“Learning for the Future” series – First Conference

Do we need to do something to our science curriculum so that science can excite all primary and secondary students?

Daniel W K Chan

Po Leung Kuk Laws Foundation College

Po Leung Kuk Luk Hing Too Primary School

Abstract

We all agree that one of the main objectives of science education is to produce scientifically literate citizens who are able to link science and technology with goals for economic growth and human well-being, to improve science-based decision-making and problem-solving, and to build future workforces capable of capturing the advances of science and technology (International Council for Science, 2006:5). From the result of PISA 2006, Hong Kong students scored relatively high in scientific literacy in terms of scientific contexts, competencies, knowledge and attitude. Yet, evidence showed that their interest in learning science, especially girls, declined dramatically when they were studying in higher forms. This finding may pose a question to all educators in Hong Kong , "Do we need to do something to our science curriculum so that science can excite all primary and secondary students?" This paper aims to explore how a school-based science curriculum focusing on hands-on experiments and problem-based learning approaches is built for P.1 to S.3 students in a 'through-train' school to cultivate, to nurture and to develop students' curiosity and imagination at their young age.

Performance of 15-year-old students from 57 countries/regions in scientific literacy in PISA 2006

Country	Mean	S.E.
Finland	563	(2.0)
Hong Kong-China	542	(2.5)
Canada	534	(2.0)
Chinese Taipei	532	(3.6)
Estonia	531	(2.5)
Japan	531	(3.4)
New Zealand	530	(2.7)
Australia	527	(2.3)
Netherlands	525	(2.7)
Liechtenstein	522	(4.1)
Korea	522	(3.4)
Slovenia	519	(1.1)

(The Third HKPISA Report: PISA 2006. p.13. Table 2.21)

Comparison of Hong Kong students' performance in science, mathematics and reading in PISA 2000+, PISA 2003 and PISA 2006

Year	Mean	S.E.
2000+	541	3.0
2003	539	4.3
2006	542	2.5

(Table 2.3.1, p.14, The Third HKPISA Report – PISA 2006)

In scientific literacy, there are no significant differences between the performance across the three cycles.
(The Third HKPISA Report: PISA 2006. p.14)

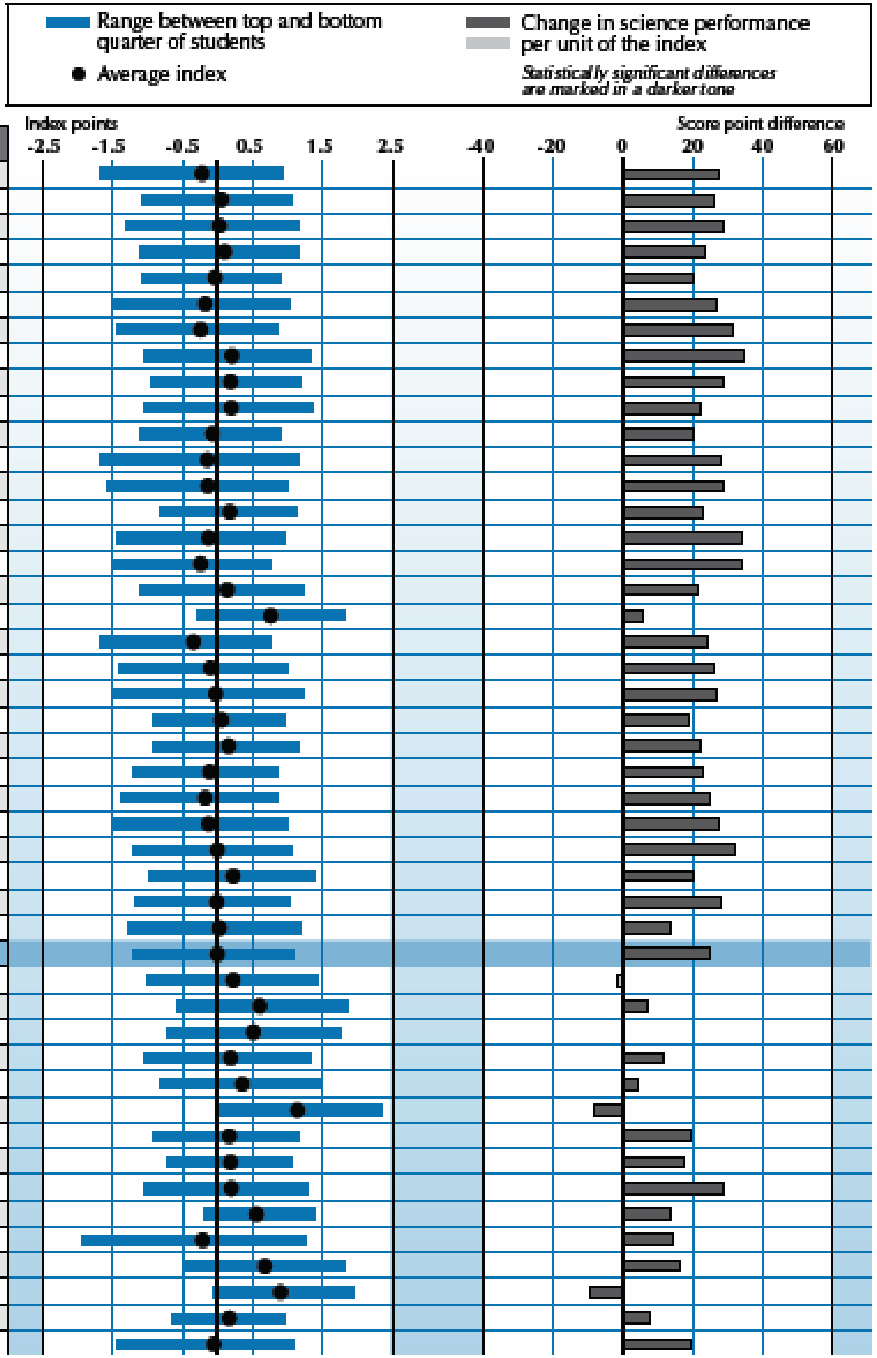
How was the "General Interest in Science" measured in PISA

