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State of the Art of Science Teaching(*)

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Teaching and Learning Science in the XXI century

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"State of the art" has differing overlapping and parallel meanings:

- **Current or contemporary trends in the field,**
- **New developments in the underlying theories,**
- **New approaches using or adapting already known models,**
- **Recent empirical data from relevant activities,**
- **Use of new equipment and/or technology,**
- **Empirical results obtained recently,**
- **Etc.**

Recent emphasis on Science education ➔ many good works everywhere

Consequently, this work presents,

A reference to collected works and available relevant sources,

A focus to some common characteristics of recent works,

A brief perspective on Science teaching.

Empirical results - **The teaching is presented and the data are discussed in terms of:**

school context (social, ethnic, economic or otherwise),

application of a specific learning strategy,

study on the Teaching of a specific Science topic,

comparison between different teaching approaches,

use of new technology, especially computers,

use of an innovative experimentation,

Etc.

Empirical results ➔ sound, empirical data useful to:

The development of teaching strategies,

The choice of a specific type of instruction,

The discussion of relevant Policy matters,

Etc.

Empirical results - Sources:

Journals specific to Science education or to education in general,

School publications (valuable data on actual school operation),

Publications from teachers' associations (quite often of a high scientific quality)

e.g. "Handbook of Research on Teaching" 4th edition, 2001 by AERA American Educational Research Association (http://www.aera.net/)

Exist in every country,

Some of them of outstanding quality

Empirical results - Sources:

Specialized International Conferences a rich supply of quality data

-CBLIS – Computer Based Learning in Science

http://www.ucy.ac.cy/cblis2003/ http://www.student.utc.sk/~jasomja/cblis/

-European Conference on Educational Research (ECER)

The University of Crete in Rethymno at Sep. 20-25, 2004 http://www.eera.ac.uk/

-ESERA Conference (biennial)

2003 Conference (http://www1.phys.uu.nl/esera2003/default.shtml)

2001 3rd International Conference in:

Science Education Research in the Knowledge Based Society

by Dimitris Psilos et al. (eds), KLUWER Academic Publishers 2003

Empirical results - Sources:

Local conferences - data addressing a specific education system.

Provide valuable data,
Addressing peculiarities of a specific education system.

Summer schools or special interest workshops valuable data on a specific region.

Activities addressing – studying a specific topic,
From the actual school operation,
Highly valued within the teachers.

Local but with International Participation (Globalization).

Surveys.

Refer to parameters of the education system of a region,

Carried out within the activities of international bodies,

Sponsored by (local or state) governments,

Focus on economic and on policy matters – but, recently, extended to include

Specific chapters directly related to Science and Technology education.

Specialized studies.

Within the above context,

Addressing a specific issue,

Quite often on the content of Science (and Technology) Teaching,

Thematic Networks.

Fostered within European Union,
In the context of promoting Science and Technology Literacy,
Science Teaching activities are promoted.

ESERA – European Science Education Research Association
(http://www.esera.org)

(EBISTE) STEDE – Science Teacher Education Development in Europe.
(http://www.biol.ucl.ac.be/STEDE/)

Hands on Science operating this Conference and international workshops
(http://www.hsci.info/)

ECTN - European Chemistry Thematic Network
(http://www.cpe.fr/ectn//Default.htm)

Special Publications.

By reputed publishers,
Collections of relevant studies on Science Education and on Science teaching,
Refereed,
On a regular basis (series)

References.

Seek for yourself in the INTERNET,

(no specific commercial advertising here)

Surveys and Specialized studies -Sources.

OECD - Organization for Economic Cooperation and Development
(http://www.oecd.org/home/)

Regular indexes on Education with specific chapters on:

- **Science and Technology education,**
- **Trends and Achievements,**
- **Outcomes of Learning,**
- **Etc.**

Many of OECD publications are also available electronically.

PISA Programme for International Student Assessment

Surveys and Specialized studies -Sources.

UNESCO - United Nations Educational, Scientific and Cultural Organization (www.unesco.org).

