Random (probably orthogonal) thoughts on Scientific Investigations in Science Education
有關科學探究的胡思亂想

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Discussions on selected problems that I observed in recent years as:

- a supervisor of MPhil/PhD students

- a teacher in undergraduate courses/final year research projects

- an adjudicator in science project competitions
  (F7- primary school students)

- a subject external examiner (General Studies) for B.Ed. (primary) programme at HKIEd (not any more!)

- someone engaged (engaging) in the revision of HKCE, HKAL (new senior secondary) physics curriculum

- a parent

Front Matter

Science Education (role)

- Languages: to speak/express oneself and pick up accompanying cultural aspects

- Mathematics: to count/calculate/do consistent reasoning (logic)

- Science: to understand the natural world that we are a part of, to appreciate our position in the natural world, and the prepare to act in an educated way when dealing with science issues

- [There are other subjects that are also of importance in the development of young people, e.g., history]

Through Science, a student will acquire

- an active mind (why and how)
- an appreciation on how causality works
- an appreciation on what is really basic
- a broader mind (look farther (stars/planet/Universe), look closer (water/molecules/atoms), look at ourselves (life))
- an appreciation on accurate descriptions (and a distaste on ambiguity)
- an appreciation on how science (through the work of people!) had led to technological advancements that, in turn, led to improvements of living standards (科教興國)
- basic skills to live meaningfully in the 21st century
- an appreciation on the beauty of Nature
- basic ideas based on which one may consider a career path in science and related areas

Basic Goals (the very least) up to P6:

- do not hate science!

- curious about various phenomena around us

- comfortable with observing, measuring, recording, describing phenomena

- realize there are much more interesting science to be learnt and discovered

- recognize science as of relevance to a person being a person (daily-life experience, how things work, life, a possible career path in science)

Looking into the future (2012 onwards):

- An era when multiple degrees become common

In a rapidly changing world, a first degree in a basic science followed by a masters' degree on a more professional/career-oriented discipline is a good combination.

Main Body –

In what follows, we will see that

- cultivate an environment (professional training, time/leisure, team work, etc.) for science teachers to perform well is the KEY ISSUE

Problems encountered in recent years in different occasions (referring mostly to products of our local school system):

Problem: Students aimed too high a goal without proper preparations

"Too wide are the eyes for a small stomach (眼闊肚窄)"
"Eyes stared up high but hands are too short (眼高手低)"

Problem stems from:

- too descriptive an approach in PS/SS (OK in PS though)

- lack of experience in carrying out achievable/marginally achievable tasks in investigative studies (IS)
  -- lack of understanding of one's ability and interests and how they match

- too traditional school/university curriculum

- plus the problems to be discussed later

Primary schools (PS) could help by:

- well-planned IS with **progressively achievable (marginally achievable) tasks** so that students can learn from experience and build up their skills/tricks

- making students understand the difference between watching people diving and practicing diving (same reason works for why so many people stayed up to watch soccer games, but fewer young people actually play soccer)

Key Point:

• **Need dedicated science teachers plus appropriate training to work for a goal and an organization that is worthy of the dedication. The latter has to do with the creation of a good working environment for teachers.**

(pulling a group of teachers together will certainly help)

Problem: Loss of patience and lack of ability in carrying out multi-step (more than 5) numerical manipulations

Problem stems from:

• a sense of downplaying “manipulations” (regarded as “low level activities”) after “understanding the principles” (in Math and science training)

• a trend of **describing science (or talking about science)** and avoiding math in science subjects (quite severe in SS)

Danger:

• missed the quantitative nature of science

PS could help by:

- designing IS tasks that (sometimes) require patience and careful manipulations on the part of the students

- asking students to **check** what they observed, measured, concluded

Problem: A lack of sense that "accuracy" is an integrated part of science **(**對「 精確」的忽視**)**

[Note: Accuracy refers to several aspects depending on the context]

Problem stems from:

- emphasized too much on "observe", "describe", "explore", etc. and downplayed some basic skills

PS could help by:

- Designing hands-on IS tasks in which accuracy is emphasized
- E.g., measuring length, volume, weight, time accurately or finding ways of measuring a quantity accurately given some tools, making models to precision
- E.g., bringing “accuracy” in daily-life examples: body-temperature measurement, 100m record in sport gala, temperature and rainfall reports from HKO, accuracy in manufacturing, etc.

