des significations du terme « Importance » dans la 2ème situation.

Dans cette situation où le mot « Importance » signifie « Rôle » ou « Effet » ou « Influence », le tableau montre que ce sens est compris de manière exacte par 32 sujets soit 65% alors que 15 sujets soit 31% le comprennent de manière erronée utilisant 7 termes différents en remplacement du terme « Influence » ou de ses synonymes pour les 2 facteurs (lumière et chlorophylle), et que 2 sujets soit 4% s'abstiennent de répondre. Il apparaît que dans cette situation, l'énoncé ait présenté moins de difficulté pour les sujets.

* « Importance de la production « à la chaîne » des végétaux » = **Intérêt** de la production « à la chaîne » des végétaux

Catégories	Intérêt Avantage Bénéfice Utilité Relation avec	Rôle Effet Influence	But Amélioration Prolifération Augmentation Diversité	Nécessité	Méthode Mode Possibilités Efficacité	S.R	Total
Effectifs	12 + 9 +2+ 1+1	4 + 4+3	1 +1 +1+ 1 + 1	2	1+1+1+1	2	49
Total	25	11	5	2	4	2	49
%	51%	45%				4%	100

Tableau 6- Distribution des significations du terme « Importance » dans la 3ème situation.

Un résultat frappant de l'analyse des réponses des sujets pour la 3ème situation consiste dans le fait que 18 termes différents sont employés par les 49 sujets pour exprimer leur compréhension personnelle du mot « Importance » dans cette situation qui paraît la plus difficile pour eux, vraisemblablement en raison de l'usage de l'expression « à la chaîne », et certains sujets ont proposé 2 termes différents dans leur réponse. Un seul sujet a utilisé l'expression : « Relation avec l'économie ». Si la catégorie qui correspond à une compréhension exacte du mot « Importance » dans cette situation, se distribuant entre 5 synonymes, groupe 25 sujets soit 51% de l'effectif, il n'en reste pas moins que 24 autres sujets (parmi lesquels les 2 S.R.) ont une compréhension erronée du terme, jugeant qu'il s'agit d'une relation de causalité ou proposant d'autres termes imprécis et divers, trahissant une interprétation subjective de la situation ou encore une incompréhension totale. Tous ces résultats appuient notre hypothèse que la compréhension du mot de manière exacte n'est pas réalisée par l'ensemble des enseignants examinés.

Un autre résultat frappant de cette recherche est que, comme conséquence de l'utilisation du terme « Importance » dans des contextes différents et avec des significations différentes dans le manuel scolaire, les enseignants adoptent la même stratégie et utilisent un même terme comme synonyme du mot « Importance » dans les 3 cas envisagés. En effet, plusieurs parmi eux ont considéré que dans les 3 cas, le terme « Importance » avait le sens d'« Influence », et d'autres ont utilisé le même terme de « Rôle » dans les 3 cas, sans s'interroger sur la pertinence du terme utilisé, dans la situation considérée.

2- Compréhension du mot « Importance » par les apprenants

En vue de savoir comment les apprenants comprennent ce mot, le même test que celui qui a été employé avec les enseignants a été utilisé. De plus, il leur a été demandé de définir le mot « Importance ». Les résultats sont les suivants :
* Compréhension du terme « Importance »
Dans cette situation, on note des cas très divers. Ainsi, certains sujets disent ne pas savoir quel terme utiliser et ne donnent aucune réponse ; d'autres considèrent que ce mot est « irremplaçable » (nothing can replace the word « Importance ») ; d'autres sujets encore en donnent la traduction en langue arabe (أهمية) et d'autres enfin traduisent des mots de la langue arabe pour exprimer leur compréhension. Ainsi, dans la première situation, un sujet fait une traduction littérale des mots de la langue arabe et utilise le mot « La volonté », ce qu'on peut comprendre comme « elle veut » traduit de l'arabe et qui signifie « elle a besoin ». Cependant, certains sujets en donnent une signification acceptable comme de dire « Rôle », « Effet », « Influence », « Nécessité ». Enfin, et réciproquement, si on leur demande de remplacer, dans un énoncé, le mot « Influence » par exemple, certains proposent de le remplacer par « Importance ». Au total, du fait que ces élèves ignorent, presque totalement, la langue française et du fait même de l'usage d'un terme polysémique, les résultats sont tout à fait négatifs.

* Définition du mot « Importance »

Quant à la définition donnée par les apprenants, les résultats sont également très divers : ainsi, certains sujets ne donnent pas de définition, vraisemblablement parce qu'ils sont incapables d'en fournir une. D'autres perçoivent la polysémie du mot lorsqu'ils écrivent : « L'importance de la chose, c'est un mot de beaucoup de définitions : nécessité, nécessaire, besoin, indispensable » ; « L'importance c'est le mot qui indique à plusieurs choses comme : le besoin, l'intérêt, la nécessité, dans tous les domaines : social, familial, année scolaire ». Certains sujets lui donnent son sens du langage courant : « c'est la valeur d'une chose par rapport à une autre » ou des synonymes : « condition principale » ; « c'est le mot pour préférer une chose à une autre » ; « quelque chose qu'on ne peut pas l'éliminer » ; « Ce mot représente quelque chose de grand, ou quelque chose qu'on a besoin, et qu'on peut pas laisser » ; « le rôle que joue quelque chose » ; « donner de la valeur ».
En définitive, les élèves eux-mêmes se rendent compte que le mot « Importance » a un sens vague et peut prendre une signification différente selon le contexte.

3- Les conséquences épistémologiques
Comme nous l'avons mentionné dans l'analyse de l'énoncé de référence, et lors de la comparaison des 2 types d'énoncés, le mot « Importance », en éliminant les mises en relation, écarte le principe de causalité et retentit à la fois sur l'acquisition des concepts scientifiques et sur la formation

scientifique expérimentale des apprenants. Il est de même indispensable de signaler que ce type de termes que l'on peut considérer comme une présentation axiomatique de l'énoncé scientifique conduit à la dogmatisation du savoir (Rumelhard, 1986 ; Astolfi et al., 1997) ce qui veut dire qu'en l'absence de la compréhension des énoncés, les sujets sont amenés à les mémoriser comme des dogmes, ce que dénoncent les didacticiens et les pédagogies non traditionnelles. En définitive le mot « Importance » est source d'incompréhension, de dogmatisation du savoir et, à sa manière un « obstacle verbal » à la connaissance et à la formation de l'esprit scientifique.

