The University of Crete
Department for Primary Education - Laboratory for Science Teaching

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Some examples of Problem Based Learning in Science and Technology teaching in the Department of Primary Education of the University of Crete(*)

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This training seminar is based on published papers – see references inside

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SOCRATES

Assumptions and Issues to be Considered

Critical and Creative thinking:

- Is considered a characteristic of developed humans (of the homo sapiens species)
- Is necessary for the well being and self-development of persons.

➔ **Critical and Creative thinking:**

- Is within the scope of education (especially of compulsory education),
- Teachers should engage actively towards this 'quest',

Contemporary Societies:

- Are globalised and multicultural
- Are dependent on each other
- Share the same earth resources and environmental problems

Consequently,

Contemporary Societies:

- Should learn to coexist,
- Must understand different cultures

in order to coexist (and not divide humanity in 'us- the good ones' and the 'others – the evil ones')

See also Art. 26 of the Universal Declaration of Human Rights

Assumptions and Issues considered (continued)

Contemporary Societies:

- Are based on Science developments (but not always on Science)
- Are dependent on advances in Technology.

Consequently,

STL - Science and Technology Literacy is:

- **Critical** for the welfare,
- **Necessary** to further development of the society,

STL is also a prerequisite for the existence of Democracy.

In Democracy, citizens participate actively on decision making process on their own and not as followers of a charismatic leader or being under the shepherd. As the decisions (regulations, resolutions … the legislation in general) are increasingly dependent on the advances in Science and Technology, active participation in democracy means that citizens should be S&T literate having also the cognitive skills permitting to make decisions on issues they are not experts. Model formation and scientific inquiry enhance such skills and they should constitute integral part of teaching, especially of Science teaching. Within this context, the effective Science and Technology teaching may be considered as a 'democratic right', a right to democracy. Otherwise, Science will be confused with religion as in the 'dark' years of Middle ages or as in some parts of the world now, e.g. see for the U.S.A. in http://www.ncseweb.org/ (visited at 29-Jun-2007) where education in Science, especially the theory of evolution, has been made a legal issue contesting religious dogma).

Assumptions and Issues considered (continued)

Due to the Rapid developments:

Society contribution (in a Vygotski -or Bakhtin- context) is not feasible (if not negative)

and so:

- Science and Technology Literacy has to be achieved through education
- Misconceptions and alternate conceptions are more frequent in S&T

Primary Education emerges as a very important factor because:

- It is the longest component of the compulsory education
- Students' age where character formation and cognitive skill development.
- Misconceptions at this age are difficult to correct later.

Cross thematic - Interdisciplinary teaching approaches seem useful and more effective(?)

Consequently:

- The effective education is emerging as a crucial issue for the future of the society
- The appropriate education of the teachers is a prerequisite

But:

- what constitutes an 'effective education',
- what can be considered as 'appropriate education of the teachers'

A Solving Approach (in a way of Problem Based Learning)

What constitutes an 'effective education', (a crucial issue for the future of the society)

Obviously: effective education = the education that accomplishes its objectives

➔Objectives of education is Learning of many differing types

➔Learning means the development of skills in various domains:

- Cognitive,
- Emotional (affective),
- Psychomotive,

(according to Bloom)

- Social (added by Massialas)

Skills in every of the above domains (areas) are of many differing types:

- starting from very simple (e.g. knowledge in Cognitive skills), and
- developing to more complex (e.g. internalizing values (characterization) in Emotional skills).

Learning of simple skills only:

- may be a prerequisite for more complex skills, but
- it is not sufficient neither acceptable in our contemporary societies.

for any domain.

A Solving Approach (continued)

Cognitive Skills:

according to Robert Gagné, (very popular in instructional design).

- Verbal Information (Labels and Facts, Bodies of Knowledge).
- Intellectual Skills include (Discrimination, Concrete concept, Rule using, Problem solving).
- Cognitive Strategy (by which the learner controls his/her own ways of thinking and learning).

Skills in other domains, according to Robert Gagné, are:
- Motor Skills -bodily movements involving muscular activity-,
- Attitude -an internal state affecting behavior toward some object, person, or event

Cognitive Skills:

according to Benjamin Bloom (1956) (more conventional and known, at least in Europe).

- Knowledge (remember data or information).
- Comprehension (Understand the meaning- repeat in one's own words).
- Application (applying learning into novel situations - practice).
- Analysis (identifying components of objects or concepts – differentiating between facts and inferences).
- Synthesis (reassemble components of objects or concepts towards new coherent forms).
- Evaluation (assessment of the significance of ideas or materials or their components).

Bloom's Revised Taxonomy by Lorin Anderson, a former student of Bloom

Knowledge, Comprehension, Application, Analysis, Synthesis, Evaluation

➔ Remembering, Understanding, Applying, Analyzing, Evaluating, Creating

A Solving Approach (continued)

Objectives of a humanistic education:

……..To come to a more fundamental cleavage; there can be no agreement between those who regard education as a means of instilling certain definite beliefs, and those who think that it should produce the power of independent judgement. Where such issues are relevant, it would be idle to shirk them……..

On Education, Especially in Early Childhood, 1926) by Bertrand Russell (1872-1980), the third Earl Russell, Mathematician (Logic- Russell's paradox), one of the greatest philosophers who wrote many of his works in jail where he was imprisoned because of his political activity.

- **Coverage of all learning domains,** and, in every domain,
- **aiming towards the more complex skills.**

in the Cognitive domain **factual knowledge only is not tolerated.**

Where is the Life we have lost in living?
Where is the wisdom we have lost in knowledge?
Where is the knowledge we have lost in information? The Rock (1934) by T. S. Eliot (1888-1965)

in the era of Informatics we may continue Where is the information we have lost in data?

Objectives of humanistic education (continued):

Coverage of all domains and towards the more complex skills in every domain.

in the Cognitive domain factual knowledge only is not tolerated.

➔ The issue of 'appropriate education' of the teachers emerges as a key factor for an efficient education

Obvious answer:

The education that will enable the teacher to teach efficiently as defined above

Which means what??

- **on the skills required,**
- **on the knowledge necessary (type, level, form,…,),**
- **on human communication abilities,**
- **….**

Appropriate education of the teachers:

It should contain knowledge – skills on:

- subject matter – to what extent?,
- on the didactics – what type?,
- on human communication – stand as paradigm,
- ….

Historically teachers' education between two extremes:

Technical – Vocational type of education

- didactic techniques,
- sample teachings,
- detailed instructions on how to teach the different modules of the existing syllabus.

Academic type of education

- psycho-pedagogy and human communication,
- subject matter (high level?) teaching,
- instructional design.

A Solving Approach (continued)

Appropriate education of the teachers (continued):

Technical – Vocational type of education- a quick low cost immediate solution

- ➢(mostly factual) knowledge,
- ➢addressed to (the hypothetical) average student profile – no anticipation for variations – individual learning patterns,
- ➢rapidly outdated,
- ➢it has to be repeated in case of changes – to the objectives, to the syllabus, … .

Academic type of education – a (theoretically) sound way

- ➢'super scientist' teachers – experts in all subjects of the curriculum?,
- ➢expensive and time consuming,
- ➢the problem of transforming scientific knowledge to school practice still persists.

➔ ➔ ➔ another approach is necessary, combining

- ➢Scientific knowledge with school practice,
- ➢Ability for self training of the teachers,
- ➢Ability to teach a subject without being a professional expert on the subject.

Appropriate education of the teachers (continued): A Solving Approach (continued)

➢Scientific knowledge with school practice,

Teachers' teaching should combine:

- knowledge at an advanced level for the teacher, and,
- 'bare essentials' versions for use at schools,
- combined with school practice.

➢Polymorphic(*) teaching is a way to this.

➢New and Flexible methods of training(**), (***) – effective alternatives should be introduced

(*)Polymorphic Practice (measurements, experiments...) in Science teaching in includes a common psycho-motive activity (doing measurements, experimentation...) which consequently is morphed into different levels depending on the (previous) cognitive attainments and/or the mentality of the students and the objectives of teaching. It resembles multilevel teaching i.e. teaching pursuing more than one sectors and levels of learning. It combines teaching in an advanced level for the teachers themselves, with teaching in a level more accessible for the pupils. See more at: P. G. Michaelides, "Polymorphic Practice in Science", pp 399-405 of the proceedings of the 1st Pan-Hellenic Conference on the Didactics of Science and the introduction of New Technologies in Education, University of Thessaloniki, Thessaloniki May 29-31, 1998 (in Greek).