- it is really to the benefit of the students to build up a habit of “accuracy”

Accuracy in describing science

Problem stems from:

• some principles can hardly be self-constructed through observations (or it would take hundreds of years), discussions, or debates (有些科學結論是十分不尋常易見的)

• i.e., science is after all a not-so-trivial human endeavour

PS could help by:

• nurturing skillful teachers who know the subject matter sufficient well (and with a certain depth)

• and who will cut in at appropriate times to describe/explain the science principles in accurate terms at the appropriate level

This relies heavily on TEAHCERS' PREPARATION and TEACHERS' TRAINING opportunities.

[I see this as the biggest hurdle!]

Problem: A habit of not writing things down in doing IS
(疏於記錄、分析**)**

Problem stems from:

• a gradual disappearing ability of taking notes among students
(all canned exercise books/worksheets/books/CD/etc)

• a lack of confidence on using language skills

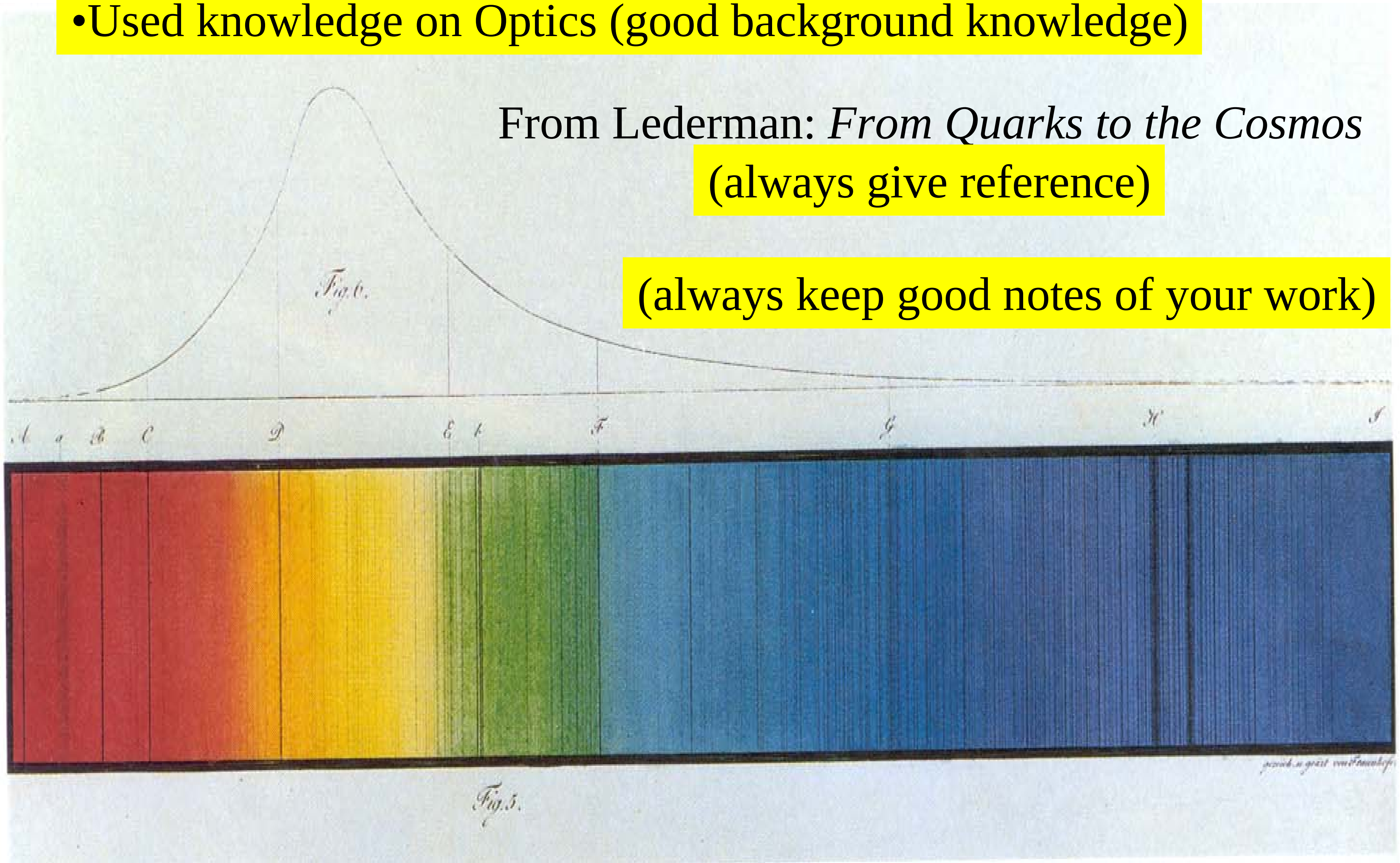
PS could help by:

• getting students into the habit of keeping a Science or General Studies IS notebook

• students can drop down hand-written notes, images, pictures, records of observation, discussions, results, reading, source materials, etc.

By mid-19th century, scientists (**Fraunhofer**) observed solar spectrum

- Well-planned and designed experiments
- Used knowledge on Optics (good background knowledge)



From Lederman: *From Quarks to the Cosmos*

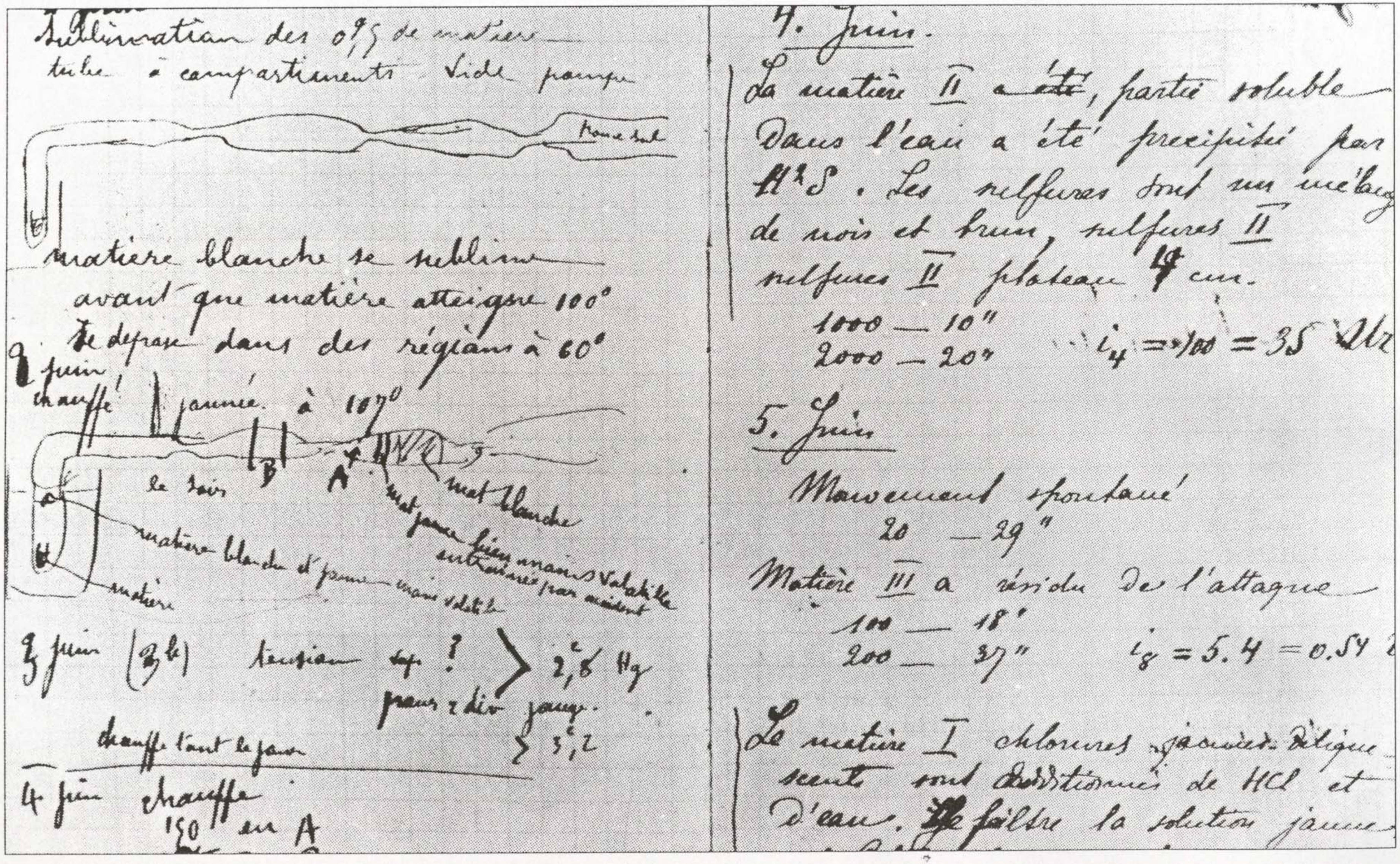
(always give reference)