- Students were asked a set of questions on: their level of interest in different subjects
  - Human biology
  - Topics in astronomy
  - Topics in chemistry
  - Topics in physics
  - The biology of plants
  - Ways scientists design experiments
  - Topics in geology
  - What is required for scientific explanations

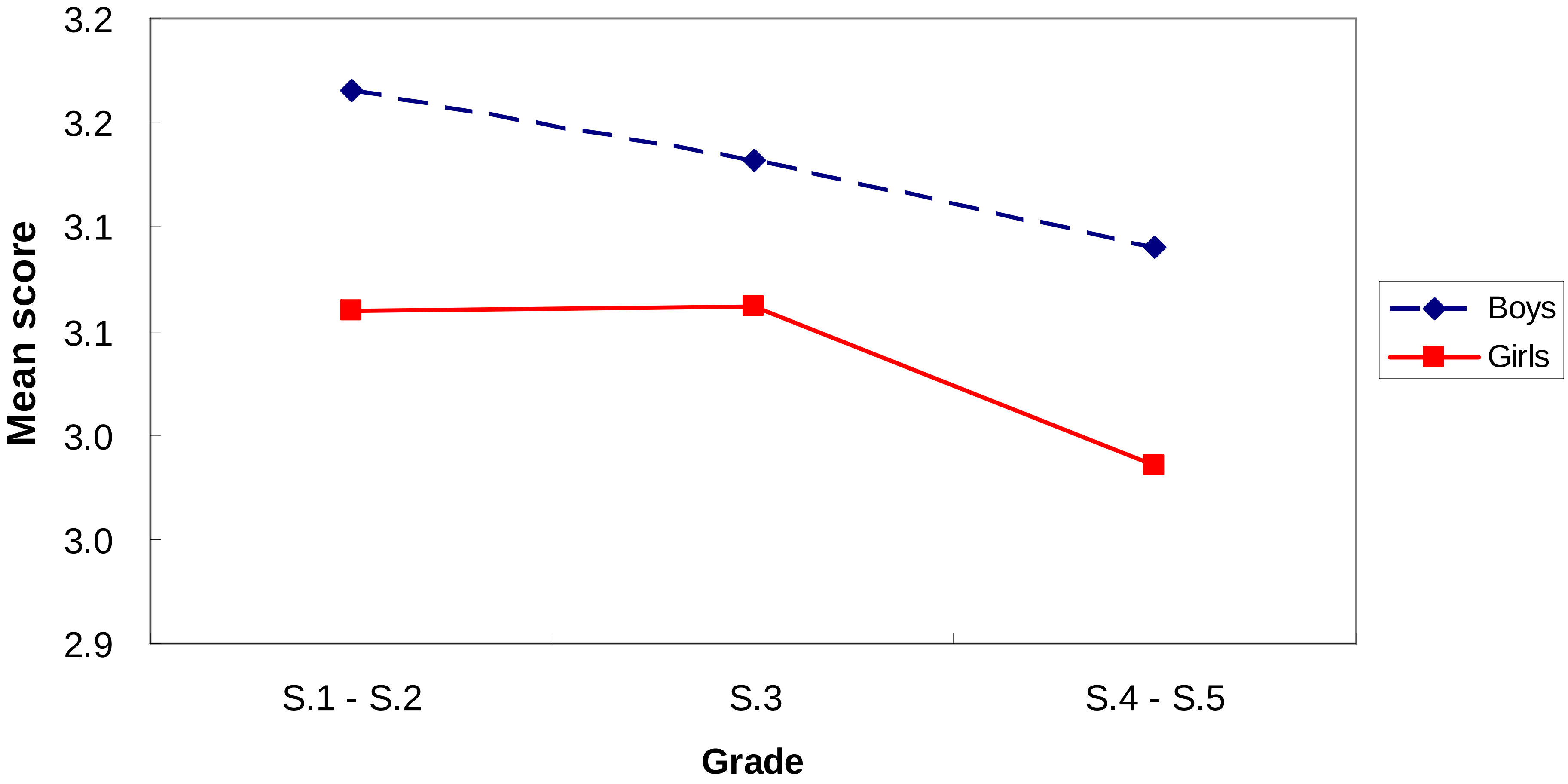
Results in PISA 2006 about "General Interest in Science"