Regular and systematic studies,
Especially on developing countries,
On matters of literacy, teaching, schooling, …
Handbooks and Source books for Science Teaching.
Many of UNESCO's publications are available electronically.

EU – European Union (http://europa.eu.int/index_en.htm)

A plethora of data on:

- **Science and Technology education,**
- **Special Studies,**
- **Ongoing projects,**
- **Thematic Networks,**
- **Relevant Legislation and Actions,**
- **Etc.**

Many of the EU –studies are available electronically.

Content.

Selected works on Science teaching were analyzed in terms of:

- **The theme and/or type of the work,**
- **The underlying learning theory, if any,**
- **Skills, dexterities and attitudes to be attained,**
- **The type of instruction used,**
- **The type of assessment, if any,**
- **The subject matter:**
  - **Its choice,**
  - **its sequence into topics,**
  - **its type (traditional versus modern Science),**
- **The target group,**
- **The experiment and, more general, the practice work involved, if any,**
- **The equipment used,**
- **Other related issues.**

Science Teaching context:

Science teacher

New Teacher Education for the Future International Perspectives
Edited by Yin Cheong CHENG, King Wai CHOW, Kwok Tung TSUI,
KLUWER Academic Publishers, 2001

Advances In Research On Teaching, Editor: Jere Brophy,
Volume 2, Teachers' Knowledge Of Subject Matter As It Relates To Their Teaching Practice,
JAI Press Inc. 1991

Science Teacher Education: An International Perspective,
Edited by Sandra K. Abell, KLUWER Academic Publishers.

School environment

Place of Science in a World of Values and Facts,
Loucas G. Christophorou, Kluwer 2001.

Science, Technology, and Society: A Sourcebook on Research and Practice,
Edited by David D. Kumar and Daryl E. Chubin,
Kluwer Academic Publishers 2000.

Underlying learning theory.

Learning may occur spontaneously (every day's experience) or even without teaching at all,

However learning theories are fundamental:

in choosing an appropriate teaching strategy,
To enhance significantly teaching effectiveness
when they are understood by the teacher and applied appropriately.

More than true for Science where:

cognitive skills (simple and complex),
other practical skills and dexterities

are to be attained.

Underlying learning theory (continued).

A specific learning theory is missing, and,
It cannot be inferred from the whole teaching architecture
in quite a few of the works examined especially in these discussing Science practice work.

Although practice work is appropriate for the development of complex cognitive skills,

It seems that, to many educators,
practice work means demonstration and/or psycho motive skills only.

(empirical evidence)

most of the teachers lack the necessary knowledge
if they possess it, they still tend to repeat the teaching they have been exposed to
than to transform their knowledge into school practice and adventure on new teaching approaches.

The scientific knowledge on teaching teachers have learned seems
abstract and remote to school reality.

Underlying learning theory (continued).

recently introduced national curricula in almost all countries

Explicit state the importance of Science education

Reveal the necessity for an effective Science teaching, and,

The requirement of a learning theory.

Piaget's work provide an expected choice,

Constructivist teaching emerges as the theory environment for Science teaching

with many relevant works appearing.

Jean Piaget (1896-1980) a Swiss biologist. Many published papers in the field.

Better known for his works in developmental and cognitive psychology.

Interested in intellectual development of young persons.

Used topics from natural sciences (field he understood well) for his empirical observations on how children were acting (stages of cognitive development).

As a result his works became a supportive host to Science teaching.

Underlying learning theory (continued).

Applied correctly in most of the theoretical works,

No time for reflection and (re)construction of students' (new) cognitive schemes
in actual school instruction, where:

The teacher:

"demonstrates inconsistencies",
"explains or proves the theory", and,
"builds the model".

In defiance of the basis of the model.

Possible reasons:

Limited school time allocated

Unawareness of its importance.

Underlying learning theory (continued).