(always keep good notes of your work)

Notebook of Marie Curie

Keep record of what we observed/thought/read/etc

Marie Curie


Sublimation des 0g5 de matière
tube à compartiments vide pompe

matière blanche se sublime
avant que matière atteigne 100°
se dépose dans des régions à 60°

3 juin chauffé jaunie à 107°

le soir B A mat blanche
mat jaune volatile
matière blanche volatile
matière

3 juin (3h) tension 4 ? 2,8 Hg
pour 2 div jauge.
3,2

chauffé tout le jour

4 juin chauffé
150 en A

4. Juin.

La matière II a été, partie soluble dans l'eau a été précipitée par H^2S. Les sulfures sont un mélange de noir et brun, sulfures II
sulfures II plateau 19 cm.

1000 — 10"
2000 — 20" i_4 = ×100 = 35

5. Juin

Mouvement spontané
20 — 29"

Matière III a résidu de l'attaque
100 — 18"
200 — 37" i_8 = 5.4 = 0.54

La matière I chlorures sont dissous de HCl et d'eau. Je filtre la solution jaune

I also dropped notes on references that I read!

17/10/2001

MG with imitation

Slanina, Physica A 286, 367 (2000) ; cond-mat/0006098
cond-mat/0107236

Also seems important : { Kalinowski et al Physica A 277, 502 (2000)
Paczuski and Bassler, PRL 84, 3185 (2000)

- Some optimal amount of imitation seems good!

Parameters : p , p_1 switching of behaviour.

Some value of p for which σ^2 is minimum.

$p_1 = 0$: Groups of winners and losers persist
$p_1 \neq 0$: Groups can break

follow action (decision-maker doesn't want others to know his strategies)
Commission ε.

- MG on small-world network? (range of p)

Problem: Too eager to be innovative! **(「過度」求新)**

Problem stems from:

- the popular voice of encouraging young people to do something new and original (that is not bad at all!)

- viewing repeating previous work as “low level job”

- lack of patience (as discussed)

It is dangerous because:

• students tend not to look for what has been done
• students tend to ignore the techniques and tricks in previous work
• students do not have the chance to go deep in understanding what others have done (technically)

By first repeating some existing works:
• students can focus on understanding how others have thought and done, and in doing so, they pick up the necessary skills for possible improvement of the work

In fact, in doing research, we often start with reproducing some existing works, e.g., repeating an experiment, repeating a computer simulation, repeating a derivation or a calculation, etc.