Percentage of students reporting high or medium interest in the following

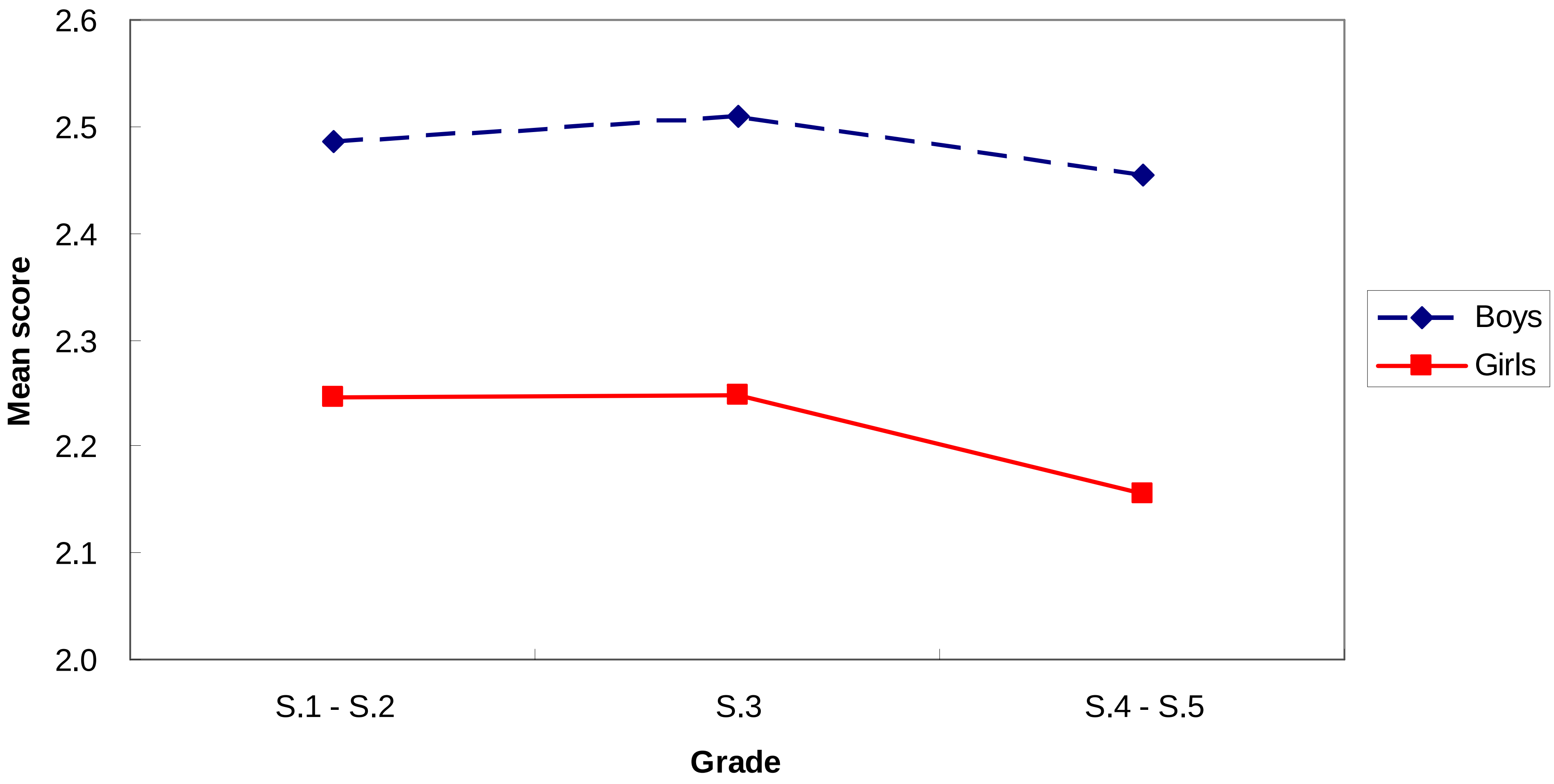
	A	B	C	D	E	F	G	H
Australia	62	46	48	44	40	36	32	29
Austria	76	51	47	49	55	53	43	34
Belgium	73	53	52	52	49	50	42	36
Canada	70	58	64	56	51	45	42	33
Czech Republic	69	57	40	47	40	54	37	35
Denmark	59	39	53	52	37	37	30	36
Finland	66	48	45	41	33	24	31	26
France	75	57	60	65	51	50	48	38
Germany	77	52	59	56	57	54	49	42
Greece	78	55	53	53	57	48	40	47
Hungary	72	59	36	41	44	43	40	37
Iceland	62	60	47	50	36	38	42	31
Ireland	77	47	44	41	55	40	34	33
Italy	74	65	46	44	48	62	49	42
Japan	65	55	48	40	58	34	33	25
Korea	62	52	42	31	45	24	42	28
Luxembourg	75	49	58	55	49	61	45	41
Mexico	84	72	74	75	76	74	65	66
Netherlands	63	36	38	40	39	30	28	27
New Zealand	66	50	55	49	44	38	36	30
Norway	47	52	58	56	36	59	43	43
Poland	77	53	42	36	58	52	43	35
Portugal	61	53	56	58	41	61	47	51
Slovak Republic	69	55	41	46	47	46	44	30
Spain	59	43	36	35	41	43	34	29
Sweden	61	53	50	48	37	44	35	35
Switzerland	51	52	59	55	41	52	47	39
Turkey	78	56	50	47	63	53	42	46
United Kingdom	75	49	55	51	47	41	35	35
United States	68	58	56	52	45	45	42	34
OECD average	68	53	50	49	47	46	41	36
Argentina	73	53	53	55	61	56	46	48
Azerbaijan	68	67	64	70	73	65	62	59
Brazil	78	55	61	58	70	71	48	63
Bulgaria	73	61	52	53	49	62	50	47
Chile	76	62	65	62	63	53	52	47
Colombia	92	79	83	80	86	79	73	75
Croatia	78	62	41	38	55	61	51	51
Estonia	69	64	49	53	49	61	45	43
Hong Kong-China	75	62	55	56	56	53	43	44
Indonesia	90	65	55	59	89	82	52	60
Israel	66	47	45	44	41	44	33	34
Jordan	86	61	73	69	82	68	58	60
Kyrgyzstan	94	74	75	77	90	70	68	62
Latvia	72	69	48	58	42	62	46	35
Liechtenstein	47	51	53	43	42	58	45	40