(**)P. G. Michaelides, An affordable and efficient in-service training scheme for the Science Teacher, "Sixth International Conference on Computer Based Learning in Science 2003 (CBLIS03), University of Cyprus, Nicosia, Cyprus, 5 - 10 July 2003" proceedings pp. 792-799.

(***)P. G. Michaelides, Improvisation – An Alternative and Heretic Approach for Informatics in Schools (in Greek), 3rd Pan-Hellenic Conference with International Participation on the «Technologies of Informatics and Communication in Education", University of Aegean, Rhodes 26-29 September 2002 proceedings pp. .

Appropriate education of the teachers (continued): A Solving Approach (continued)

- Ability for self training of the teachers, and,
- Ability to teach a subject without being a professional expert on the subject.

Best choice seems to be:

- Teachers' teaching based on Problem Based Learning,
- Using constructionistic(*) principles,
- With syllabus including school subjects.
- Incorporating research practices →mentor type tutoring without detailed teaching guidance.

- Examples and applications from everyday life(**) may be used directly in school practice.
- In Science teaching, the use of self-made apparatus(***) is very constructive.

(*)Constructionism was introduced by Seymour Papert, a mathematician born in Pretoria, South Africa, who has done pioneer work on artificial intelligence and has introduced the LOGO© educational environment and, recently, its sequence, the LOGO© MindStorms© as an implementation of Educational Robotics. Constructionism may be considered as an advance of the constructivist theories based on the model that learners actively construct mental models and theories of the world around them. Constructionism holds that this way of learning is enhanced and more efficient when students are actual constructing things in the material world.

(**)P. G. Michaelides, Everyday observations in relation to Natural Sciences, in Learning in Mathematics and Science and Educational Technology, University of Cyprus July 2001, Volume II pp. 281- 300.

(***)P.G.Michaelides and Miltiadis Tsigris, Science Teaching with self-made apparatus, 1st International Conference on Hands-on Science: Teaching and Learning Science in XXI century", Ljubljana 5-8 July 2004, proceedings pp.47-52.

Appropriate education of the teachers (continued): A Solving Approach (continued)

Problem Based Learning,

- **Choice of the Problem**
- **Definition – clarification**
- **Analysis – relation with known situation – previous relevant knowledge**
- **Objectives – exploring areas of possible solutions**
- **Definition of tasks – time scheduling – type of monitoring the progress**
- **Implementation – monitoring of progress**
- **Completion of tasks – assessment – retrospection**

Implemented examples in the Department of Primary Education - The University of Crete

Laboratory of Educational Robotics[1]

Everyday observations in Science Teaching[2]

Science Teaching experiments with self made equipment[3]

(1)

Simos Anagnostakis, P. G. Michaelides, 'Laboratory of Educational Robotics' - An undergraduate course for Primary Education Teacher - Students, proceedings pp. 329-335, HSci 2006 - 3rd International Conference on Hands-on Science, 4th - 9th September, 2006, Braga, Portugal, proceedings published by University of Minho. (http://www.hsci.info/hsci2006/index.html).

Simos Anagnostakis, P. G. Michaelides, 'Results from an undergraduate test teaching course on Robotics to Primary Education Teacher – Students' 4th International Conference on Hands-on Science, 23 – 27 July 2007, Universidade dos Açores, Ponta Delgada, Portugal http://www.hsci.info/hsci2007.html, Proceedings pp. 3-9. (http://www.hsci.info/hsci2007.html).

Anagnostakis S., Margetousaki A., Michaelides P. G., 'The Feasibility of a Laboratory of Educational Robotics in Schools', 4th PanHellenic Conference on the Didactics of Informatcs, University of Patras, Patra, 28 – 30 March 2008 (in Greek). (http://www.ecedu.upatras.gr/didinfo/).

Margetousaki A., Anagnostakis S., Michaelides P. G., 'Informal Learning in the context of Educational Robotics', 4th PanHellenic Conference on the Didactics of Informatcs, University of Patras, Patra, 28 – 30 March 2008 (in Greek). (http://www.ecedu.upatras.gr/didinfo/).

(2)

P. G. Michaelides, Everyday observations in relation to Natural Sciences, in Learning in Mathematics and Science and Educational Technology, University of Cyprus July 2001, Volume II pp. 281- 300.

(3)

P.G.Michaelides and Miltiadis Tsigris, Science Teaching with self-made apparatus, 1st International Conference on Hands-on Science: Teaching and Learning Science in XXI century", Ljubljana 5-8 July 2004, proceedings pp.47-52.

Laboratory of Educational Robotics

Educational Robotics present an appropriate teaching environment:

- **Familiarization to New Technologies, methods and materials,**
- **Development of problem solving skills,**
  through the design and implementation of a Robot artefact,
- **Promotion of cooperative learning through the assignment of group tasks,**
- **Better understanding of Science and Technology basics**
  through the construction of the robot artefacts.

- **Robots are present in everyday applications**
  electric kitchens and laundries, car engines, phones, …
- **Many relevant Laboratory kits**
- **We used the Lego© Mindstorms©**
- **May be considered as the evolution of the LOGO environment.**

Laboratory of Educational Robotics (continued)

Course Design

Objectives:

- Understanding the basic concepts of robots,
- Familiarization with robot programming,
- Apprehension of the possibilities and limitations of robots,
- Development of problem solving skills.

Syllabus:

- Familiarization with the material Lego Mindstorms©,
- Construction of simple robots under guidance,
- Construction of a robot on their own,
- Design and implementation of (part of a) smart house,

Laboratory of Educational Robotics (continued)

Results of a Test-Teaching – course organization:

an undergraduate course at the spring semester of 2007

as an optional choice in the area of Informatics in Education of the Department for Primary Education of The University of Crete.

- addressing students at the 5th or higher semester of their studies
  graduates of this Department are qualified to be appointed as teachers in the primary school.
- the course was delivered by the authors of this work who also made observations (‘action – research’).
- in course announcement:
  - no formal prerequisite knowledge was demanded from course candidates
  - Computer literacy extending to computer programming → potential advantage
- course planned for 16 students in one class
  due to its experimental character and the limited number of robot kits.
- course chosen by 26 students – all were accepted:
  - two classes were formed
  - in groups of 3 to 4 students instead of the planned two students per group, due to the limited number of robot kits.
  - expected to be compensated by students’ drop-out
    large in similar subjects in the Mathematics, Science and Technology area of the curriculum.
- most of the students:
  - had already completed their basic courses in Science and in Methodology of Teaching.
  - they were computer literate
- drop-out rate was zero we comment on it later.

Laboratory of Educational Robotics (continued)

Results of a Test-Teaching – course organization (continued):

- **The course was delivered in intervals of three teaching hours per week for 13 weeks.**
- **Students were free to use the laboratory for more hours - almost all they exploited this**
  to prepare or study for their assigned tasks
- **The equipment used was the LEGO© Mindstorms (see Picture 1)**
  easier purchase – students were familiar with Lego parts from their infancy.
- **There were two different versions of the robot processor units.**
- **The programming was made on PC's with Windows XP or Mac's with OS X.**
- **The Robolab© Software supplied by LEGO was used** an icon based programming language.
- **The program was then transferred through the infrared link to the robot units.**

Picture 1. Some of the equipment used

Laboratory of Educational Robotics (continued)

Results of a Test-Teaching – course delivery:

First 3 weeks, all class together:

- Introduction to concepts related to robots and robot programming,
- Examples of robots used already in different applications were given,
- Students were encouraged to propose possible applications of robots in other areas also,
- Familiarisation with available equipment,
- Teaching of common techniques of robot programming.

- Practice experience with the equipment (robot kits),
- Task assignment within the groups (designer, programmer, constructor …)
- Construction (assembly) of simple robots from the examples given in the manuals.

Next 4 weeks (weeks 4 - 7), in groups (formed on their own initiative):

- Construction (assembly) of simple robots from the examples given in the manuals (continued),
- Clarifying explanation of the logic of the respective robots was demanded,
- Students were asked for alternative approaches,
- Design and assembly of a robot of their own for a specific task
  i.e. to construct a robot that could transfer objects from a place to another one - contest.
- Introduction to the concept of a smart home.
  i.e. to construct a robot that could transfer objects from a place to another o.