•The idea is to crack the untold tricks and techniques, and to set up some "tools".

• Most innovative works are based on a thorough understanding of what worked in the past.

• The belief is that if one understands in depth the trick of doing one thing, it is highly likely that he/she could think of something new to do!

It may sound a bit remote, but could PS help? Of course!

PS could help by:

- designing some IS tasks on asking students to first re-construct a sample product and after that improve on it
- designing IS tasks on reading (understanding) how things really work and reporting findings to classmates

Again, teaming up teachers' forces will be useful!

This could also be a good way to initiate a science project competition among schools

E.g., every year we see the coin-sorting device in PS science competitions (holes of different sizes in different layers)

• teacher could first construct a (already quite good) sample

• ask students to look at the sample and find ways to re-construct the sample (“reverse engineering”) – in this process, students learn the necessary skills and experience, based on which improvements on the design may be possible

• ask students to improve on the design (e.g., setting an improved specification)

By having more experience on reproducing stuffs, I believe our young people can actually be MORE innovative!

Problem (intrinsic): Language problem in Hong Kong is an intrinsic problem. Using a dialect (Cantonese) in learning causes problems. For example, students are usually unable to enjoy many wonderful TV (DVD) documentaries with either English or Putonghua commentary. Learning by reading books in English or simplified Chinese may also be problem.

And this problem can only become more severe as the students proceed to higher forms or university education!

A no-way-out situation?   Could PS help?

PS could help:

- for science education – teachers select good supplementary reading materials, e.g., “hundred-thousand whys”, “the young Newton”, or even “Doreamon” (DingDong) and design some focus topics to encourage students to read and learn
- teachers select good documentaries (with Cantonese commentary or Chinese subtitles) for students
- this serves as an easy way to introduce students to the important science problems that people are working on (a weak point in HK science education)

Possibly, science education can even play an important role in language enhancement programmes, as there is always a group of students who find reading science books more interesting than reading Harry Potter!

Problem: Another language problem is that students often do not present their work clearly (no matter which language they use)

Problem stems from:

- not much chance to practice
- the low-level of usage of words in the media in general
- the descriptive way of learning science

PS could help by:

• simply letting students TALK!
• encourage short discussions with classmates
• encourage short talks on something that the students can understand (e.g., how something works) in good usage of a language
• encourage talking while thinking, and thinking while talking (very often we see PS students memorizing a whole script in science competitions and that looks painful and unintelligent)

Problem: Pseudo and quasi team-work

Problem stems from:

• unfamiliar with how a team works and how to make a team works

• general lack of guidance in doing team-work

• poor time-management among students

What happens often is that near the due date, the team gets together and rush!

But team-work is needed in almost every job!

PHYSICAL REVIEW D, VOLUME 63, 091101(R)

Search for the supersymmetric partner of the top quark in $p\bar{p}$ collisions at $\sqrt{s}=1.8$ TeV