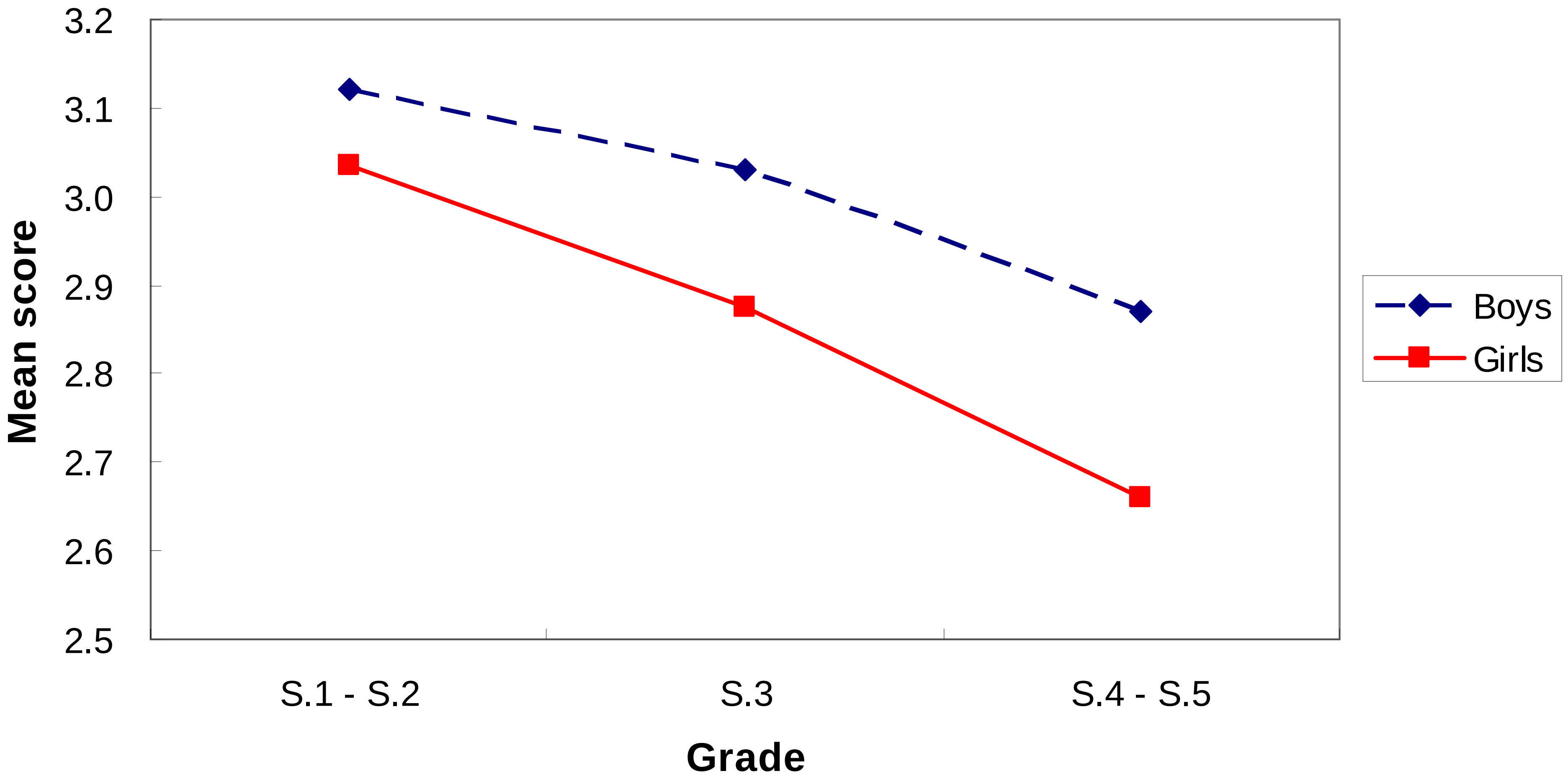
Personal value of science
(Reference: Question 17, PISA 2006)