Laboratory of Educational Robotics (continued)

Results of a Test-Teaching – course delivery (continued):

Next 3 weeks (weeks 8-10), in groups:

- Construction and testing of their own robot,
- Contest,
- Introduction to the concept of ‘Smart Home’ and its components

water heater and central heating, internal-external house lights, the garage gate, refrigerator with food stock monitoring, … .

Next 2 weeks (weeks 11-12), in groups:

- Construction (assembly) of a prototype of a component of ‘Smart Home’.

i.e. to construct a robot that could transfer objects from a place to another one - contest.

Last (week 13), in class - assessment:

- Through an ‘anonymous’ questionnaire during the last week.
- Brain storming type discussion commenting on the course

after the questionnaire was completed by the students.

Students were free to use the laboratory for more hours - almost all exploited this opportunity

- Supervisor always present during the laboratory use by the students.
- Providing guidance during the first weeks
- To help and advice, if asked, afterwards,

- Students submitted a short weekly report (one per group) on their work.
- They get also involved (voluntarily) to the translation of selected parts of the manuals.

Laboratory of Educational Robotics (continued)

Results of a Test-Teaching – Teachers' observations:

No students' drop-out:

- **Remarkable – usually 30%-50% when practice work starts,**
  students have a rather negative attitude towards Mathematics, Science and Technology.
- **Achieved high marks (at the upper 25%)** similar to other courses for continuing students,
  perceived (?) as a positive change towards Science and Technology.

None of the students had any previous experience with computer programming:

- **They managed quite well** using the supplied software with the (intuitive) icon based robot programming language.
- **They had to work in the laboratory outside the teaching hours**
  in order to get experience with the programming, a fact that added to their workload significantly
- **They worked on a trial and error basis** without resorting to the manuals (even if they were translated),
- **When failed, they asked for help** with self-ironic comments on their abilities.

indication (?) of increased interest, of self-esteem and of a friendly teaching environment

further supported by the fact that the teaching proceedings of the course were known widely arousing the curiosity of other people (students, technicians, even outsiders) and many times there were outside observers during the teaching.

Groupwork:

- **Work within the groups was mostly on an equal basis with peer discussions**
  even at the 2 groups where there was an evident domination of activities by one of its members, all members were active
- **Sometimes lengthy discussions leading to disputes** especially during the first weeks,
- **In 3 groups the advice to assign responsibilities was implemented literally**
  and it seemed to be another source of dispute.

Laboratory of Educational Robotics (continued)

Results of a Test-Teaching – Teachers' observations (continued):

- No apparent differentiation in task responsibilities between girls and boys
  - Girls were equally involved in constructions with gears, wheels, etc
    although this is considered, to some extent at least, a male occupation.

- Course objectives attained at least at the students' group level
  - successful assembly and operation of the robot under guidance (end of the 7th week),
  - successful design and construction of a robot of their own (end of the 9th week - very little guidance),
  - participation to the contest (end of the 9th),

A 'by product' of the course:
- the experience from the attempt to form a Greek – English dictionary
  of terms related to robots and robot programming

- someone was uploading a term
- others (or the same person) were proposing translation and explanation.
- Links to relevant web sites was also indicated.

Laboratory of Educational Robotics (continued)

Results of a Test-Teaching – Teachers' observations (continued):

On the final task requested, namely that of a component of a 'smart home':

- all groups made a rough analysis of one of the components, but,
- at the end all groups choose to construct a rather simple household item
  - a mechanism counting entries and exits
    to be used as a Gate counting persons in a place or as a post-box indicating new mail,
  - a solar device following the sun
    to be used on household solar devices used in Greece to increase their efficiency,
  - a toy producing soap bubbles activated by light or movement to be used with children,
  - automatic irrigation control system to be used in watering flowers on the owners absence,
  - a lighting device activated by detection of sound or movement
    to be used in corridors, outside of the house areas, etc.

It seems that the time allotted to this activity was not sufficient, one or two more weeks were missing.

However the main objective was achieved by all groups more or less successfully:

- detect application areas for a robot work and 'invent' an implementation.
- increased self esteem towards Science and Technology

all were keen to have their pictures and videos from the contest published on the web site of the Department.

Laboratory of Educational Robotics (continued)

Results of a Test-Teaching – Students' response:

- 24 students (8 boys, 16 girls) registered to the course
- 22 (7 boys, 15 girls) answered questionnaires were received.
- Percentages: boys – girls equal male – female primary school teachers.

- In the following we present the answers we received from the students.
- The answers are grouped.
- Mostly open type questions – students' answers included many issues.
- Students included, mostly, more than one characteristic in their answers.
- The answers are still being analysed.

Laboratory of Educational Robotics (continued)

Results of a Test-Teaching – Students' response (continued):

1.-Write briefly your impressions from the course. **Students found the course:**

- interesting (very interesting, most interesting),
- creative,
- different from the courses they were used to,
- a nice experience,
- useful.

2.-What you think you will remember from this course 5 years from now.

- The team work,
- A pleasant course,
- The construction,
- Our efforts and time devoted to solve construction – programming problems,
- The contest,
- The new ideas (1 answer),
- Nothing (1 answer).

Laboratory of Educational Robotics (continued)

Results of a Test-Teaching – Students' response (continued):

3.-Write up to 2 of the best characteristics of the course.

- teamwork,
- useful,
- creative – intelligence – originality (in 18 out of the 22 questionnaires),
- pleasant,
- practice work.

4.-Write the worst characteristics of the course.

- A lot time (10 out of 22),
- not enough materials,
- no manuals in Greek,
- not detailed guidance (4 out of 22),
- sending reports every week was tiresome,

- 'no bad or worst characteristics it simply requires more time than other courses' -1 answer.

Laboratory of Educational Robotics (continued)

Results of a Test-Teaching – Students' response (continued):

5.-The guidance was sufficient? (Yes/No). 22 out of 22 Yes.

6.-Write up to two of the best characteristics of the guidance.

- **helpful remarks,**
- **always present,**
- **patience,**
- **Socratic Method.**

7.-Write the worst characteristics of the guidance.

- **no detailed guidance (we had to complete the task ourselves),**
- **no praise on our efforts,**
- **left to follow wrong threads without early warning.**

Laboratory of Educational Robotics (continued)

Results of a Test-Teaching – Students' response (continued):

8.-Was there cooperation in the group? (Yes/No). 20 Yes, 2 No.

9.-Write up to two of the best characteristic in your group.

- effectiveness,
- enthusiasm,
- teamwork,
- mutual assistance,
- understanding,
- none (in the 2 that said No to the previous question).

10.-Write the worst characteristics in your group.

- none (7 out of the 22),
- disputes,
- trying to impose decisions,
- fixed responsibilities (in one case),
- many persons (in one case).
- No reply from one of the students who answered no cooperation
- no teamwork-disputes-trying to impose decisions-no respect to other opinions'.
  from the other student who answered no cooperation

Laboratory of Educational Robotics (continued)

Results of a Test-Teaching – Students' response (continued):

11.-What was missing from this course?

- more detailed guidance,
- manuals in Greek,
- shortage for some materials,
- a more spacious laboratory,
- links with other departments teaching this course to exchange ideas (in 1 out of the 22).

12.-What was surplus in this course?

- nothing (in 9 out of the 22),
- the weekly reports,
- the demands to improve our artefacts,
- the theory (in 2 out of the 22).

13.-What issues should also cover this course?

- none (in 7 out of the 22),
- more theory including the context and its role in pedagogy,
- use of other equipment also,
- smart home should be a common project for the whole class (in 2 out of the 22),
- 'Coffee and snacks (!)' (in 1 out of the 22).

Laboratory of Educational Robotics (continued)

Results of a Test-Teaching – Students' response (continued):

14.-Would you recommend this course to your fellow-students? (Yes/No). 22 Yes.

15.-Would you choose another course of a similar type? (Yes/No). 21 Yes, 1 no reply.

16.-Do you think you could teach such a subject in school? (Yes/No). 15 Yes, 7 No.

17.-Justify your previous answer.

Yes because:

- it is not so difficult – it is within the abilities of the students and mine (in 12 of the 15 yes).
- Yes provided there exist the infrastructure parts, equipment, computers, laboratory, time … (in 3),
- Yes provided that there is adequate preparation and more training (in 1 of the 15 yes).

No because:

- with the current situation in (Greek) schools there is no infrastructure,
- it is outside the culture, it is very demanding, it is time consuming, it is very difficult,
- I do not learned the programming.

Laboratory of Educational Robotics (continued)

Results of a Test-Teaching – Students' response (continued):

18.-Add any other relevant comments you think appropriate. (10 replies).