Issues of a constructivist teaching approach are studied in:

Constructivist Teaching In Primary School:
Social Studies, Mathematics, Science, ICT, Design And Technology

Suzanne Gatt & Yosanne Vella, **Published by Agenda - Malta, 2003.**

A useful source of related issues may be found also in:

Children and Primary Science,

Tina Jarvis,

NICHOLS PUBLISHING 1991

Type of instruction used.

(empirical evidence)

Narration, although still practiced to a large extent, diminishes,

Instruction is at least enriched with audiovisual means,

Experimentation is constantly increasing,
at least as a demonstration quite often performed by the students themselves

Active student's participation (i.e. essays, observations) appear frequently
either at atomic level or in group work.

Project assignments and experience teaching are constantly increasing.

Assessment seems improving as an integral part of the teaching, but
there is a lag in formative assessment.

Type of instruction used – Some Comments.

(Instruction)

A slow but constant improvement.

(Group work)

Increasing tendency to use group work almost exclusively.
Seems appropriate for lower grades.

(Atomic works)

May be more advantageous for personal and vocational development, especially for practice (psycho motive) skills.

(Formative assessment)

Missing (mostly), or,
Partial summarise assessment (sometimes),

if achievement results are low ➔

The teaching is repeated in the same way.

Formative Assessment and Science Education by Beverley Bell And Bronwen Cowie

Science & Technology Education Library VOLUME 12, KLUWER Academic Publishers.

Subject matter.

Traditional management of the subject matter,

Within the analytical way imposed by the curriculum (Mechanics, Heat, Electricity, ….)

An expected outcome even when the curriculum permits flexibility

Encouraging is the increasing advocating of:

A more synthetic approach

(e.g. study of a phenomenon in total not its partial aspects),

An interdisciplinary approach.

Research and Field work started to appear

Recently attention attracted to:

Real life observations

Their connection to the "theory" of Science disciplines.

Relevant teaching actions begin enter classrooms.

Target group.

Mostly primary education may be because pedagogy is associated with childhood,

Middle and High (general education) school follow.

Technical vocational education is almost absent
despite its significance in a technology based society

Higher levels of education mainly in pre- and in- service Science teacher training.

Not clearly defined or stated to cover a wide range of grades – ages (in a few works)

Target group (continued).

Practical skills:

Interlaced with Science education,

need (still) a proper attention and a systematic study

Study Focus (usually ambitious):

(complex) cognitive skills (e.g. problem solving),

conceptual change, scaffolding and related methods.

are used but quite often in a controversial way.

Practical Work in Science Education: Recent Research Studies,
Editors: John Leach and Albert Paulsen, Roskilde University Press, KLUWER 1999.

Practice work.

Experimentation:

Compulsory in most of the curricula introduced recently,

Increasingly included in school Science teaching.

Problems still remain and include:

The type of experiment(s) used
(demonstration or testing, by the teacher or by the students, …),

The equipment used
(simple or modern, in the classroom or in special laboratory,
actual experiments or simulated ones, …),

The role of experiment within the teaching process,

Reporting on experimental findings,

Etc.

Practice work (continued).

Most problems may be traced to the:

Downgrading of practice work that prevailed,

Lack of experienced teachers.

Significant progress has been made.

The field is open to:

the investigation,
the research,
the teaching.

Focus to the smooth and consistent incorporation

of experiments into the teaching practice.

Studies on this field:

Will provide useful data about the outcome of students practice,

May help to understand better the influence of practice work,
to conceptual learning, skills and processes associated with Science,
to cognition.

(Notes on the equipment used)

Practice work (continued).

Complex equipment may be necessary in high grade (age) experimentation where:

the phenomena under study impose its use,

the measurement accuracy should be rather high,

Technical skills are to be developed.

But when a conceptual understanding of basic principles is the objective:

complexity may hinder the principles of the phenomenon under study

as is the case especially in lower grades - ages (primary education)

(Notes on the equipment used)

Practice work (continued).

Simulations may be appropriate for:

Downgrading of practice work that prevailed,

An easier understanding of the workings (theory),

Difficult to operate situations (e.g. volcanoes, nuclei, etc),

The manipulation, process and multivariate presentation of the data.