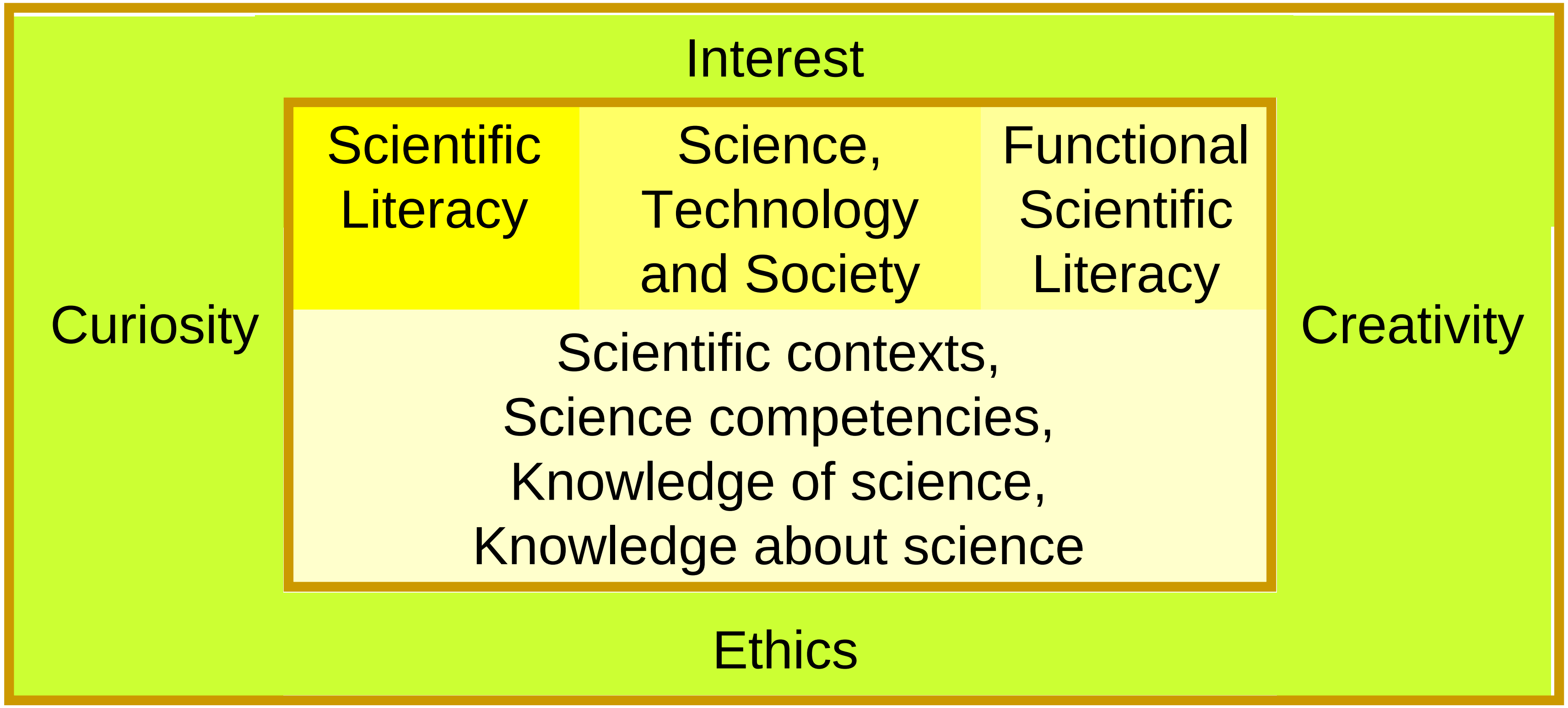
Future-oriented science motivation (Reference: Question 28, PISA 2006)



Instrumental motivation to learn science (Reference: Question 34, PISA 2006)



Science Education Framework



Science educators have struggled for decades with the question of how to design and evaluate curricula through which scientific knowledge ***does not end up in isolated, artificial settings such as tests, but leaves sustainable traces in students' daily lives.***

Michiel van Eijck* and Wolff-Michael Roth

Affective abilities of Hong Kong's students in science

*"However, **nurturing of the affective abilities is most effective through experiential learning or action in a real context.** We therefore recommend science educators and curriculum specialists to **work towards a more action-oriented science curriculum, i.e. promoting active and direct participation in real life issues and problems as an essential component of students' learning experience.**"*

(HKPISA 2006: Preliminary Report. p.43)

General Studies in Primary

There are six strands in the GS curriculum, which are derived from the elements of learning in the KLAs of PSHE, SE and TE . They are:

- **Health and Living**
- **People and Environment**
- **Science and Technology in Everyday Life**
- Community and Citizenship
- National Identity and Chinese Culture
- Global Understanding and the Information Era

Strand 1: Health and Living

- to develop healthy living and eating habits
- to exercise self-discipline in managing one's hygiene, safety and emotions in daily life situations
- to observe safety codes in daily life situations
- to use the support and advice of adults to make personal decisions related to health
- to use appropriate verbal and non-verbal ways to communicate with others
- to manage oneself in daily life situations
- to practise planning one's use of time

Strand 2: People and Environment

- to make careful observation of our surroundings
- to identify and locate features on maps and photographs
- to observe and compare patterns shown on maps and photographs
- to draw pictorial maps to illustrate key features of our surroundings
- to work with peers in taking care of living things
- to develop environmentally friendly practices

Strand 3: Science and Technology in Everyday Life

- to make careful observation, simple measurement and classification
- to observe natural phenomena to predict changes
- to identify the characteristics and changes of materials using senses
- to design and make artifacts with daily materials
- to work individually/collaboratively with peers to identify problems and design feasible solutions

Core Elements for Key Stage One

- observing natural phenomena
- the wonder of Nature
- sources of energy and ways in which energy is used in daily life
- properties of heat
- properties of movement
- how technology contributes to daily life
- using science and technology to solve problems at home
- safety issues in relation to science and technology
- famous scientists and inventors and their contributions