- **amusing, interesting,**
- **I think you should have encouraged us more as it was totally unknown to us,**
- **at the beginning I was afraid but I do not regret choosing it – it was hard work but worthy,**
- **it was the most amusing course we had – in its negative are your criticism giving the impression you did not value our efforts,**
- **I liked the teaching approach, the friendly within the group and with the teachers – in general the nicer and most interesting seminar,**
- **it should have only two persons per group,**
- **next time more parts (in 3 of the 10 replies),**
- **constructive, original. Good to be introduced in schools,**
- **constructive and creative for school students who could learn in parallel Science, Mathematics and Information Technology.**

Laboratory of Educational Robotics (continued)

Some Comments (analysis still going on):

The course objectives have been met successfully:

- **Students became familiar with the concept of robot and its possible uses.**
- **Students learned the basic principles of assembling and programming a robot.**
- **Students learned to locate areas where a robot may be used and plan its implementation.**
- **Students had the opportunity to develop problem solving skills.**

This is supported also from the, negative for some students, comments of them, that they missed detailed guidance or that they were left to follow wrong threads (see 4-7 above) more detailed guidance.

On the management and delivery of the course problems were located:

- **expected due to the initially planned test teaching on a small scale - they are under study.**
- **limited number of kits – more than large number of students per group**

➔purchase of more kits on a variety of component parts

however, more groups ➔ increased teachers' workload

- **no manuals in Greek ➔ translation, however:**
  - **not a problem actually,**
  - **preference of a trial and error approach or of teachers' help (even if manuals in Greek existed).**

Laboratory of Educational Robotics (continued)

Some Comments (analysis still going on) (continued):

On the management and delivery of the course problems were located (continued):

- the course needs a lot of time ➔ some thinking required

  ➔students' workload is high as already the students have indicated

However:

- normal workload 1 teaching hour corresponds to 1-2 hours of homework (a reasonable assumption)
- no student worked in the Laboratory for more than three hours in excess of the three teaching hours per week.

Consequently, the higher workload may be subjective feeling, due to:

- homework had to be done in the Laboratory during work hours not in home at any convenient hour

  lending the robot kits to students could be a remedy at an increase to the course's logistics ➔

- homework had to be done in time for the next teaching session while in other courses this could possibly be left for a later time – even till the examinations

  a view supported by the students' comments on the weekly reports monitoring homework study

Laboratory of Educational Robotics (continued)

Some Comments (analysis still going on) (continued):

Balance between theoretical context – practice work – school curriculum:

- closer connection between the robot assembly techniques and underlying Science concepts,
- balanced level of detail for the guidance on the actual practice work is essential,
- the sophistication required on the robots constructed should balance the time available.

Students liked the course. They judged it as:

- interesting, creative, different (with a positive meaning) from other courses,
- 'it took us a lot of time but it was worthy' as one student explicitly wrote.

Even some of the negative aspects they were provoked by the questionnaire's structure to write may be considered as positive remarks, for example students' comments about the worst characteristics of the guidance.

No differentiation between girls and boys:

- similar achievements and marks obtained,
- similar involvement as 'programmers' or constructors' or otherwise,
- No apparent sex differentiation on the groups the students had formed,

they included all girls or all boys as well as mixed groups.

Laboratory of Educational Robotics (continued)

Some Comments (analysis still going on) (continued):

The self-esteem of the students towards Science and Technology has increased:

- **they feel confident that they could manage a similar teaching in school with themselves as teachers.**

An explicit objective of the course that may explain, to some extent, the origin of the (negatively perceived) comment 'no praise on our efforts'.

Relation to the school curriculum:

- **students have, in general, the opinion a similar course can be incorporated into schools even most of the negative answers accept this possibility on the fulfilment of some conditions.**

Although this cannot be considered as 'experts' opinion' it is noticeable moreover as the students who had attended the course had some school experience through their school practice courses.

Laboratory of Educational Robotics (continued)

A second Test-Teaching – winder semester of 2007:

Course organization and delivery was, in general, the same as previously with the following adaptations:

Students were divided in 2 distinct groups.

In the 1^{st} group (control group) the teaching was the same as in the previous semester
The competition was to make a robot able to follow a certain path as depicted in Figure 1.

In the 2^{nd} group (test group) instead of the final task (a robot made on the students' own initiative) students were assigned the task: Design and deliver a teaching on Educational robotics to primary school (Grades 5^{th} or 6^{th} i.e. ages 11 or 12).

Figure 1. Sample path to follow by the robot constructed in the 2^{nd} part avoiding possible obstacles.

Laboratory of Educational Robotics (continued)

A second Test-Teaching – winter semester of 2007 (continued):

The objective of this test teaching was to study the feasibility of introducing Educational Robotics to Primary school.

Specifically:

- To check if teachers could be (self-) trained to the basics of Educational robotics to the extent that they could organize similar courses in their schools

As a consequence in the test group the guidance was limited to answering specific questions only – usually the answer was in the form of another question that could lead students.

- To check if a course on educational robotics is within the abilities of school students.

Students selected their group on the base of their other course they were enrolled and without knowing the different content.

At the end of the course students were asked to answer the same questionnaire as in the previous test teaching

Laboratory of Educational Robotics (continued)

A second Test-Teaching – winter semester of 2007 - Results:

In general, the assessment of the course was similar to the findings presented earlier.

There were no statistically significant deviations between the test group, the control group and the students in the previous test teaching.

Only a tendency for the test group to use more positive expressions for the course.

Based on observations during the course, on the students' logbooks and their reports and on the discussion that followed the conclusion of the course the following observations were made:

- **Students in the control group developed dexterities of robot construction somewhat earlier than the students in the test group although at the end both reached the same level.**
- **Students in study group emphasize more the problem solving characteristics of the course as a positive and as a negative (requires more effort) aspect of the course.**
- **Cooperation within the test group was on a more on a par and without evident role assignment**

(all consequences of the different guidance).

Laboratory of Educational Robotics (continued)

A second Test-Teaching – winter semester of 2007 – Results (continued):

7 primary school teachings were organized, each by a different group of 2 to 3 student from the test group.

The following were observed:

- **The teaching achieved its objective of familiarization of the school students with the basic concepts of robots - functioning and design.**

  according to the reports from the students in the test group and their tutors

- **The design of the teaching was, more or less, on the same trend as the teaching the students in the test group were exposed to.**

- **Teaching was done in two teaching hours (1 in one case). As a consequence, the time left to school students for thinking and retrospection on the problems posed to them was limited and tutor guidance was extensively used with verbal explanations.**

- **To cope with the (very) limited skills of school students on computer programming cards with the icons of the iconistic robot programming language were cut on cardboard. School students placed them on a table in the order they thought correct and then they tested it – a method of quick programming and debugging.**

Laboratory of Educational Robotics (continued)

A second Test-Teaching – winter semester of 2007 – Results (continued):

With one exception for which we comment later, in all the teachings in school:

- **The teaching achieved its objective of familiarization of the school students with the basic concepts of robots - functioning and design.**

according to the reports from the students in the test group and their tutors

School students:

- Show an interest vivid throughout the teaching. Almost all asked to repeat the teaching and advance more into robotics.
- In most cases, school students were active and continuously changed roles (constructing the robot body – programming - …), an expected observation for this age (maximum time of focused attention in the order of 10-15 minutes, a fact that has to be taken into account).
- With the one exception mentioned already, all school students show an interest for the construction and for the programming of the robots. They suggested novel ideas to cope with problems of construction and/or programming. They also suggested robots with a variety of functions.

Laboratory of Educational Robotics (continued)

A second Test-Teaching – winter semester of 2007 – Results (continued):

With one exception for which we comment later, in all the teachings in school:

- **The teaching achieved its objective of familiarization of the school students with the basic concepts of robots - functioning and design.**

according to the reports from the students in the test group and their tutors

In one of the teachings in schools:

- **School students lost their interest in the construction of the robot artefact and concentrated, almost exclusively, on the computer (a nice portable Mac) used for the robot programming.**
- **It was the school with only an adequate success of the teaching objectives.**

Further study showed that in this school, almost all the school students were immigrants from former east European countries with no previous experience at all on Lego type activities, while computers were more familiar to them.

Laboratory of Educational Robotics (continued)

A second Test-Teaching – winter semester of 2007 – Results (continued):

In the final assessment of the course:

- **All the students consider the course as very worthwhile,**
- **They would recommend the course to their fellow students,**
- **They would enrol in courses of a similar type.**

However:

- **They consider it as a difficult course**
- **The obligation of keeping a logbook and submitting reports on a regular weekly basis was considered as a very good or a very bad characteristic of the course.**

This phenomenal inconsistency is under investigation.