But they deprive the experience of:

A direct observation,
The planning and execution of an experiment.

Not appropriate to smaller ages when complex cognitive skills are to be attained.

Perspectives

……..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……..

(Bertrand Russell, On Education, Especially in Early Childhood, 1926)

Bertrand Russell (1872-1980), the third Earl Russell.

One of the greatest philosophers.

He is widely known for his peace initiative during the "cold war" period.

Current Logic in advance from Aristotle is heavily based on his works (Russell's paradox).

Some of his works were written in jail where he was imprisoned because of his political activity.

He was also author of many articles addressed to general public

(http://www.humanities.mcmaster.ca/~russell/)

(Science teaching efficiency)

Perspectives (continued)

Reasons to include Science in the school curriculum:

Cultural - A cultural asset of human civilization
and has its place especially in compulsory education
→ Narration may(?) suffice,

Utilitarian - Basis of technology and thus a sine qua non
for technology dependant societies and a significant means to welfare for the rest
→ Factual knowledge on methods, techniques, data is necessary,

(Science teaching efficiency)

Perspectives (continued)

Reasons to include Science in the school curriculum (continued):

Personal Development - Poses inherent advantages to the cognitive development especially of young persons (Piaget)

→ **Teaching oriented to the development of (complex) cognitive skills is necessary,**

Social - Science literacy is crucial to democracy as an active participatory system many decisions are directly influenced by Science and Technology advances

→ **Teaching towards problem solving and decision making,**

Educational - Helps interdisciplinary teaching approaches Very useful to Mathematics and Language

→ **Holistic approaches and project work are advantageous.**

(Science teaching efficiency)

Perspectives (continued)

In our societies: **Personal Development and Social reasons are highly valued**

Also: **the Utilitarian reason has been declared a core interest at an EU level**

Consequently: **Science teaching has to be efficient**

in order to improve (or at least to not deteriorate) the quality of our societies.

Publication on related subjects:

Science, Technology, and Social Change,
Edited by Diederik Aerts, Serge Gutwirth, Sonja Smets and Luk Van Langehove,
KLUWER Academic Publishers, 1999.

(a brief commentary)

Perspectives (continued)

Syllabus a twofold revision is necessary:

1.-A modernization of the subject matter (*)

Quantum Mechanics, Relativity, Statistical and Particle Physics

Century old human acquirements

2.-Teaching approach and the sequence of topics

A new approach coherent with current knowledge

The historic (and analytical) approach only confusion provokes

(*)George Kalkanis 'Which (and How) Science and Technology Education for Future Citizens?',
'1st IOSTE Symposium in Southern Europe–Science and Technology Education: Preparing Future Citizens',
University of Cyprus, Paralimni-Cyprus 29/4-2/5 2001, proceedings Vol. II pp. 199-214.

(a brief commentary - continued)

Perspectives (continued)

Physics by Inquiry (*) an advantageous choice:

Open type questions and problems

are necessary to complex cognitive skill development

They should, however, be accompanied with scientific discipline.

Physics by inquiry is a valuable resource

(*)Lillian C McDermott, Peter S Shaffer and C P Constantinou, "Preparing teachers to teach physics and physical science by inquiry", Phys. Educ. 35(6) November 2000, pp. 411-420.

(a brief commentary - continued)

Perspectives (continued)

Experiments and Scientific observations - an integral part of Science teaching:

Self-made equipment:

presents inherent advantages, and,
helps towards a better understanding of the basic notions, especially in primary education.

Experiments should be incorporated smoothly to the teaching activities,

An explicit aim the skill of planning an experiment to test a hypothesis

Very important the distinction:

of observational and/or experimental data from their interpretation and the corresponding theory.

(a brief commentary - continued)

Perspectives (continued)

Models in Science - an inherent constituent:

To be incorporated in Science teaching

Enhance the development of reasoning skills (logic)

Very advantageous to decision making.