Conclusion

La recherche a fourni des résultats qui montrent que les termes polysémiques, par leur imprécision, affectent la compréhension des énoncés, et bloquent le développement de la pensée causale chez les sujets ainsi que leurs activités mentales en particulier les capacités de mise en relation qui perdent, de ce fait, l'opportunité de s'appliquer aux éléments du réel. Elle montre également que l'usage du terme « Importance » affecte l'acquisition des connaissances conceptuelles et expérimentales. En définitive, l'utilisation du mot « Importance » dans les manuels est une solution de facilité attirante pour certains enseignants qui adoptent la même stratégie d'utilisation d'un seul et même terme en remplacement de « Importance » dans les mêmes contextes. Au total, il est possible de dire que l'utilisation de ce mot dans un manuel de sciences du niveau secondaire, comme de tout autre mot ayant plusieurs sens, est un « non-sens ». Ces résultats appuient l'hypothèse qui opte pour l'utilisation des termes scientifiques dans les énoncés des manuels, et suggère qu'une attention particulière soit portée au vocabulaire aussi bien dans les manuels que dans le discours de la classe.

Implications pour les rédacteurs de manuels, pour les enseignants, et pour l'évaluation

*Pour les rédacteurs de manuels

Il importe pour les rédacteurs de manuels, non seulement d'éviter l'emploi du mot « Importance » dans les manuels de sciences, mais de le rayer totalement du vocabulaire de ces manuels. Une analyse des textes en vue de déceler les facteurs en jeu devrait être effectuée ce qui permettrait de présenter le titre sous forme de relation en utilisant de préférence, lorsque la situation s'y prête, les mots « Influence », « Rôle » ou « Effet » d'un facteur sur un autre facteur. Il est également recommandé de prendre soin d'effectuer l'analyse de l'objet lui-même ou du phénomène, comme cela s'est présenté pour la photosynthèse, pour y déceler le facteur étudié dans l'expérience présentée. Notre position, basée sur les résultats de notre recherche et sur ceux des recherches antérieures est, non pas de supprimer les termes difficiles et en particulier les connecteurs de causalité, mais, au contraire, de faire l'effort d'en diffuser l'emploi en vue de la formation scientifique des apprenants.

* Pour les enseignants

Une solution réside dans le fait de remplacer le mot « Importance » par le terme scientifique précis qui devrait être utilisé dans une pareille situation. Cela nécessite que les enseignants possèdent la capacité à analyser le document ou bien l'image présentée dans le manuel et à y repérer le facteur dont on veut connaître l'effet. Toute variation d'un facteur entre les 2 conditions de l'expérience indique qu'il s'agit du facteur dont on veut connaître l'effet. De même, l'analyse des images présentées et la comparaison avec le connu peuvent aider à déceler la signification du terme. La consultation d'autres ouvrages ou manuels de référence en vue de comprendre clairement ce qui est entendu par ce mot dans la situation considérée peut constituer une solution. Enfin, la solution proposée par Sutton (1992) qui consiste à formuler une même phrase dans différents niveaux de vocabulaire peut également aider à dépasser l'ambiguïté des termes polysémiques.

* Pour l'évaluation

Les résultats ayant montré que la majorité des élèves ne comprennent pas la signification des énoncés qu'ils étudient, il serait intéressant d'utiliser le type de tests employés dans cette recherche pour une évaluation plus valide des connaissances des apprenants.

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INTERACTIVE SESSIONS

Mathematics

Preparing students of grades 6 and 7 for analysis in geometry

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Abstract

Mathematics is one of the most important subjects that students study at school .One of the most important aims of teaching math is building up analytic members, who have the ability of proving certain points in geometry employing suitable properties and definitions. The main purpose of this presentation is to underscore the importance of providing delicate interrelated analysis that bridges the gap between grades 6 and 7.Also some solutions and ways that can help participants to solve the most difficult problem that students of grade 7 face- which is how to deal with any problem required to prove in geometry- will be presented and discussed. Besides, some prepared activities (table of missing information), questions, and samples of chapters taken from the old curriculum and others from the new one of grades 6 and 7 will be distributed to participants to work on ,solve and then discuss different ideas.
Finally participants present their ideas and discuss the solutions shown on an overhead projector.

Introduction

Mathematics is one of the most important subjects that students study at school .One of the most important aims of teaching math is building up analytic members, who have the ability of proving certain points in geometry employing suitable properties and definitions. The main purpose of this presentation is to underscore the importance of providing delicate interrelated analysis that bridges the gap between grades 6 and 7.
This session addresses mathematics teachers of grades 6 and 7 of Basic Education. The main purpose of the workshop session is to increase the participants awareness of the wide gap the new curricula creates between grades 6 and 7 concerning analysis which is neglected in the book

"Building Up Mathematics", published by the Educational Center for Research and Development (ECRD) for grades 6 and 7.Actually students of grade 7 find difficulties in learning geometry . The most difficult problem that the 7^{th} graders face at the beginning of the scholastic year: it is how to prove certain points in geometry. Students suddenly have to change from those who memorize things to ones who analyze. Some of the main math objectives concentrating on analyzing at this level will be presented to participants.

Strategy:

a) Brief introduction :(power point presentation, on LCD projector, 10 slides).
b) Distributing two lists of questions to the participants to answer and then to discuss them.
c) Arrange the participants into small groups (5 participants in each group) and distribute to them

chapters from the old and the new curriculum to focus on some points (with a power point presentation, (LCD projector, 10 slides).

d) Distributing a table to complete it, then making a discussion about it.

e) Presenting and discuss the solution of the problem (power point presentation, 5 slides)

g) Distributing the evaluation sheet to complete it.

Description of session:

a) Participants will take on the role of the learner by answering certain prepared questions (student questionnaire) then making a discussion with the presenter.

b) Participants will take on the role of the teacher by answering other prepared questions (teacher questionnaire) then making a discussion with the presenter.

c) Making a discussion about chapter “36” (Remarkable Straight Lines in a triangle) and chapter “37”(Isosceles triangle pages 166,167,168) from “The National Text Book Project”, Mathematics, second year intermediate, published by the Educational Center for Research and Development (ECRD), old curriculum, and chapter”12” (Triangles pages 69,73 ,74) from “Building up

d) Mathematics” grade 6 (new curriculum) .