It may mean that the students were satisfied by their successful efforts but that, in comparison with other courses the course on the robotics was more demanding. The strict time schedule imposed together with the requirement to be in the laboratory for their 'homework' may also contribute to the impression of a difficult course.

Laboratory of Educational Robotics (continued)

A second Test-Teaching – winter semester of 2007 – Results (continued):

In conclusion:

- **The teaching approach on 'self-teaching' in the test group achieved the planned objectives:**
  - **Familiarisation with the concepts of robot and robot programming,**
  - **Development of complex cognitive skills like problem solving,**
  - **Development of skill for self personal development,**
  - **Facilitating the design of a corresponding teaching in school**

As a result:

The introduction of educational robotics in schools as a regular school subject seems feasible.

Laboratory of Educational Robotics (continued)

A second Test-Teaching – winter semester of 2007 – Results (continued):

Epilogue:

Computers in schools caused a lot of controversies, nevertheless, when used appropriately, they are a useful tool for the cognitive development and learning.

Today, the Laboratory of Educational Robotics may provide a similar but more powerful learning environment for the development of complex cognitive skills and practical dexterities

Currently, we exploit this idea with a 'deprived' school in a rural area of Crete, where school students are indifferent to school subjects and activities.

Our first results are very encouraging – students start to change their attitudes towards schooling

Everyday observations in Science Teaching

(introductory to critical and creative thinking)

Science Teaching experiments with self made equipment

(extensive use of Problem Based Learning)

Motivation:

- Experiments and Scientific observations constitute an integral part of Science teaching:
- Self-made equipment:
  - present inherent advantages,
  - help towards a better understanding of the basic notions,

    especially in primary education.
- Experiments should be incorporated smoothly to the teaching activities,
- The skill of planning an experiment to test a hypothesis is an explicit aim,
- Very important the distinction:
  - of observational and/or experimental data from
  - their interpretation and the corresponding theory.

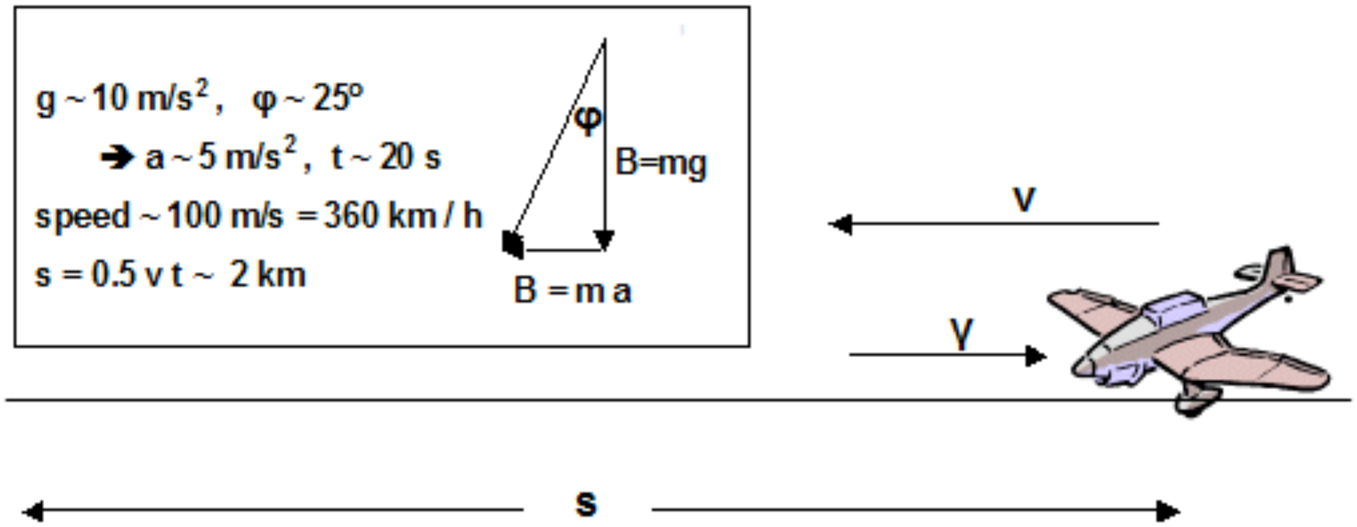
- Hands-on Science(*) context.(*)

(*)The core notion of Hands on Science may be traced back to the works of Johann Heinrich Pestalozzi (1746-1827) a Swiss educational reformer, a follower of J. J. Rousseau who brought the principles of the Enlightenment into the then very authoritarian education. He advocated education for all especially the poor. He influenced other educators introducing together the infant school stressing the emotional and spiritual nature of the child, encouraging self-understanding through play activities and greater freedom, rather than the imposition of adult ideas.

Everyday observations in Science Teaching

(introductory to critical and creative thinking)

Estimate an airplane’s landing speed



Everyday observations in Science Teaching

(introductory to critical and creative thinking)

A TV commercial

A saloon in the middle of nowhere at twilight.

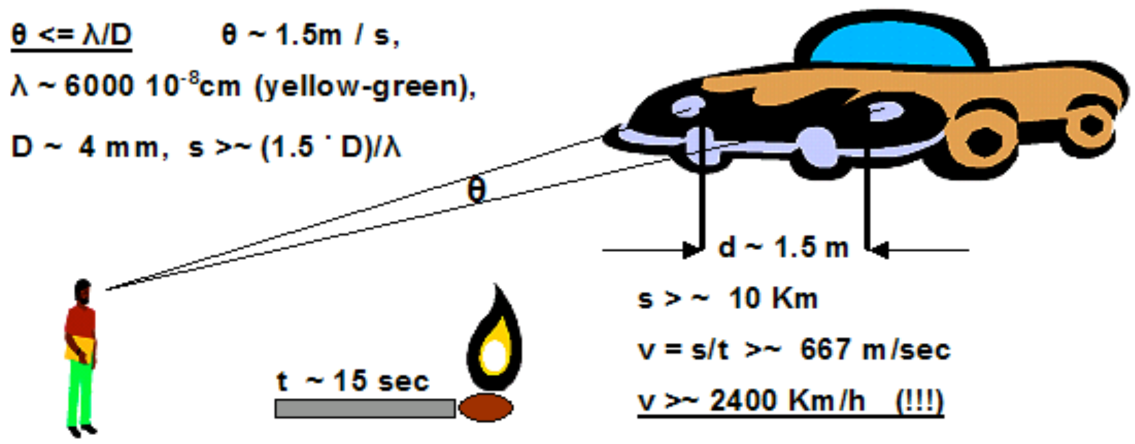
A cowboy strikes a match to light a cigar when, far in the horizon, one light catches his attention. He freezes staring it.

Sometime later a car (vroom, vroom, vroooo…m) is passing.

At this time the match burns the finger of the 'freezing observer'.

A fiction or a fantasy?

Other ways to estimate the distance???



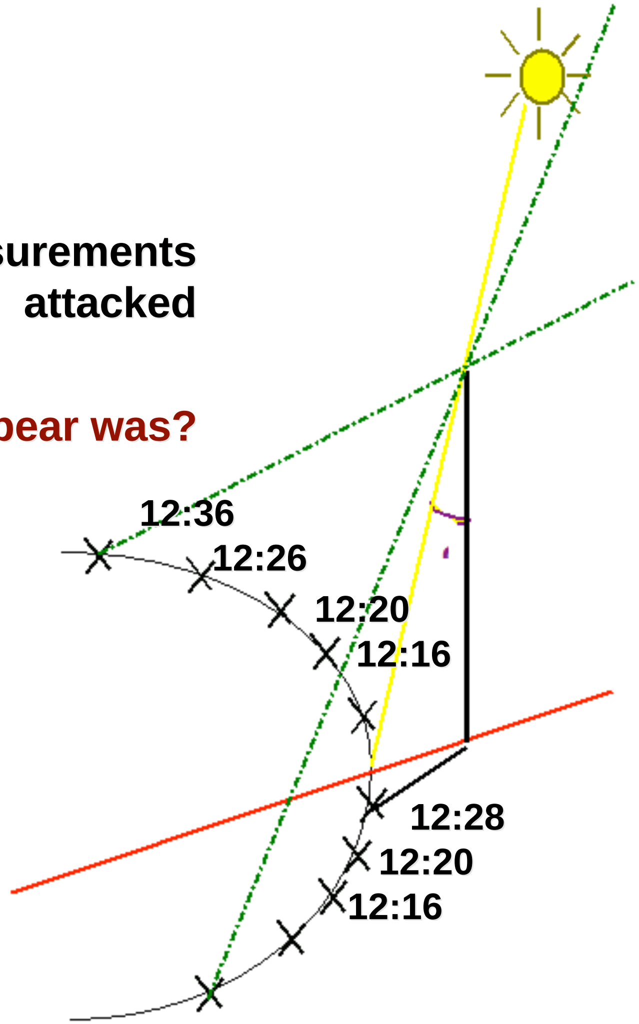
Everyday observations in Science Teaching

(introductory to critical and creative thinking)

A Fiction (?)