Developing Models in Science Education, Edited by John K. Gilbert and Carolyn J. Boulter, KLUWER Academic Publishers 2000.

Reasoning in Physics: The Part of Common Sense by Laurence Viennot, KLUWER Academic Publishers.

(a brief commentary - continued)

Perspectives (continued)

Teaching hints:

Everyday observation (*) must be related to Science

Enhancement of observation skills and Appreciation of the importance of Science

What children think (**) must be taken into account

Better understanding of Science.

(*)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.

(**)Everyday Thoughts about Nature, William W. Cobern, KLUWER Academic Publishers 2003.

(a brief commentary - continued)

Perspectives (continued)

Teacher education - a matter of urgency:

Polymorphic Practice (*) – necessary for experimentation.

New and Flexible methods of training (**) – effective alternatives

(*) Polymorphic practice (measurements, experiments...) in Science includes a common psycho motive activity (doing measurements, experimentation...) which consequently is morphed into different levels depending on the (previous) cognitive attainment and/or the mentality of the students. They resemble 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.

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.

An example

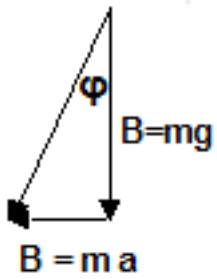
Airplane landing speed

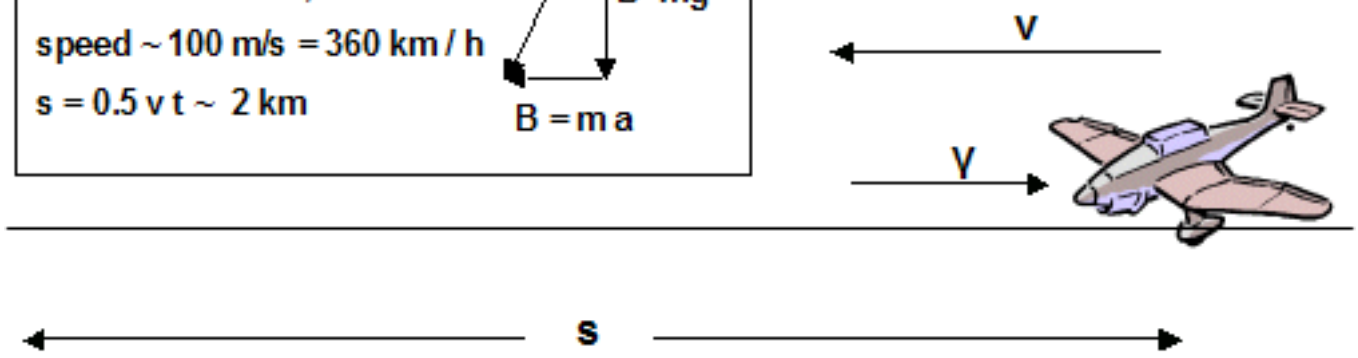
$g \sim 10\ m/s^2$, $\varphi \sim 25^o$

$\rightarrow a \sim 5\ m/s^2$, $t \sim 20\ s$

speed $\sim 100\ m/s = 360\ km/h$

$s = 0.5\ v\ t \sim 2\ km$





A TV commercial

Another example

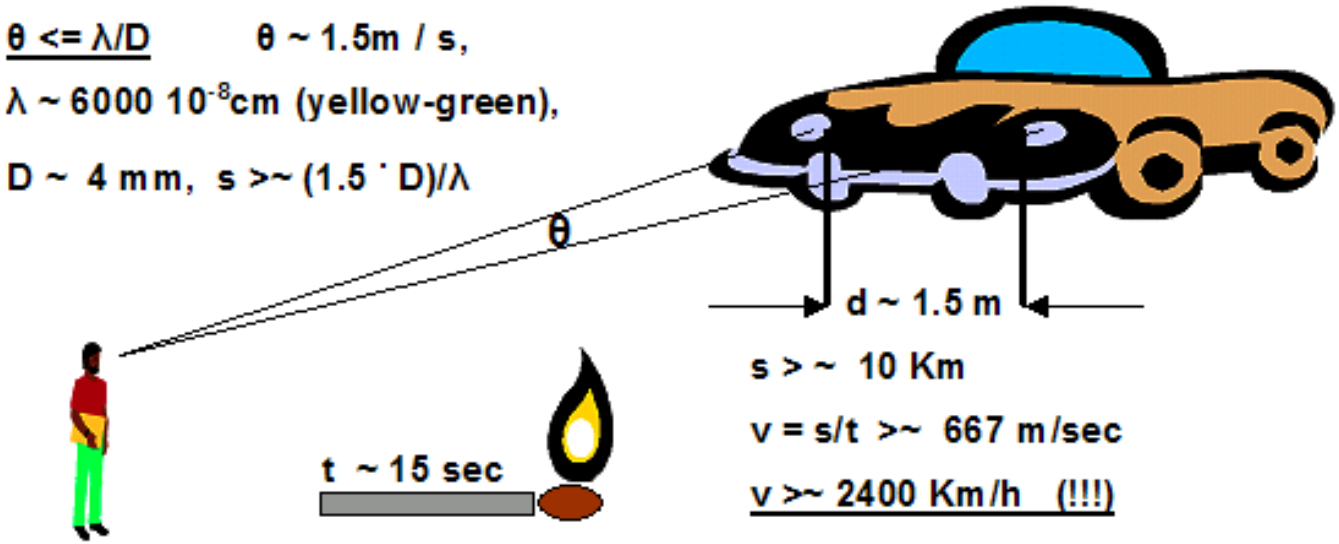
A saloon in the middle of nowhere at twilight.

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?

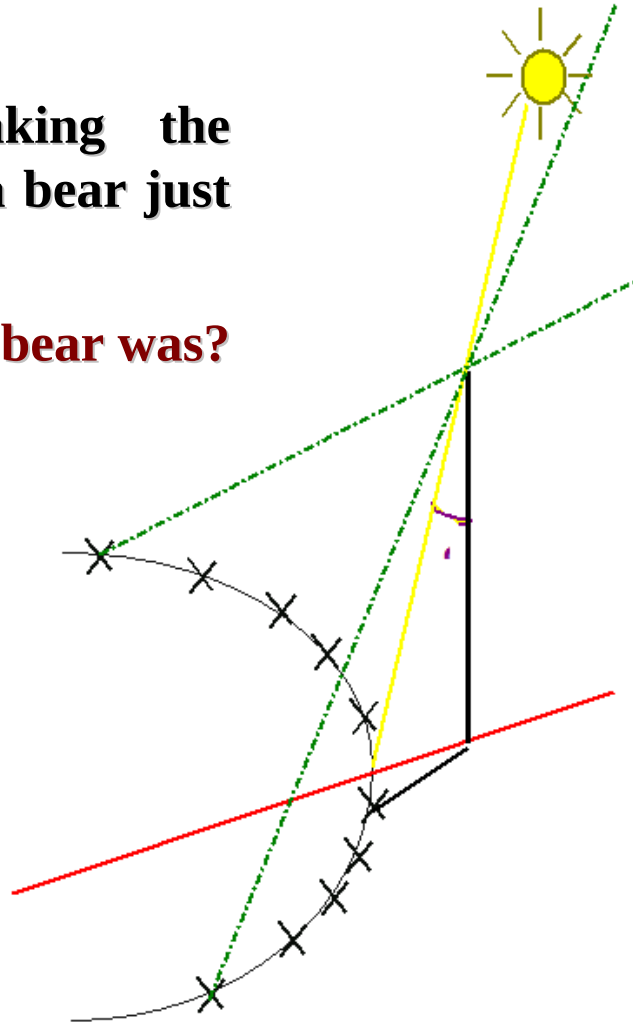


A Fiction (?)

Still another example

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

What colour the bear was?



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 anaesthesia 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?

Some more Homework (!!!)

Etc.

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.

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