Based on the mentioned chapters a table to be completed by writing the information they believe it is missing in the new curriculum of grades 6 and 7 to allow them to understand the big problem.

e) The workshop session will end by presenting and discussing some solutions.

Conclusion:

The workshop should be well organized, with clear objectives and offer new information and skills with possibilities of application. Sufficient time should be given to discussion and sharing of ideas. The physical setting should be appropriate. The presenter should be knowledgeable and provided enough activities on the topic.

References:

1) “The National Text Book Project”, Mathematics, second year intermediate, published by the Educational Center for Research and Development (ECRD), old curriculum .

2) “Building Up Mathematics”, published by the Educational Center for Research and Development (ECRD) for grades 6 and 7.

STUDENT QUESTIONAIRE

1) **Complete the following table**:

Element	What information is always implied in?
Height	
Median	
Bisector of an angle	
Perpendicular bisector of a segment	
Isosceles triangle	
Right triangle	
Equilateral triangle	

Teacher Questionaire

1) Do you agree with me that at the beginning of grade 7 students don't know how to analyze and get benefit from what they studied in grade 6, they feel afraid of the word "prove"?

____
____
____
____

Do you think that a lesson containing analytic problems is missing?
If yes, where should we add this lesson? To the curriculum of grade 6 or to the curriculum of grade 7.

____
____
____
____

If you agree

2) Whose role is it to prepare students for analysis?
The math teacher in grade 6 or that in grade 7.

____
____
____
____

3) Does the math teacher in grade 6 have to focus his explanation only on definitions and properties or on many analytic problems to move with students step by step?

____
____
____
____

Information you believe that it should be added to the curriculum of:	
Grade 6	Grade 7

166

37 Isosceles triangle

1 | DEFINITIONS

Definition: An isosceles triangle is a triangle which has two congruent sides.

In figure (1) ABC is an isosceles triangle: $|AB| = |AC|$.

The side [BC] is called the base of the triangle. The height relative to the is called the height of the triangle.

Construct an isosceles triangle whose base is 5cm in length and whose side is 6cm in length.

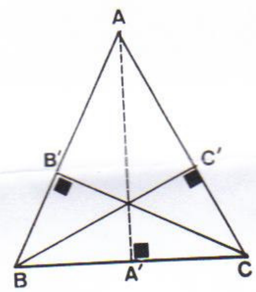


Fig. 1

If a triangle ABC is isosceles, ($|AB| = |AC|$), whose height is AA′. [AB] and [AC] being two congruent obliques with respect to [BC]. Therefore their projections [A′B] and [A′C] are congruent Fig. (1).

So AA′ is an axis of symmetry of the triangle ABC.

Then $\widehat{ABC} = \widehat{ACB}$.

Propositions: In an isosceles triangle the angular sectors adjacent to the base are congruent.

Conversely.

If in a triangle, two angular sectors are congruent.

Let $\widehat{ABC} = \widehat{ACB}$ and x′x the perpendicular bisector of [BC] (figure 2). By folding about x′x, B and C being symmetrical, they will be coïncident, and BA coïncides with CA because the angular sectors $[\widehat{BC, BA}]$ and $[\widehat{CB, CA}]$ are congruent. Thus $|AB| = |AC|$.

Then the triangle ABC is isosceles.

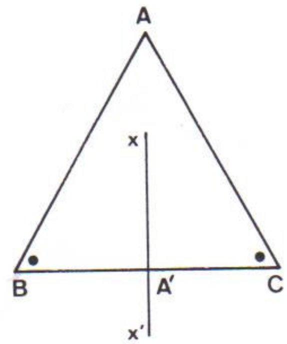


Fig. 2

Proposition: A triangle which has two equal angles is isosceles.

— *An isosceles triangle has a base 5cm in length such that the angular sector adjacent to this base measures 70 . Draw this triangle.*

2 | PROPERTY OF THE HEIGHT IN AN ISOSCELES TRIANGLE

In figure (3) ABC is an isosceles triangle: $|AB| = |AC|$.

— Prove that AH is an axis of symmetry of ABC (by the same way as in the first paragraph).

— Deduce that [AH is the bisector of $[\widehat{AB, AC}]$. AH is at the same time the median and the perpendicular bisector.

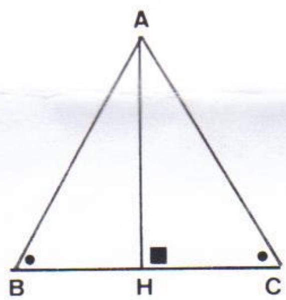


Fig. 3

Proposition: In an isosceles triangle the height relative to the base is at the same time the bisector, the median and the perpendicular bisector of this triangle.

Triangles

12

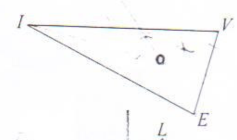
Objectives

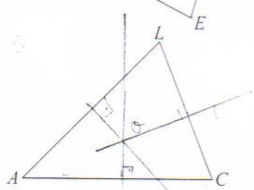
At the end of this chapter, I will be able to:

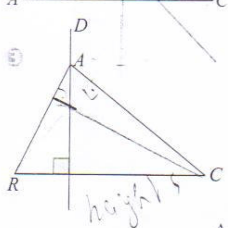
- define and construct bisectors, heights, medians and perpendicular bisectors in a triangle, and know that they are concurrent;
- determine the center of the circle passing thru 3 non-collinear points;
- identify particular triangles;
- know that the sum of angles in a triangle is equal to 180°.

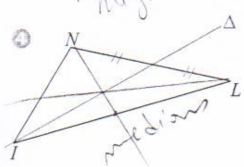
Activities

Activity 1









a) Reproduce triangle *VIE* shown in figure 1, and draw the bisectors of the three angle $\widehat{V}$, $\widehat{I}$ and $\widehat{E}$.
What can you say about these 3 bisectors?

b) • Reproduce triangle *LAC* shown on figure 2, and draw *d* and *d'*, the perpendicular bisectors of sides [*AC*] and [*LC*] respectively. Let *O* be their point of intersection.

• Draw the circle of center *O* and radius *OL*.
Does this circle pass through the other two vertices of triangle *LAC*?