T. Affolder,[23] H. Akimoto,[45] A. Akopian,[38] M. G. Albrow,[11] P. Amaral,[8] S. R. Amendolia,[34] D. Amidei,[26] K. Anikeev,[24] J. Antos,[1] G. Apollinari,[11] T. Arisawa,[45] T. Asakawa,[43] W. Ashmanskas,[8] F. Azfar,[31] P. Azzi-Bacchetta,[32] N. Bacchetta,[32] M. W. Bailey,[28] S. Bailey,[16] P. de Barbaro,[37] A. Barbaro-Galtieri,[23] V. E. Barnes,[36] B. A. Barnett,[19] S. Baroiant,[5] M. Barone,[13] G. Bauer,[24] F. Bedeschi,[34] S. Belforte,[42] W. H. Bell,[15] G. Bellettini,[34] J. Bellinger,[46] D. Benjamin,[10] J. Bensinger,[4] A. Beretvas,[11] J. P. Berge,[11] J. Berryhill,[8] B. Bevensee,[33] A. Bhatti,[38] M. Binkley,[11] D. Bisello,[32] M. Bishai,[11] R. E. Blair,[2] C. Blocker,[4] K. Bloom,[26] B. Blumenfeld,[19] S. R. Blusk,[37] A. Bocci,[34] A. Bodek,[37] W. Bokhari,[33] G. Bolla,[36] Y. Bonushkin,[6] D. Bortoletto,[36] J. Boudreau,[35] A. Brandl,[28] S. van den Brink,[19] C. Bromberg,[27] M. Brozovic,[10] N. Bruner,[28] E. Buckley-Geer,[11] J. Budagov,[9] H. S. 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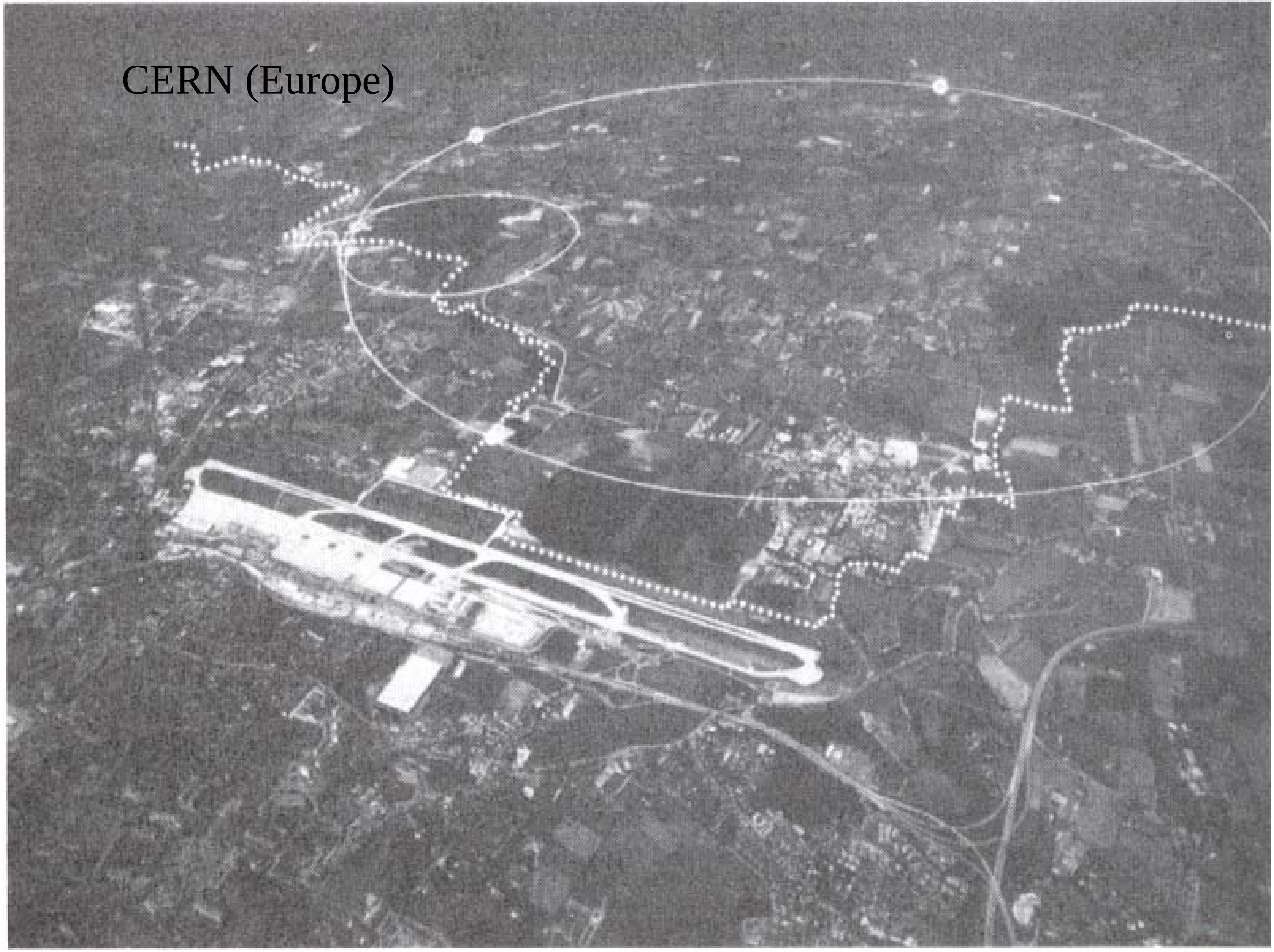
47 research institutions