Core Elements for *Key Stage Two*

- planning and conducting simple investigations
- investigating some simple patterns and phenomena related to light, sound, electricity, movement and energy
- efficient transfer of energy and the interaction between energy and materials
- the patterns of changes / phenomena observable on Earth caused by movement of the Earth and the Moon around the Sun
- the wonder of the Universe
- contributions of space exploration to everyday life
- the application and effects of technological and scientific advances in daily life
- technological advances leading to the detailed observation of distant big objects and very small objects

Suggestions for Extension

- they might take part in science competitions, visit resource-based learning centres such as laboratories in secondary schools or institutes.
- Schools may also consider extending the depth of study on all or part of the core elements. Schools can get students to undertake the sort of scientific investigation that requires them to make hypotheses, design and carry out experiments, collect and analyse data, make judgements and report results and conclusions.

The question lies with….

- **Is the existing hardware for scientific investigation of the primary schools in Hong Kong good enough to cater for the needs towards the establishment for the '*extended science curriculum*'?**
- **Would there be sufficient expertise in the *General Studies Department in primary schools* good enough to support the establishment for the '*extended science curriculum*'?**

Scientific investigation in primary school

- With the increase in prominence of the investigative approach in Hong Kong science curricula from the primary to the senior secondary level, ***there is urgency for local science educators including primary school teachers to gain a better understanding of pupils' existing cognitive understanding and reasoning ability for performing science investigation.***

(Lee Yeung Chung and Ng Pun Hon (2004) Hong Kong primary pupils' cognitive understanding and reasoning in conducting science investigation: A pilot study on the topic of "Keeping Warm". HKIEd APFSLT. Vol 5 (3) Article 8.)

http://www.ied.edu.hk/apfslt/download/v5_issue3_files/leeyc.pdf

Scientific investigation

- "Scientific knowledge and understanding are not only, nor even principally, about other people's discoveries.
- An important and integral part of primary education is to help children develop the ability to investigate things for themselves: to perceive problems, think up possible answers, find out whether their ideas stand up to testing and communicate their findings clearly.
- Scientific investigation has an important and direct contribution to make to this process, but it also has a wider relevance in helping to develop a critical awareness of science and its influence within the community."
- The first aim of investigations in science is to increase the knowledge and understanding of those who carry out, whether they be research scientists or children in primary school.

(Martin Wenham (2004) Understanding Primary Science: Ideas, Concepts & Explanations. p.5, 8)

Patterns of investigative study

- The two extremes of learning-style can be represented by the 'knowledge first' and 'experience first' models:

- ***Knowledge first***: facts, concepts and theories are learned and integrated with remembered experience and existing knowledge. They are then made meaningful, extended and modified by being applied to observation, interpretation and prediction of real-life situations.

- ***Experience first***: hands-on experience, coupled with existing knowledge, is used to develop a new idea. This is then verbalized, communicated and made meaningful by modifying or extending existing knowledge.

(Martin Wenham (2004) Understanding Primary Science: Ideas, Concepts & Explanations. p.5-6)

Patterns of investigative study (continued)

- In practice, no one seems to rely on either of these methods. Any person's learning is likely to be a complex, interactive activity within which elements of both can be identified, but individuals may show a marked preference for one of these styles of learning and avoid the other.

(Martin Wenham (2004) Understanding Primary Science: Ideas, Concepts & Explanations. p.6)

Investigations in primary science

Goldsworthy (1998)

- Fair testing
- Classifying and identifying grouping objects or events
- Pattern Seeking surveys
- Exploring observations made over time
- Investigating models
- Making things/Developing systems

Progressive expected learning outcomes leading to junior secondary

P.1 to P.2 students

- **are interested in and understand the world around them**
- **Are able to demonstrate their interest and in scientific investigation.**
- **Are aware of the safety issues of scientific investigation**

P.3 to P.4 students

- **Are able to identify questions about the world around them**
- **Are able to care about the environment**
- **Are aware of the principle of fair testing in doing experiments**
- **Are able to tell the result of their investigation**

P.5 to P.6 students

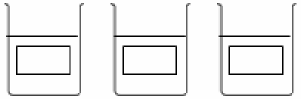
- **Are able to collect data through instrument or apparatus**
- **Are able to form hypothesis, to design their own experiments, to control variables and to examine the procedures as well as the result**
- **Are able to draw evidence-based conclusion about their investigation**

Investigative study (Science, Primary 1)

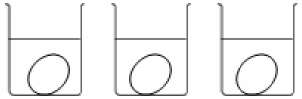
Example 1

- Key learning topic: Teeth brushing
- Learning objective: Students will know that it is necessary to brush teeth after eating.
- ***Investigation***: Every day, when we brush teeth, we use toothpaste. Do we really need to use toothpaste to brush teeth after eating?
- Students then investigated whether toothpaste is the necessary material to remove dirties from teeth (eggs used as a model of teeth). Students needed to think about any other things which can also be used to clean teeth.