• Draw the perpendicular bisector of [*AL*]. What do you notice?

c) • Observe figures 3 and 4 then complete:

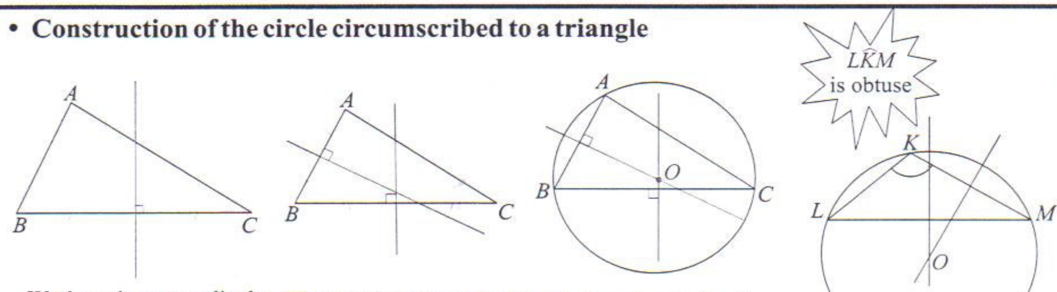
- In triangle *ARC*, we drew the straight line *D* possing through the vertex ..A... and that is ..⊥........ to the side [*RC*].
- In triangle *NIL*, we drew the line Δ passing through the vertex ...N... and the ..midpoint.. of side [*NL*].

• Reproduce the triangles in figures 3 and 4 then draw:

- in triangle *ARC*, the lines *D'* and *D''* having same characteristics as D but passing through *R* and *C* respectively.
- In triangle *NIL*, the lines Δ' and Δ'' having same characteristics as Δ but passing through *I* and *L* respectively.

• What can you say about the three drawn lines in each of the two triangles? concurrent

- **Construction of the circle circumscribed to a triangle**



We draw the perpendicular bisector of one side

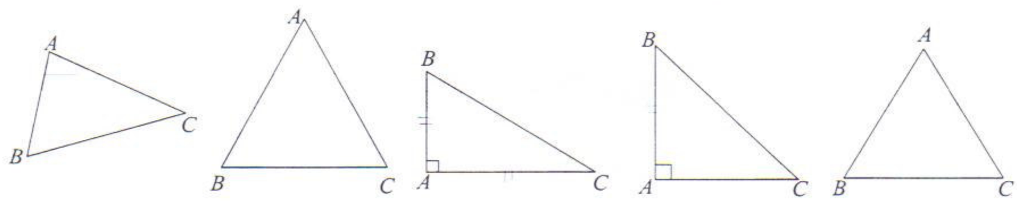
We draw the perpendicular bisector of another

We draw the circle of center O and radius OA

I am free of my sides but not of my angles

- **Angles in a triangle**

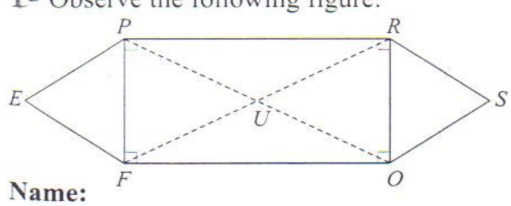
Any triangle	Isosceles triangle	Right triangle	Right isosceles triangle	Equilateral triangle



$\widehat{A}+\widehat{B}+\widehat{C}=180°$	$\widehat{B}=\widehat{C}$ $\widehat{A}+(2\times\widehat{B})=180°$	$\widehat{A}=90°$ $\widehat{B}+\widehat{C}=90°$	$\widehat{A}=90°$ $\widehat{B}=\widehat{C}=\frac{90°}{2}=45°$	$\widehat{A}=\widehat{B}=\widehat{C}=\frac{180°}{3}=60°$

Exercises

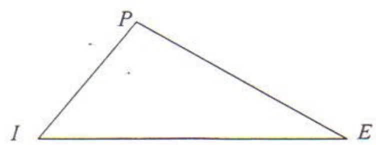
1- Observe the following figure:



Name:

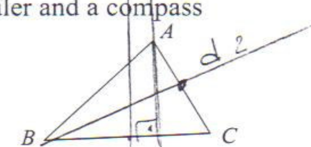
- The right triangles;
- The isosceles triangles;
- The equilateral triangles;
- A non-particular triangle.

2- Reproduce triangle PIE given below then draw:



- in red, the height issued from E;
- in green, the bisector of $\widehat{PIE}$;
- in blue, the median issued from P;
- in black, the perpendicular bisector of $[PI]$.

3- Reproduce using a ruler and a compass the triangle ABC.

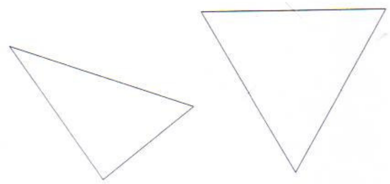


a) Draw:

- the line d_1, the height issued from A;
- the line d_2, the median relative to side $[AC]$;
- the line d_3, the perpendicular bisector of $[BC]$.

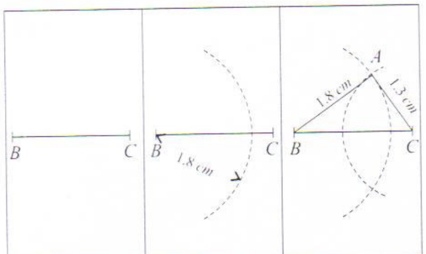
b) What can you tell about d_1 and d_3? Why? d1 // d 3

4- Reproduce, using your ruler and compass the triangles given below, then construct the circles circumscribed to these triangles.



5- Construction of triangles of known side lengths.

a) **Example:** Construct a triangle *ABC* such that :
$AB = 1.8cm$; $AC = 1.3cm$ and $BC = 2.2cm$.



- We draw a segment [*BC*] of length 2.2 *cm*	- We draw an arc of center *B* and radius 1.8 *cm*.	- We draw an arc of center *C* and radius 1.3 *cm*. - *A* is one of the point of intersection of the 2 areas.

b) **Construct the triangles:**

- *RIZ* such that
  $RI = 8cm$; $ZR = 5cm$; $ZI = 7cm$.
- *LAC* such that
  $LC = 7.5cm$; $AL = 2cm$; $AC = 6.5cm$.
- *ELF* such that
  $EL = 4.5cm$; $LF = 7cm$; $EF = 3.5cm$.

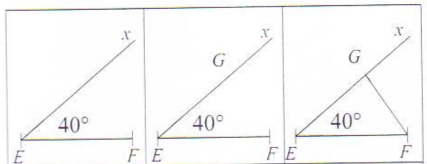
6- Construct an isosceles triangle *LOI* of vertex *O* such that LO=4.3*cm* and OI=6.5*cm*. What is the base of this triangle?