A Science expedition was taking the measurements shown. Suddenly, a bear just awakened attacked them.

What colour the bear was?



Everyday observations in Science Teaching

(introductory to critical and creative thinking)

Some Homework (!!!)

- **Big brother watches you.** It is said that surveillance by artificial satellites might reveal the plate numbers of car. Is it possible? Under what assumptions?
- **Driving.** The default speed limit in urban areas is 50 km/h. However in most villages this limit is less 40, 30 or even 20 km/h. Any justification?
- **Circulatory System.**
  - Why is it lethal to inject air bubbles in an artery or a vein?
  - How food eating and air inhale may affect arteries and veins?
  - To how many glasses of wine the alcohol driving limit of 0.5% corresponds?
- **Kinetic Theory.**
  - How the ‘sweating’ pottery from Aegina works? Is there any connection with the chilling after a warm bath or the mild skin anesthesia with a volatile substance?
  - How, in the hot summer Mediterranean days, a warm to hot water melon may be transformed into a refreshing (and hopefully delicious) meal?
  - Why mouth air blowing may blank out a candle but explode a fire, or may warm our hands but cool down our soup?

Everyday observations in Science Teaching

(introductory to critical and creative thinking)

Some Homework (!!!)

- **Various subjects.**
  - **Is there any connection between the inward thickness of the Earth’s crust in mountainous areas and in the sea with the draught of a large ship and a small boat?**
  - **Can you estimate the endurance of the tendons in the legs or in the arms?**
  - **Why are there usually rivers in the gorges?**
  - **Why the string for drying the laundry has to be loose?**
  - **How fuel consumption may relate to the fact that commercial ships do not usually sail on their full speed?**
  - **Why long car queues are formed even in slight road narrowing?**
- **etc.**

Science Teaching experiments with self made equipment

(extensive use of Problem Based Learning)

Assumptions:

- Self-made apparatus to be used in classroom Science experiments:
  - is a very creative process
  - associated with the development of cognitive and psycho motive skills
  - and facilitates the logical process of induction.
  - facilitates the development of social skills (in a group work construction),
  - covers the sentimental sector the "pleasure of creation".

- Other inherent advantages of self-made apparatus:
  - facilitates query situations and the process of planning an experiment;
  - demonstrates an immediate application of some of the relevant Science issues;
  - removes the "black box" feeling associated with the use of hi-tech devices;
  - it develops the ingenuity of the teacher for alternatives to expensive equipment;
  - easily discriminates observations' data from their interpretation.

Science Teaching experiments with self made equipment

(extensive use of Problem Based Learning)

Assumptions (continued):

- Sophisticated complex equipment may:
  - Give accurate measurements,
  - Be necessary in quite a few times.

- However:
  - Hinder the principles under study
    in the effort of understanding how to use the equipment.
  - Converts the experiment to a demonstration process
    in which the student observes the results of an apparatus he-she does not understand
  - It removes the authentic creative activity,
    get the results of the experiments instead of inquiring a Natural phenomenon.

- Science teachers lack, the skill to transform scientific knowledge into teaching practice
  - ➔Science and Technology are considered as difficult subjects,
    although they are rather simpler and possess inherent teaching advantages(*).

(*)Science subjects of study are easily perceptible through the senses, an irrefutable advantage for most of the compulsory education students who, in a Piagetian context, have not as yet reached the formal logic stage.

Science Teaching experiments with self made equipment

(extensive use of Problem Based Learning)

The construction of self-made apparatus must follow some principles:

- Simplicity and Safety
- Problem solving
- Accuracy, sensitivity and calibration
- Assessment

Science Teaching experiments with self made equipment

(extensive use of Problem Based Learning)

The construction of self-made apparatus must follow some principles:

➢**Simplicity and Safety**

- Simple construction with easily available materials from the environment of the school and the students.
- Feasibility of assembly within the abilities of a “do it yourself layman”.
- An (optional) objective the dexterities and knowledge
    - on the properties of the materials used and
    - on how to handle them.
- Simple constructions:
    - facilitate the understanding on the apparatus functioning
    - minimize safety problems.
- Safety is always an important issue that must be stressed, even over emphasized:
    - to students (especially children) involved
    - to teachers (especially Primary School Science Teachers)
    - who, in general, lack a professional training in Science.
- Development of good safety awareness attitudes.

Science Teaching experiments with self made equipment

(extensive use of Problem Based Learning)

The construction of self-made apparatus must follow some principles:

- **Problem solving**
  - **The construction process must provoke the ingenuity and creativeness of the students.**
  - **The guidance offered must:**
    - **remain within the above general goal,**
    - **Leave the initiative to the student.**
  - **Detailed guidance should be limited to specific queries related to technical or specialized issues.**

Science Teaching experiments with self made equipment

(extensive use of Problem Based Learning)

The construction of self-made apparatus must follow some principles:

- Accuracy, sensitivity and calibration
  - The prime goal is to understand the principles ("natural law") involved.
    ➔high levels of accuracy are not necessary.
  - Adequate Accuracy and Sensitivity must be present
    ➔if the apparatus constructed is used as a measuring instrument.
  - Calibration is a necessary step for apparatus used as measuring instruments.
  - Usually calibration is done by comparison with a professional instrument but
    but a discussion on the principles used to make measuring standards is enlightening
  - Estimation of the accuracy and errors helps
    on the conceptual meaning of measuring errors and their treatment.

Science Teaching experiments with self made equipment

(extensive use of Problem Based Learning)

The construction of self-made apparatus must follow some principles:

- Assessment
  - When the construction is finished it is advised to perform a retrospective evaluation:
    - on the whole process,
    - on the choices made,
    - on the other possible alternatives,
  - a comparison to apparatuses made by others
    - recapitulates on the subject under study and facilitates meta-cognitive effects.
  - Aesthetics of the final construction is an important issue
    - Showing practicality and an indication of deliberation and diligence
    - although it is highly subjective.

Science Teaching experiments with self made equipment

(extensive use of Problem Based Learning)

Examples:

- **A Gas Thermometer**
- **A Hydrometer**
- **A weighing-machine**
- **An amperometer**
- **Geographical coordinates**
- **More examples**

Science Teaching experiments with self made equipment

(extensive use of Problem Based Learning)

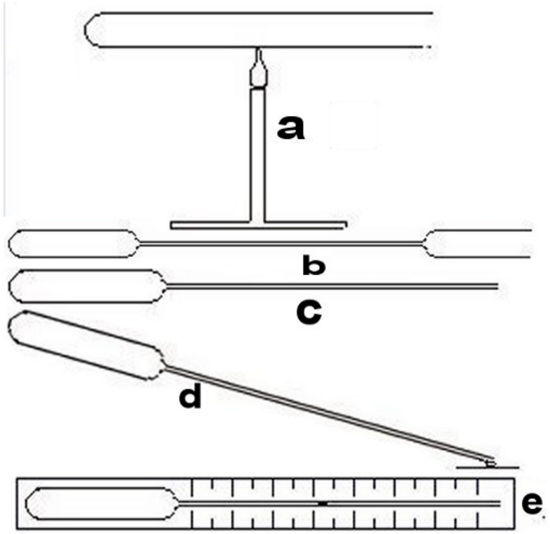
Examples:

- A Gas Thermometer
- A Hydrometer
- A weighing-machine
- An amperometer
- Geographical coordinates
- More examples

Science Teaching experiments with self made equipment

(extensive use of Problem Based Learning)

Gas Thermometer



The task is to construct a thermometer.