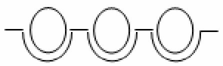
Investigative study (Science, Primary 1)

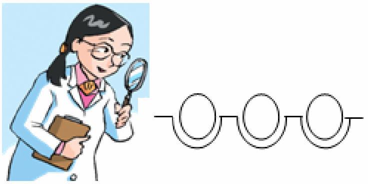


1. Label 3 beakers (with 250ml lemon tea).



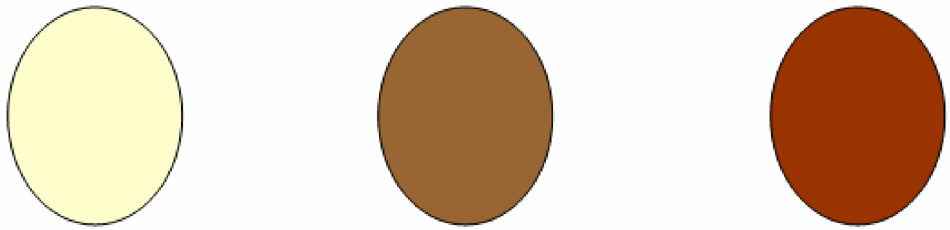
2. Put 3 hard-boiled eggs into 3 labeled beakers separately and wait for 10 minutes.





3. After 10 minutes, take out the hard-boiled eggs from the beakers and follow the instruction written on the labels to wash the hard-boiled eggs.

4. Repeat steps 2-3 for two times, observe the color change of the hard-boiled eggs and draw the results on the worksheet.



Washing eggs with toothpaste and water	Washing eggs with water only	Without washing

✓ Interest: related to daily life
✓ Curiosity: what is the magic in toothpaste which can clean teeth?
✓ Creativity: study whether different types of things (e.g. tap water only) can also be used to clean teeth.

✓ Control variables / fair test: Test one potential cleaning agent each time
✓ Repeated experiment: do the investigation again to ensure the result is accurate.

Discover science in our daily life → Habit of scientific investigation → Innovation for better life

Example 2: Sugar test

- To find out the amount of sugar in foods.
  - How to find out the truth without using their sense of taste?
  - Experiment procedures
  - Data analysis skill
  - Conclusion

Discover science in our daily life → Habit of scientific investigation → Innovation for better life

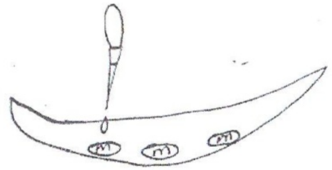
- Develop their habit of scientific thinking skills
- We focus on some items:

1. Hand-writing skill and design their own procedures. (e.g. Food colouring)

Group 1

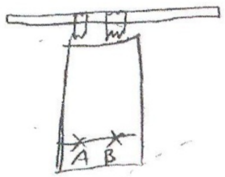
First, put three M&M(3) in the watch glass.

Second, use the dropper to put some water in the watch glass.



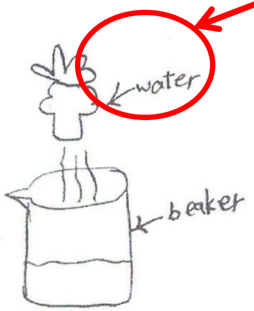
third, use the toothpick make a spot on the absorbing paper.

4. Fourth, use the sticker to stick the absorbing paper on the chopstick.



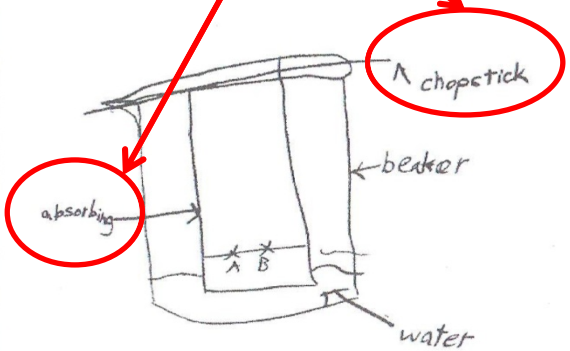
Writing skill / logical thinking

5. Fifth, put the water in the beaker.



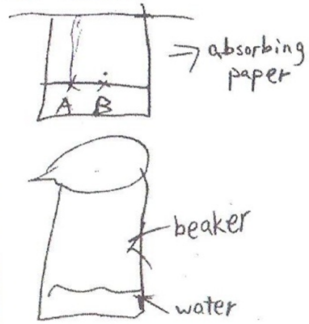
6. Sixth, put the absorbing paper in the beaker.

Labeling of drawing



7. Seventh, wait for ten minutes to see the result.

8. Finally, get out the absorbing paper and see the result.



Discover science in our daily life

Habit of scientific investigation

Innovation for better life

- Develop their habit of scientific thinking skills
- We focus on some items:

1. Hand-writing skill and design their own procedures. (e.g. Food colouring)
2. Open mind to ‘Negative’ result.
3. Fair Test.

New senior secondary science curriculum in Hong Kong

- Scientific investigations become a compulsory part in NSS science curriculum.

    - Biology (20 hours)
    - Chemistry (20 hours)
    - Physics (16 hours)
    - Integrated Science (14 hours)
    - Combined Science (~18 hours)

Total lesson hours for science subjects: 270

Investigative approach in science

Question

Hypothesis

Experiment / investigation

Data Collection & Analysis

Answer the question / Raise a new question

Curiosity,
Interest,
Creativity,
Ethics

Scientific literacy

A reality check for non-science students

Biotechnology-related curriculum

	S.1-3 I.S.	NSS L.S.	NSS Bio/I.S./ Comb. Sci.	S.4-5 Biology	S.6-7 Biology	University
	No related topic	Public Health (e.g. ...chnology- ...d societal ...s. Yet, ...tific ...ledge about biotechnology may not be included.)	**I.S.:** From gene to life **Bio:** Part II, VII and VIII **Comb. Sci:** Genetics and Evolution	Genetics	Genetics	Biotechnology Biology Medicine etc.