7- Construct an equilateral triangle *PLI* of 162 *mm* of perimeter.

8- Construct a triangle *REC*, right at *E*, such that $RE = 3.5$ *cm* and $EC = 65$ *mm*.

9- Construction of triangles of 2 known side measures and one angle.

a) **Example:** Construct a triangle *EFG* such that: $EF = 2cm$; $EG = 1.7cm$ and $\widehat{FEG} = 40°$.



- We draw a segment *EF* of length 2 *cm*. - We draw a semi-line [*Ex*) such that $\widehat{FEX}$=40°.	- We locate on [*Ex*) the point *G* such that $EG = 1.7cm$.	- We draw the segment *GF*.

b) **Construct the triangles:**

- *ROC* such that RO=6*cm*, OC=4.5*cm* and $\widehat{ROC}$=75°.
- *BAL* such that BA=4.5*cm*, AL=7.5*cm* and $\widehat{BAL}$=45°.
- *VER* such that VE=5*cm*, VR=8*cm* and $\widehat{EVR}$=130°

10- a) Construct a triangle *ABC* such that: $AB = 2.5cm$, $BC = 3cm$ and $CA = 3.5cm$.

b) At the exterior of this triangle, draw:
- the equilateral triangle *ABE*;
- the isosceles triangle of vertex *C* and such that $\widehat{BCF} = 50°$
- the triangle *ACG*, right at *A*, and such that $AG = 3.5cm$.

11- Construct the isosceles triangle *ISO* of vertex *I* and such that SO=6*cm* and IS=9*cm*.

a) **Draw:**
- the 3 heights that intersect at *H*.
- the 3 medians that intersect at *M*.
- *O* the center of the circle circumscribed to that triangle.

b) What do you notice regarding the points *H*, *M*, *N* and *O*?

Science

Designing experiments in science

Viviane Khoury Saab & Suheir Sleiman-American Community School

Abstract

Hands on activities and experimental work are a crucial part in the teaching of sciences. It helps students understand better the concepts they are learning and helps develop their manipulative skills. This workshop focuses on the step by step process involved in the experimental design. Participants will be taking the role of students where they will be given different research questions that integrate physics and biology and involved in activities that include writing a hypothesis and a procedure then performing experiments and discussing the results.

Introduction

Performing experiments is an important tool to enhance the understanding if the theories introduced in the classroom. Experiments could be carried in different ways: one of them is when a lab sheet with a detailed procedure is given to be followed and another alternative is to ask the students to choose a certain variable and design their own experiment based on it. Some teachers find it time consuming for different reasons. However, when the students are asked to design their own procedure for a certain experiment and perform it, they find it more "fun" and get actively involved in the process. Whether the results comply with their hypothesis or not the students get curious to learn more about that particular topic. The equipment needed do not have to be complex. Basic lab equipment can be sufficient.

Strategy

The following guidelines were introduced to the participants during the session.

Guidelines for designing experiments

1- Design:

a) **Objective/ research statement:**
A research statement that is very clear and specific is written.

b) **Explained hypothesis/ prediction:**
The prediction of the outcome is stated and explained. The result is described quantitatively where applicable, for example if x doubles y is also doubled with explanation.
The dependent, independent and controlled variables are listed.

c) **Materials:**
All materials and equipment needed with quantities and sizes where applicable, are listed.

d) **Procedure:**
Instructions to describe how the experiment will be performed are written clearly in numbered steps.
While designing your experiment, the following points should be kept in mind:
-The procedure collects sufficient data; that is, the data range and the amount are sufficient for processing and evaluating.
- Passive form is used.
- Labeled diagram for your set up is included.

2- Data collection and processing:
Data could be either quantitative or qualitative. Quantitative data should be clearly organized in tables with proper titles, units and uncertainties where applicable.
Data processing includes any calculations performed and graphs that are clearly labeled and presented.

3- Conclusion and evaluation:
A detailed explanation and interpretation of the processed data is written to be able to reach a conclusion. Limitations and errors should be clearly identified and possible suggestions for improvement should be mentioned. References should be cited.

Steps 1 to 4 are performed by the students individually, either in class or at home. The designs are then collected and checked by the teacher. The performance of the experiment can be either performed individually or in groups depending on the commonality of the factors chosen and the availability of the equipment.

Grading

The complete lab report submitted by the student can be assessed using a rubric that the teacher develops or a rubric adopted from a scientific source.

It is preferable that the rubric be shared with the students before they design and carry out the experiment.

Description of session

Participants were divided into mixed groups of biology and physics teachers. Each group was given on of the topics from the following list and asked to write a design based on the guidelines shared. Then they performed their experiments at the different stations prepared earlier. The participants showed a lot of enthusiasm and interest in the activities.

List of experiments that participants will use for planning

1- Design an experiment to investigate the power/pulse rate/ blood pressure when climbing stairs.

2- Design an experiment to investigate the evaporation of water.

Physics: Factors affecting the rate of evaporation.
Biology: comparing the change in water temperature versus alcohol or any other liquid.

3- Design an experiment to compare your reaction time with that of a friend.
Biology: you can even expand to compare two different reflexes of yours (eyes open / eyes closed).
Physics: application to free fall.

4- Design an experiment to test the effect of concentration of sugar in solution on:
Biology: plant cells.
Physics: the index of refraction of light.

Conclusion

Suggestions for those interested in applying the addressed strategy:

- Try it with one class first.
- Share the guidelines with the students as well as the available equipment in the school.
- Start with a design exercise (not graded) and give written feedback
- If you need any further clarifications, you can contact the presenters at their email address.

Following is a list of some possible design labs for biology and physics.