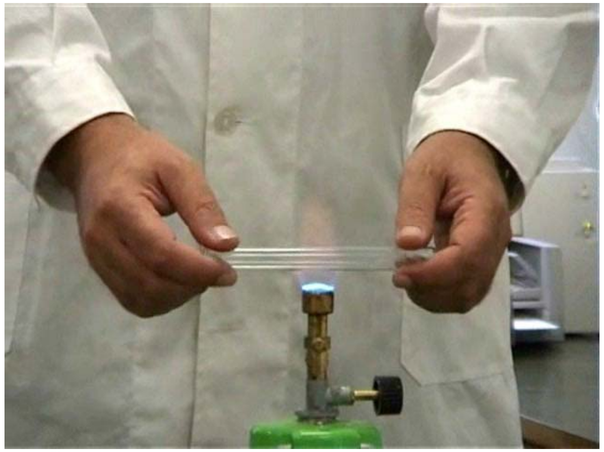
Objectives may include (on top of the subject matter):

basics on glass treatment,

a useful skill for chemistry experiments,

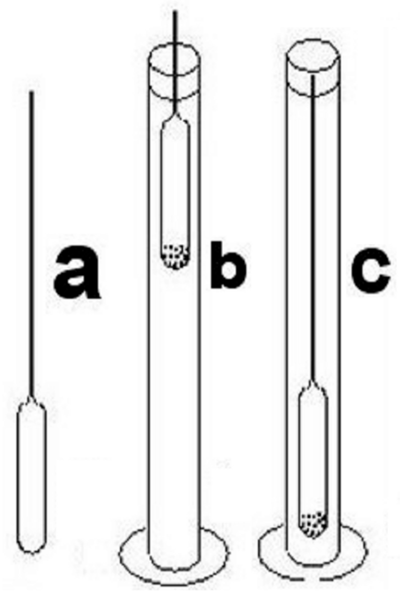
notions of calibration, accuracy and sensitivity, error.

The device may be used also as a dropper, a hydrometer, etc.



Science Teaching experiments with self made equipment

(extensive use of Problem Based Learning)



The task is to construct a Hydrometer.

To measure the density of liquids

Objectives similar to those of the Gas Thermometer.

Construction as in the Gas Thermometer

the elongated pipe should not be too thin;

Put into the small lead balls (e.g. thin shot) or sand;

Immerse it into liquids of different densities

in b – a relatively dense liquid

in c - a relatively thin liquid

Fix the device into a cardboard with the scale

Seal the open end of the elongated pipe.

Calibration is done by preparing liquids with a known density

Salt into water – alcohol and water, etc

Used to measure the density of wines and spirits ("infer" the alcoholic content).

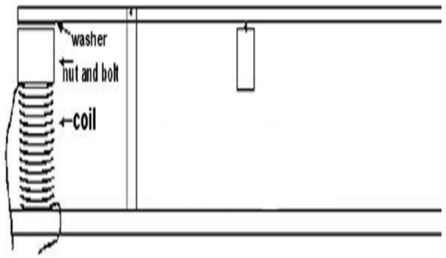
Advantageous to the understanding

of density, of the different ways of titration of solutions, etc.

Science Teaching experiments with self made equipment

(extensive use of Problem Based Learning)

An amperometer



Objectives electromagnetic forces:

Construction based on the weighing machine.

The plate is replaced by an iron washer fixed on the balance rod and a coil around an iron bolt.

Connecting the coil serially to an electric circuit, an electromagnetic force is induced which holds the washer to the bolt.

Moving the weight along the rod the electromagnetic force may be measured comparing the mechanical moments.

An adaptation:

Replace the weight by a (coil) spring. Fix the bolt in the place of the washer.

Increase the height of the rod supporting the balance rod.

When the electromagnet is activated the bolt is attracted into the (hollow) coil and the corresponding force may be measured by the elongation of the spring.

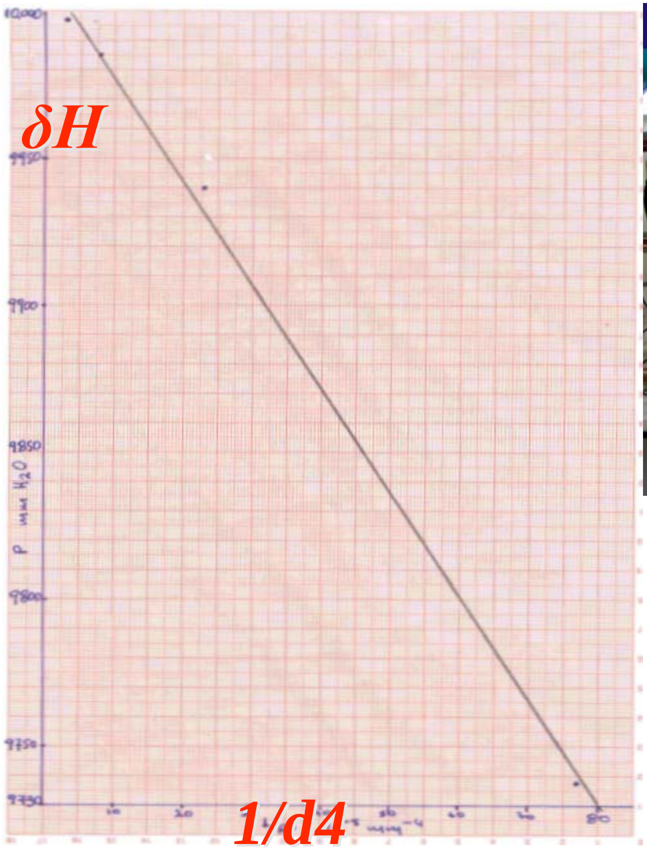
Fixing the spring in different distances from the supporting the balance joint, different current ranges may be measured.

Science Teaching experiments with self made equipment

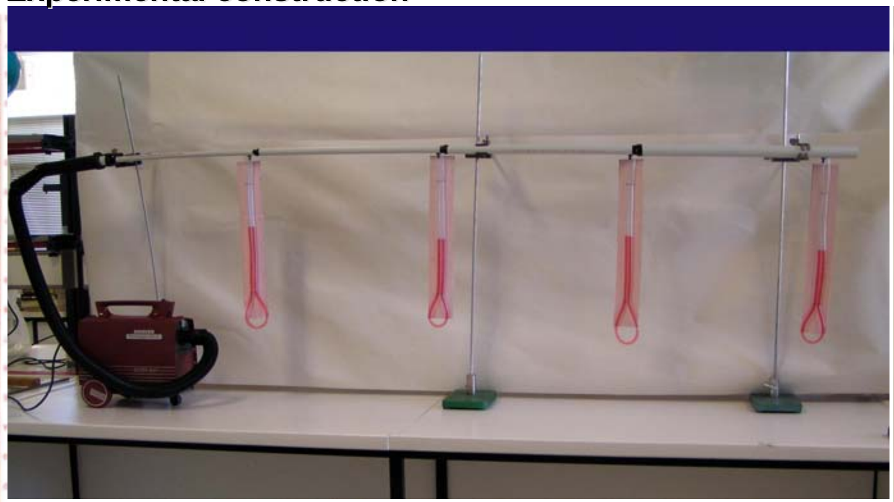
(extensive use of Problem Based Learning)

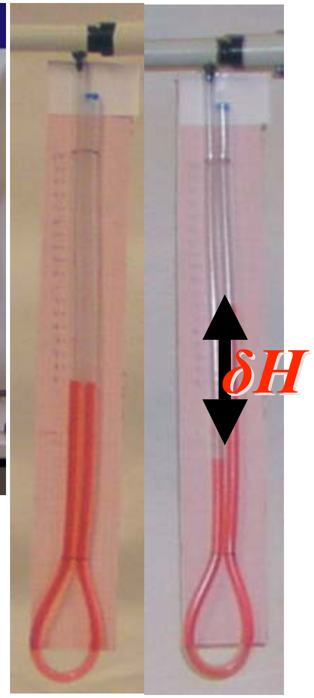
Bernoulli's Law When a fluid of density ρ flows in a pipe with velocity **v** at a height **z** $\rightarrow$

$$P - P_{atm} + \frac{\rho v_1^2}{2} + g\rho z_1 = P_0 - P_{atm}$$



Experimental construction





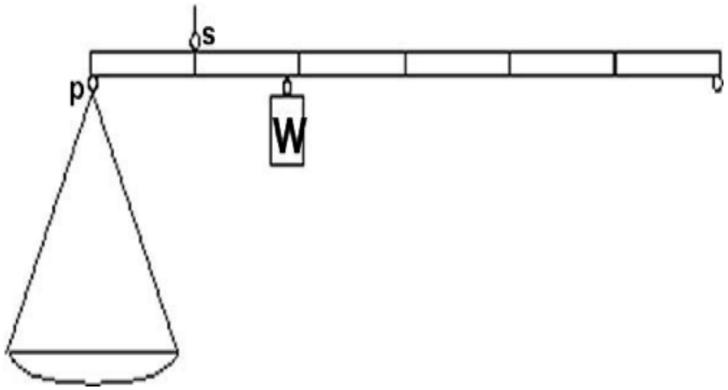
For a horizontal pipe and a constant flow:

$P\text{-}P_{atm}$ ~ δH ~ $1/d^4$, *d = the diameter of the pipe*

Science Teaching experiments with self made equipment

(extensive use of Problem Based Learning)

A weighing-machine



The task is to construct a Weighing machine.