Our target group of students

Less and less students can learn biotechnology-related subjects.

Biotechnology curriculum *strengthens* and *enriches* current science curriculum

Integrated Science (S.1-3)

Biotechnology (S.1-3)

Biotechnology knowledge, techniques/skills and attitudes

Science competence

Curiosity, interest, creativity, ethics

What areas does our biotechnology curriculum support I.S. curriculum?

- **Knowledge**
  - Molecular biology
  - Cell biology
  - Microbiology
- **Skills**
  - Experimental techniques
  - Investigative skills
- **Attitude**
  - Interest
  - curiosity
  - Ethics

With our school-based biotechnology curriculum, our students show

- the enrichment of ***knowledge*** on
  - Molecular biology (e.g. How do DNA, RNA and Proteins work? What is the role of gene mutation in cancer?)
  - Cell biology (e.g. What do plant cells need so that they can grow? What are the signals when cells are going to die?) **[Plant tissue culture / Neuronal culture]**
  - Microbiology (e.g. What is the use of microorganisms? How to stop the growth of fungi?)

With our school-based biotechnology curriculum, some of our students show

- the enhancement of ***skills*** on
  - Experimental techniques (e.g. Students know how to culture bacteria in an agar plate, do plant tissue culture, extract DNA, operate a high-speed centrifuge, use an inverted microscope etc.)

  - Investigation (e.g. Students are able to identify/look for/think about more variables in an investigation. For example, students would suggest to try more different concentrations of sugar solution in the seed-germination experiment. Students conduct repeated experiments to ensure that the experimental result is more reliable. Students have much experience in getting results which are different from other classmates.)

With our school-based biotechnology curriculum, some of our students show

- Great interest in science
  - Students are always engaged in doing experiments.
  - Students suggest to do some experiments which cannot be found in the I.S. and biotechnology curricula.
  - Students sometimes raise questions about recent issues of biotechnology during/after the lesson.

- Curiosity in science
  - Students usually suggest to test more variables. For example, students are curious about the possibility of the co-culture of animal cells and plant cells.

- More concerns in the ethical issues related to biotechnology
  - Students sometimes raise questions about ethical issues of biotechnology during/after the lesson. For example, should we eat green fluorescent chicken? Should some of our cells (or cancer cells) be labeled with green fluorescent protein?

Ethics (scientific ethic e.g. honesty, social ethics, …)

- Key learning topic: Preservation of food (S.1 Biotechnology)
- Learning objective: Students will know that cold temperature cannot kill most micro-organisms.
- ***Investigation***: You're a boss of an ice-cream company. Yesterday's night, there was no electrical supply. All of your ice-cream melted. This morning, when you came back the company, you turned on the electrical supply. Two hours later, all melted ice-cream changes to solid state again. Now, do you still sale this batch of ice-cream to your customers?
- Scientific knowledge → Make decision (Ethical concern)

  (Experiment: culture bacteria from melted ice-cream)

Students' view about the curriculum content

The most interesting topic chosen by our students

S.1 topics:

	Classification of organisms			
	Animal	Plant	Bacteria	Fungi
S.1 students	52.6 %	6.6 %	16.8 %	24.1 %

	Classification of organisms	Ecosystem	Culture of microorganisms
S.2 students	33.3 %	9.5 %	57.1 %
S.3 students	28.8 %	30.5 %	40.7 %

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Students' view about the curriculum content

The most interesting topic chosen by our students

S.2 topics:

	Biological prefixes and suffixes	Atom, mole, molar mass, molarity	Plant tissue culture	Cellular organelles	DNA and chromosome
S.2 students	14.3 %	32.3 %	53.4 %	-	-
S.3 students	4.1 %	18.9 %	29.5 %	1.6 %	45.9 %

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Students' view about the curriculum content

The most interesting topic chosen by our students

S.3 topics:

	Gene and Genetic diseases		
	DNA extraction	The concept of gene	Heredity and genetic diseases
S.3 students	54.6 %	17.7 %	27.7 %

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Do our students find the biotechnology curriculum *interesting*?

	Interesting	Neutral	Not interesting
S.1	34.3 %	35.5 %	30.2 %
S.2	56.9 %	31.3 %	11.8 %
S.3	59.0 %	29.1 %	11.9 %

Less students think that biotechnology curriculum is not interesting when they learn more about biotechnology.

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Which part of our biotechnology curriculum do our students appreciate most?

	Topics	Experiments	Teacher and his/her teaching	Assessment	Other
S.1	7.9 %	83.5 %	5.8 %	0.7 %	2.2 %
S.2	15.6 %	66.7 %	15.6 %	1.5 %	0.7 %
S.3	23.4 %	58.6 %	14.8 %	3.1 %	0.0 %

Many students appreciated the experiments done in biotechnology lessons.

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"To raise new questions, new possibilities, to regard old problems from a new angle, requires creative imagination and marks real advance in science. "

Abert Einstein

The most exciting phrase to hear in science, the one that heralds new discoveries, is not Eureka! (I found it!) but rather, "hmm.... that's funny...."

Isaac Asimov