Suggested list of experiments to design in biology

Biological Processes	**Suggested variables**
Enzyme controlled reaction	temperature, PH, substrate concentration, enzyme concentration…
Photosynthesis	Light intensity, wavelength of light, temperature, concentration of carbon dioxide, plant type…
Respiration	Temperature, Concentration of substrate, example glucose, amount of respiring tissue example amount of yeast , PH of medium
Transpiration	Relative humidity and pressure of the atmosphere, velocity of air currents, temperature, number and surface area of

	leaves, thickness of waxy cuticle….
Osmosis	Solute concentration of cell contents relative to surrounding external medium, temperature and membrane permeability….
Diffusion	Solute concentration, temperature, particle size…
Blood pressure/ pulse rate	Body position, exercise, smoking, diet, age…..
Human reaction time	Closed eyes, open eyes, distractions, no distractions…
Skin sensitivity	Different materials, different parts of the body……

Suggested list of experiments to design in physics

Mechanics

1- Predict the landing of a ball projected horizontally from the surface of a table.
2- Investigate one/two factors affecting the range of a projectile.
3- Investigate one/two factors affecting the motion of an object falling under the action of air resistance. (Parachute)
4- Investigate one/two factors affecting the motion of a cart that is launched on a horizontal surface after being stretched by rubber bands.
5- Investigate factors affecting the elongation of a spring.
6- Archimedes' Principle: Investigate factors affecting the volume of displaced water. (Volume of object, mass, density, shape).

Thermal Physics

1- Investigate factors affecting heat transfer through white polished and dark colored mugs.
2- Investigate the rate of cooling of tea in different types of containers. (glass, plastic, foam, porcelain…)
3- Investigate the cooling of coffee when milk is added as soon as the coffee is made, or when milk is added after 10 minutes of making it.
4- Investigate factors affecting the rate of evaporation of water.

Waves and optics

1- Investigate one/two factors affecting the period of a simple pendulum.
2- Investigate the characteristics of images formed using a convex lens and find the focal length of the lens.

Electricity and Magnetism

1- Build your own electromagnet and investigate one/two factors affecting its strength.

Practical Use of Analogy In Science

Mrs. Mariam Qubaa' & Mrs. Arabia Bouz-Beirut Modern School, Lebanon

Abstract

Analogy is an important process that serves teaching our students specific scientific concepts. General principles of this process will be discussed through the integration of analogies and scientific concepts taught in Intermediary and Secondary classes.
Participants will have an important role in developing and sharing their own experiences to make the process of teaching science more f

The History of Analogy

Analogy has been studied and discussed since classical antiquity by philosophers, lawyers and scientists. Greek biological theories and political thoughts were colored by the use of images drawn from one another. For example they compared the state with a living organism. Aristotle, too, compares the living creature with a well-governed city, describing the heart as central seat of authority in the body. Anaximens compared lighting with the flash made an oar in water. The last few decades have shown a renewed interest in analogy, most notable in cognitive science.

Introduction

In the process of teaching we use textbooks, chalkboard, debates, demonstrations, films, software and lab work.

BUT

Have you ever tried to make use of analogies?
What is analogy?

The world analogy means likeness, correspondence similarities and resemblance.

Analogy is a comparison in which different items are compared point by point, usually with the idea of explaining something unknown by something known. Analogies are offered to provide insights; and can be very instructive. More over Analogy is both the cognitive process of transferring information from a particular subject and linguistic expression corresponding to such process.

When to use Analogy?

The analogy should be used during the explanations, the act or process in which processes, or skills are made plain, comprehensible and clear. Thus providing students the opportunity of understanding scientific concepts, and teacher to demonstrate conceptual understanding, while introducing scientific concepts.

Analogs are often used in theoretical and applied sciences in the form of models or simulations which can be considered as strong analogies. Other analogies assist in understanding and describing functional behaviors of similar systems.

For instance, certain analogies are commonly used to compare
(1) In electronics textbooks electrical circuits to hydraulics.
(2) In chemistry an atom to solar system.
(3) In biology a chromosome to clothespin.

Are analogies always applicable?

Although analogies are helpful in pointing out relationships that may not at first be visible, they have their limitations.

How analogies make the process of learning easier?

Analogies make the process of learning easier by:
(1) Directing students' learning by clarifying concepts and ideas.
(2) Facilitating and monitoring interaction students and instructional situations.
(3) Providing students with basic understanding of ideas and facts.

Closure: Be sure that students understand the analog, how and when to use it.

Activity

Scientific Concept	Analog's Number
Humoral Specific immune Response	
Cell-Mediated Specific Immune Response	
Mechanical digestion of food	
Storage of glucose in the form of glycogen	
Specificity of enzymes	
Absorption of nutrients	
Diffusion process	
Nerve Vs nerve fiber	
Speed of nerve influx through myelinated and non- myelinated nerve fiber	
Active Vs passive transport of ions	
Speed of nerve and Diameter of a nerve fiber	
Mixed nerves efferent and efferent messages	
Pd does not vary with the intensity of stimulus	
Blood groups	
Interphase	
Chromosome	
Heart	
Model of Atom	
Electric Circuit	
Differences in proteins	

Comments

The expected number of attendees was 20 but actually more than 30 teachers attended the session (as you can refer to your recorded notes). For this reason each 2 or 3 teachers shared one copy of the 20 distributed presentation's summary with an activity sheet including the attached table and a set of hand drawing analogies.

During the activity attendees were asked to match each analogy with its appropriate specific scientific concept. It was an interesting session where all attendees participated actively. Some of them took my phone number and e-mail to be in contact in case they needed any help in using an analogy for a specific scientific concept.

Mathematics and Science

Integrating Information Technology with Science & Math at the middle school level

Charbel Bitar – City International School

Abstract

The primary purpose of this session is to demonstrate how to integrate technological skills with science and math content. The participants will take on the role of learners by actually working on six activities that reveal how teachers could make use of information technology (I.T.) while teaching. The participants will use information from the internet in addition to information provided by the presenter on a CD in order to complete the assigned activities. The participants will engage in Web Quest about human body machine, Guided Scavenger Hunt about the digestive system, Spreadsheet about weights on planets of the solar system, Electronic presentation about different types of polygons with electronic presentation guidelines, Web design about various type of solar eclipse with web sites evaluation rubrics, and photo editing about electric field patterns of different configurations of charges.

Introduction

The advances in science and math have made significant use of information technology (I.T.). As a result, integrating technological skills with science and math content is essential to prepare well equipped students for the 21st century. The following session selects certain topics in math and science to demonstrate how students would integrate technological skills to learn scientific and mathematical content. The 1st issue raised in the session is how to build the main six blocks of a Web Quest; the 2nd issue is how to organize a guided scavenger hunt; the 3rd issue is how to build a table and pie charts in a spreadsheet and how to convert weights from Kg to Newton using an online calculator; the 4th issue is how to run an electronic presentation by following guidelines; the 5th issue is how to build a photo gallery web site and how to evaluate sites; the 6th issue is drawing electric fields using rendering effect on photo editing program.