CERN (Europe)

PS could help by:

- asking students to set up a schedule
- occasionally checking on students’ progress
- asking students to divide labor in such a way that each student feels that he/she is an important part of the studies

- this will be a life-long useful skill

Again, this needs dedicated teachers.

Problem: Too much information, but too few who actually read them!

Problem stems from:

• the misconception that getting hold of some information is equivalent to understanding the information (if so, that could have happened as soon as there were libraries!)

PS could help by:

• not only encouraging students to search for information, but also to read and understand the information

• this skill provides an edge over others

Problem: Functionality vs curiosity in choosing tasks

Problem stems from:

• an inclination towards functionality in choosing school projects (as opposed to curiosity-driven questions), perhaps easier for students

• E.g., we see many more projects like "how to cool a bottle of soft drink quickly", "how to recycle water in a house", etc. in science project competitions in recent years than investigations on curiosity-driven topics

But, students may find many **curiosity based questions** more interesting.

Problem: Too afraid of failure!

Problem stems from:
• failure usually leads to low score!
• failure usually implies more work to follow!
• that sounds stupid!

PS could help by:
• allowing honest (tried hard) mistakes
• letting students know there may be successful failure (at least they learned in the process)

Problem: And yet, lack the drive for excellence

Problem stems from:

• students tend to perform on par and not to stand out (peer pressure)

• students tend to do the optimal amount of work – a minimum that will lead to a reasonable grade

• don’t see a good reason to do better

PS could help by:

• finding ways to encourage a sense of going for better performance among students (I don’t have good suggestions)

• obviously this is a good attitude

Summary -- Obviously, science education (investigative studies in particular) has much to do in solving these problems at an early age.

Actions A –

• create/motivate a group of dedicated teachers
• plan collectively for good strategies for different grades
• share resources
• make science as important as languages/math

Actions B –

• provide serious and tougher training for science teachers, as it really requires a good mix of basic understanding of the subject matter AND teaching strategy to make science alive in schools

And the result will be –

- Primary 6 graduates whom every secondary school loves to have!
- Graduates who are equipped with many useful skills for the rest of their life!

-- The END --

A few years ago, I was asked to talk to a group of secondary schools students when they started to plan for their entries to a science project competition. The following pages are excerpts from that talk.

Carrying out an scientific investigation

- Aim and Objectives: (Broader view and narrower objectives) (研究目的)

- What others have done on your and related problems? [Be honest, give references] (研究現況)

Involves search for information, **reading**, digesting information, discussions among team members, setting up goals

- Based on what you read, what’s new that can be done? (Point out how your work differs from others in an honest way) (定下研究目標)

- Here is where curiosity plus knowledge from background reading work!

- The questions WHAT IF…, HOW ABOUT…, WHY NOT…, WHY… would help!

- How to achieve your goal? (Methodology) (研究方法)
  Select strategy (what to do), division of labor, set up time schedule, turn project into smaller portions, aware of critical portions, test runs on critical portions first, keep raw data, record difficulties/thoughts, adjustments, re-design, further testing, put portions together, improve performance, what to do next?, etc.

- It is the process that is important! You learn as you go through the process!

- Reporting: Draw conclusions, discuss difficulties, directions for further work, etc. Written/oral presentation, poster (總結研究與報告)

(prepare an honest report through team effort)

- Always give references (研究參考資料)
- Perfectly OK to ask others for opinion/help. But always give deserved credits to whoever assisted you!

Do your project seriously, with *passion*, and HAVE FUN!