Objectives mechanical moments:

In the Calibration process

mechanical moments may be clarified.

Made with materials used to hang slide curtains in house windows.

The weight, W, hangs from a hook used to hold the curtain within the slide rod.

Similar hooks are used for the joints in p and s.

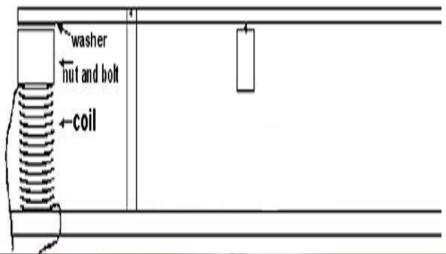
The construction, if done with diligence, may be very accurate.

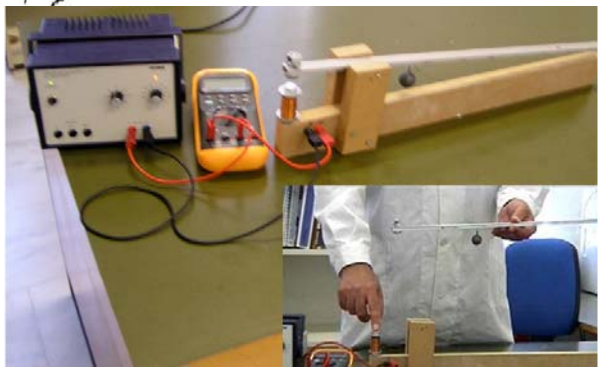
It is also used in other apparatus (see for example “An amperometer” later on).

Science Teaching experiments with self made equipment

(extensive use of Problem Based Learning)

An amperometer





Objectives electromagnetic forces:

Construction based on the weighing machine.

The plate is replaced by an iron washer
fixed on the balance rod and a coil around an iron bolt.

Connecting the coil serially to an electric circuit,
an electromagnetic force is induced
which holds the washer to the bolt.

Moving the weight along the rod
the electromagnetic force may be measured
comparing the mechanical moments.

An adaptation:

Replace the weight by a (coil) spring. Fix the bolt in the place of the washer.

Increase the height of the rod supporting the balance rod.

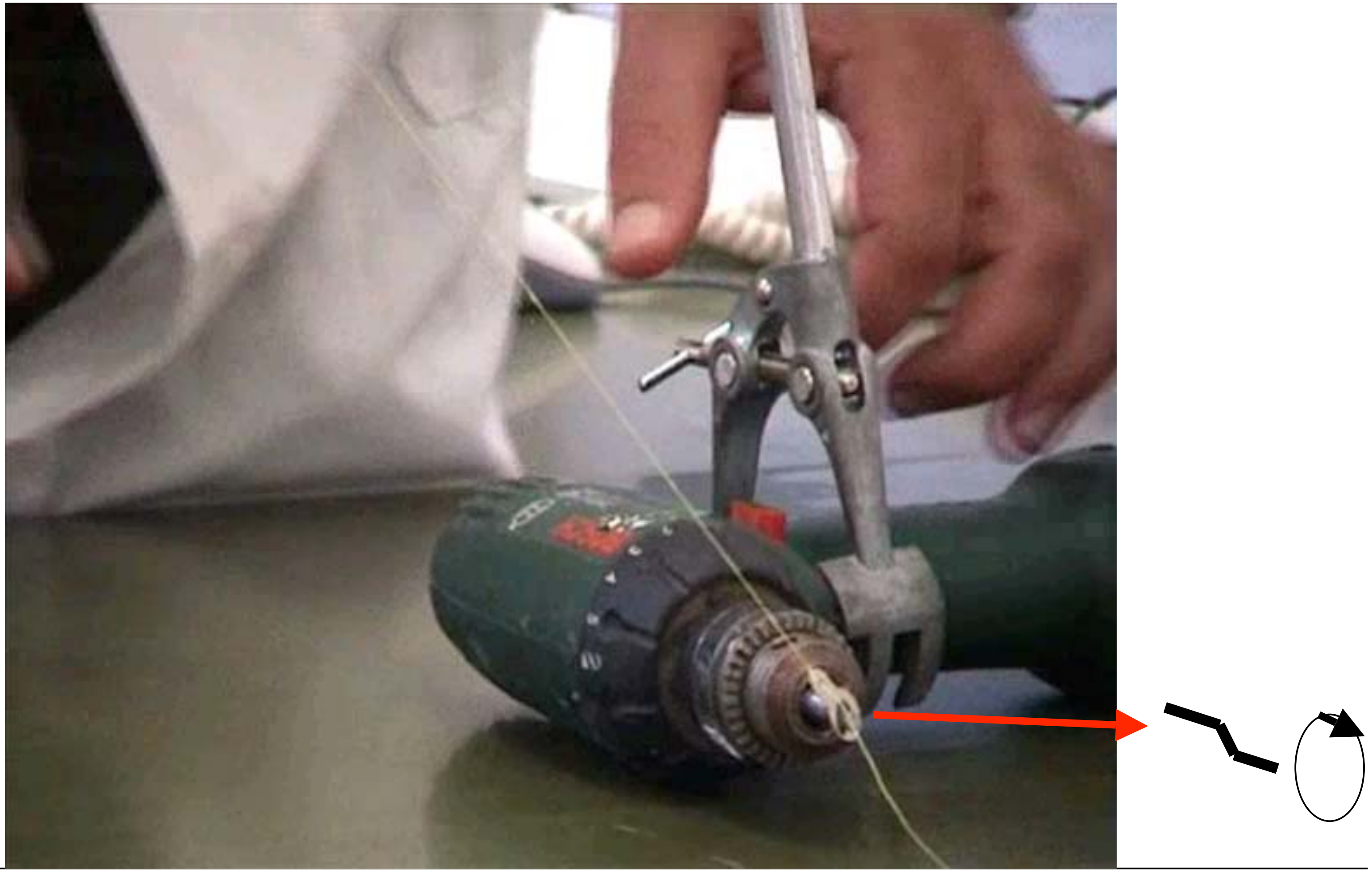
When the electromagnet is activated the bolt is attracted into the (hollow) coil
and the corresponding force may be measured by the elongation of the spring.

Fixing the spring in different distances from the supporting the balance joint,
different current ranges may be measured.

Science Teaching experiments with self made equipment

(extensive use of Problem Based Learning)

Mechanical Resonance



Science Teaching experiments with self made equipment

(extensive use of Problem Based Learning)

An electric motor

Science Teaching experiments with self made equipment

(extensive use of Problem Based Learning)

Variable Lens

Science Teaching experiments with self made equipment

(extensive use of Problem Based Learning)

Epilogue

Realized as assigned projects by students in the Department for Primary Education of The University of Crete.

Many of them have also been realized partially or totally by school students.

Some indicative responses from the University students are:

- I imagined that for Science experiments a special laboratory was necessary
- I realized that doing experiments is not so complicated a matter.
- I learned to work on my own (a comment made more often by female students).
- I realized that what we had learned in school may have direct applications.
- What I learned can be used directly to schools.
- The construction helped me to understand what I had only memorized.
- I realized a difference between graphs in the Science books and the actual data referring to the scattering of measurements due to measurement errors, a fact usually absent in the graphs of textbooks).
- It was difficult but I learned to work on my own.
- A good course, but the effort I made was worth of two or more other courses.

Science Teaching experiments with self made equipment

(extensive use of Problem Based Learning)

Variable Lens

More:

http://www.clab.edc.uoc.gr/aestit/

http://www.clab.edc.uoc.gr/hsci/

michail@edc.uoc.gr

A view from The University of Crete campus at Rethimno - Thank you