Strategy

During the session, many key aspects of the teaching/coordinating/administrating strategies were introduced. First, we are facilitators and not just educators or tutors. Second, the I.T. teacher must organize with other subject coordinators or teachers in order to make the integration effective. Third, list the activity objectives, rubrics, programs, skills, Internet resources, and the learning areas concerned. Fourth, if the Internet connection is slow or unavailable, we must have an offline copy of the electronic resources.

Description of session

The first activity in this session is a Web Quest about Human body machine in which the participants recognize and build the six key blocks of a Web Quest which are introduction, task, process, resources, evaluation, and conclusion. At the end of this activity, the participants will have a list of online Web Quest samples. The second activity is about Guided Scavenger Hunt in which the participants use technological skills in order to organize, present, and answer information on the digestive system. The third activity is about Spreadsheet concerning weights on other planets where participant compare their weights on different planets of the solar system by constructing tables, graphs, pie charts, using online calculator to convert between units and to estimate the acceleration gravity, drawing out conclusions, and finally playing online educational space games including word search, crossword puzzles, cryptogram, and more. The fourth activity regarding Electronic presentation on Polygons whereby participants gather mathematical information about different types of polygons and present it in a specific PowerPoint format and guidelines. The fifth activity is about Web design that requires participants to construct a website which exhibits a photo gallery about various types of solar eclipse including information about the specificities of about each type and publish it on a free internet hosting service TRIPOD where participants create account and then start uploading the web folder on their local computer. The sixth activity on Photo editing in which participants draw and explain electric field patterns for different configurations of charges. The task is accomplished through artistic renderings made in Adobe Photoshop.

References

Activity & Additional material	**Online Resources**
Human body Web Quest	http://questgarden.com/46/94/7/070226180933/t-index.htm
Search for Web Quests	http://webquest.org/search/index.php
How the body works Scavenger Hunt	http://www.kidshealth.org/kid/closet/activities
Scavenger Hunt Examples	http://www.ccsdedtech.com/cc/projects/scavengerhunt
Weights on planets Spreadsheet	http://www.metric-conversions.org/weight
Gravity on other planets	http://van.physics.uiuc.edu/qa/listing.php
Educational Space games	http://www.tsgc.utexas.edu/space_games/
Polygons presentation	http://mathworld.wolfram.com
Free Publishing web sites	http://www.tripod.com

Children's Stories Cross Transdisciplinary Themes and Subject Domains

Kathleen Battah & Nisreen Ibrahim-Well Spring Learning Community

Abstract:

Inquiry has equal relevance in language arts as in science and math. However planning and implementing this pedagogical approach, which is based on the learner's prior knowledge, is a process of teacher and subject collaboration within a curriculum framework of questions which are student generated, teacher guided and related to transdisciplinary themes. Participants acting as third graders will generate their own questions, participate in the recording of their inquires, organize information, look for patterns and have the opportunity to expand their thinking and make real life connections to concepts they learn in different subjects. Transdisciplinary concepts drive the inquiry towards a fully integrated and well-balanced curriculum which requires learners to not only reflect but to fully participate in the learning process. Participants will be shown ways to integrate separate subjects and share ideas through collaboration.

Introduction:

The primary purpose of this session is to introduce or augment participants' understanding of integration across transdisciplinary units within an international curriculum context and how the articulation of grade three elementary language arts, science and math builds meaning and refines understanding about the world they live in.

> What is evident in the interdisciplinary, integrated and integrative approach is the conscious effort to provide students with more meaningful learning experiences. All three approaches attempt to connect the student with the abstract world of disciplinary knowledge and the real world of experience (Mathison & Freeman, 1997, p. 12).

Participants will move their current knowledge level of the reading and comprehension process and the importance of children's literature as a way of understanding one's self and others to a newer level of understanding through wondering, questioning, applying and reporting. Based on participants' self-generated provocative inquiries, educator will act only as moderator, while participants seek knowledge, gather information, reflect on collected data and connect the learning experience by active engagement with their environment and the world around them.

The challenge of integration and student based inquiry provides opportunities in all subject domains to synthesize, analyze, manipulate and apply new skills in a real world context and real life situations. Because learning is substantially influenced by personal experience, a familiar children's story was selected to be the connection between learners' prior knowledge and to the creation and connecting of new learning and new applications. Familiar children's stories provide multiple opportunities for teaching language arts, science and mathematics in a relevant and interesting context related through a unit of inquiry. "Teaching children scientific concepts within a familiar story context thus making science 'relevant and conceptually in tune with the child's abilities" (Butzow & Butzow, 1989, p. 3).

After reading, reflecting and writing answers to self generated inquiries about *Jack and the Beanstalk*, third grade students were given the opportunity to plant beans and watch them grow. Based on their observations, the third graders came to realize that beans cannot grow in one day nor can they grow strong enough or tall enough to support a giant (as in the story) thus developing an understanding of the difference between fiction and scientific fact.

> If we want students to be able to reason critically and flexibly with data, these activities should be firmly anchored in the everyday practice of school subject-matter study, not relegated to an isolated mathematics or social sciences unit in data and statistics (Lehrer & Schauble, 2002, p. ix).

Expanding the learning process from a different perspective, besides generating inquiries about *Jack and the Bean Stalk,* (as the third graders were asked to do) workshop participants will be provided with a display of authentic bean data which was originally collected by the third graders as part of their lesson. The actual data has documented their observations and measurements, which show the growth rate of the beans and the amount of water used in the growing process.

> The exploration and re-exploration of concepts leads students towards a sense of the essence of each discipline and an appreciation of ideas which transcend disciplinary barriers. If concepts are approached from a range of perspectives, students can gradually arrive at a deeper understanding (Making it happen in the classroom ISCP Vol.2, 1996, p. 11).

During the latter portion of the workshop, participants will be asked to actually design, organize and model the third graders' data into creative charts or graphs depending on each group's preference. This activity will help participants clarify patterns and make real life conclusions about bean growth. Participants will relate to the third graders who had the chance to practice their skills of measuring length and volume (length of stem growth and volume of water used) along with collecting, recording and organizing scientific and mathematical data.

> Interdisciplinary/integrated/integrative approaches are not simply attempts to combine two or more knowledge cases, but also to do so in ways that are more inquiry oriented, hands-on and connected to the real world (Mathison & Freeman, 1997, p. 14).

Strategy:

Teachers aim at providing opportunities for students to become efficient problem solvers, communicators, thinkers and effective workers and citizens. These opportunities should cross subject domain to transfer to students the idea that inquiry has relevance in language arts as in science and math. Several aspects encompass the teaching strategy introduced to participants during the session. First, an investigation is initiated by students' questions driven by their natural curiosity and observations. At the beginning of any inquiry the teacher promotes higher level thinking and questioning by acknowledging and valuing all students' questions regardless of relevancy. Second, teacher uses open ended questions to push students' questions beyond what they initially asked. Third, students design strategies for testing their ideas and finding answers. Based on their strategy for collecting data to answer their questions, students devise a way to record their observations. Fourth, students study their data, represent it using graphs and look for patterns. Finally, they construct a model of the phenomena they decided to track and come up with conclusions.

Teacher encourages students to extend their investigation in an attempt to test their model and then compare results. According to this teaching strategy, teachers develop opportunities for students to formulate theories and to look for and consider evidence that confirms or disconfirms these ideas.

> The teacher's design tools included asking questions that pushed students' questions farther, establishing norms of argumentation based on evidence, focusing upon displays and inscriptions invented by students, and engaging students in evolving chains of inquiry (Minstrell & Van Zee, 2000, p. xiv)

Description of session:

The session proceeded as follows: a) Participants were asked to sit in groups of fours or fives. (3-4 minutes). b) Educator/moderator distributed one "large post-it" sheet and one black marker to each group. A volunteer from each group acted as secretary-recorder. (5 minutes.) c) Educator/moderator presented to the audience one enlarged color poster of *Jack and the Bean Stalk*. Only the book's colorful picture of Jack, the giant and the bean stalk were represented d) From only viewing the colorful poster, educator/moderator asked each group to discuss and record questions their group would like to "Ask the poster cover if it could talk" or what additional information participants would like to learn from reading *Jack and the Bean Stalk*. (5-10 minutes). e) Group members brainstormed while recorders wrote their group's inquiries (both relevant and irreverent) on large "post-it" wall sheets. f) Participants' questions continued to be solicited until all inquiries had been recorded (10 minutes). g) Groups and educator/moderator reflected together as one group all potential inquiries about *Jack and the Bean Stalk,* while educator/moderator recorded each group's inquiries on the center stage whiteboard for all to see. h) Educator/moderator then proceeded to read the entire story out loud without interruption (5 minutes). i) As educator/moderator finished the story, groups were asked to reflect understanding and record answers to their generated inquires (which were already written on each group's "post-it" sheet). (5 minutes). k) Educator/moderator then invited all groups to focus together and participate in a general discussion. The importance of differentiating fact from fiction based on story plot furthered the discussion by soliciting all possible answers to the initially generated questions. (10 minutes). l) Educator/moderator discussed with participants the question "Can beans grow overnight?" Participants were then asked to use this inquiry to develop a research project where by students could collect data to find answers. Participants then moved on to create graphs, record the third graders' bean data (which was presented in handout form to each group) and to connect patterns. m) Groups further discussed and shared different ways to model student data about the growth rate of beans (For example, charts, graphs…) (10 minutes). n) Participants finally looked for patterns in the data which might explain the relationship between the amount of water used and the beans' growth rate (10 minutes). o) The groups reunited the original workshop group at which time, the entire session was discussed and participants provided written feedback.

Conclusion :

Story selection is crucial for successful inquiry. Short familiar fables or childhood fairytales instead of longer unfamiliar stories are better suited for young inquirers. When students are familiar with a story, they become greater risk takers and their questions become more complex which ultimately leads to more "in depth research". Stories that can be read within 5-10 minutes balance the longer time needed to discuss, develop data collection and representation. The familiar connection of well known stories enables young learners to revisit and reconnect their prior knowledge to newly acquired concepts and new skills.

Students' questions guide all inquires developed in classrooms. Teachers are recommended to instill in their students the skill of asking research questions that require data collection and analysis. Making sense of data is another skill that students are required to learn in an inquiry-based classroom. "Data interpretation begins with the basic acts of constructing, collecting, and recording data, but making sense of raw of data also requires to abstract, structure, and objectify the data collected" (Lehrer & Schauble, 2002, p. 2).

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Appendix A

Appendix B

SMEC November 10, 2007
Workshop Title: Children's Stories Cross Transdisciplinary Themes and Subject Domains
Presenters: Nisreen Ibrahim and Kathleen Battah, Wellspring Learning Community

Jack and the Beanstalk

Based on a Traditional Folk Tale
Retold by Iona Treahy

Based on the philosophy that education begins with curiosity and keeping in mind that young children instinctively ask questions and enjoy "hands on" activities, nursery rhymes, folk and fairy tales help learners to not only nurture an appreciation and love of literature but to develop a rational process of scientific inquiry where learning outcomes can be explored.

Through the use of personal experience, and prior knowledge of familiar story book characters, structured inquiry and engaging transdisciplinary skills (social skills, communication skills, thinking skills, research skills and self-management skills) integrated with social studies, art, and music, help learners to develop "personal, family, ethnic and cultural identities: to make informed and reasoned decisions about their classroom, the school and the world; and to understand themselves in relation to the past, the environment and society" (p. 7 International School's Curriculum Project 1996)

Inquiry can move learner from current level of knowledge and understanding by

- Questioning, wondering
- Experimenting, variables
- Researching, collecting data, reporting, observing
- Clarifying existing ideas
- Making predictions
- Reflection

Learners' questions must be significant Enough (open ended) to move The inquiry

5 W's and H

Who, When, Where, Why, What and How?

Additional reading: http://www.thirteen.org/edonline/concept2class/inquiry
http:// www.inquiry.uiuc.edu/index.php

Appendix C
Data collected on bean's growth rate:
Amount of water is 150 ml.
Plant 1
Day 1: 3 cm
Day 2: 3 cm
Day 3: 4cm
Day 4: 4 cm
Day 5: 5 cm
Day 6: 7 cm
Day 7: 8 cm
Day 8: 9 cm
Day 9: 11cm
Day 10: 14 cm

Amount of water is 250 ml.
Plant 1
Day 1: 3 cm
Day 2: 4 cm
Day 3: 4cm
Day 4: 6 cm
Day 5: 7 cm
Day 6: 8 cm
Day 7: 11 cm
Day 8: 12 cm
Day 9: 15 cm
Day 10: 18 cm