Science Education Research
What is it, why do it?

Homi Bhabha Centre for Science Education, Tata Institute of Fundamental Research
V. N. Purav Marg, Mankhurd, Mumbai – 400088
www.hbcse.tifr.res.in

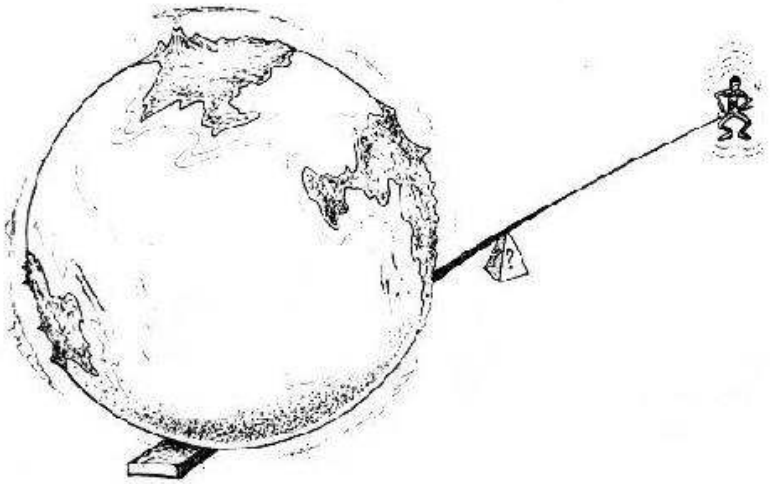
Why did we choose to learn Science?

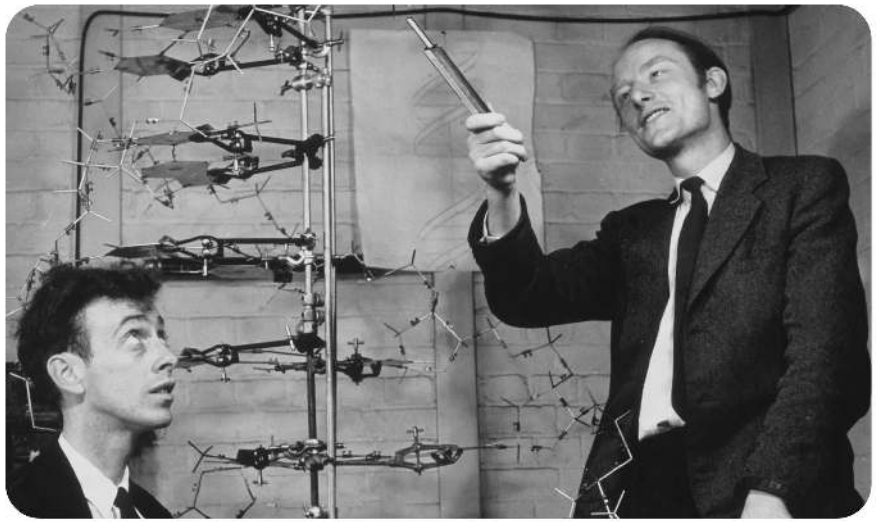
The promise…

… (S)cience alone… can solve the problems of hunger and poverty, of insanitation and illiteracy, of superstition and deadening custom and tradition, of vast resources running to waste, or a rich country inhabited by starving people… The future belongs to science and those who make friends with science. – Jawaharlal Nehru, 1946

Education is the most powerful weapon… to change the world. – Nelson Mandela, 2003

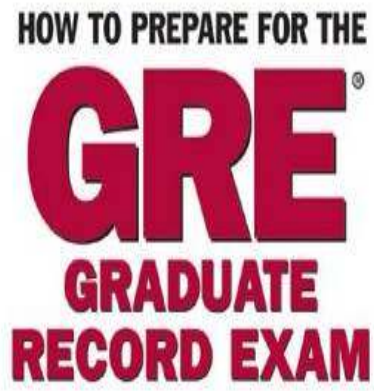
…Allure of science

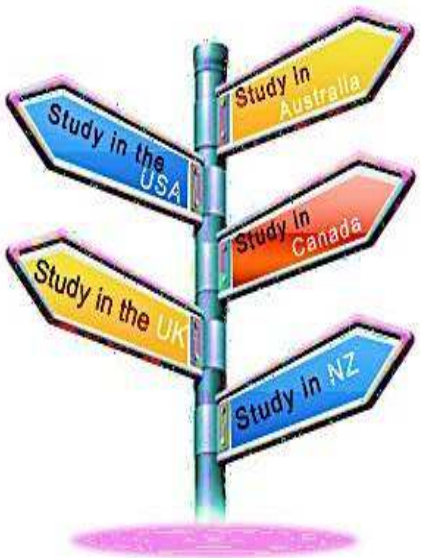




...Allure of science

Today's attractions…



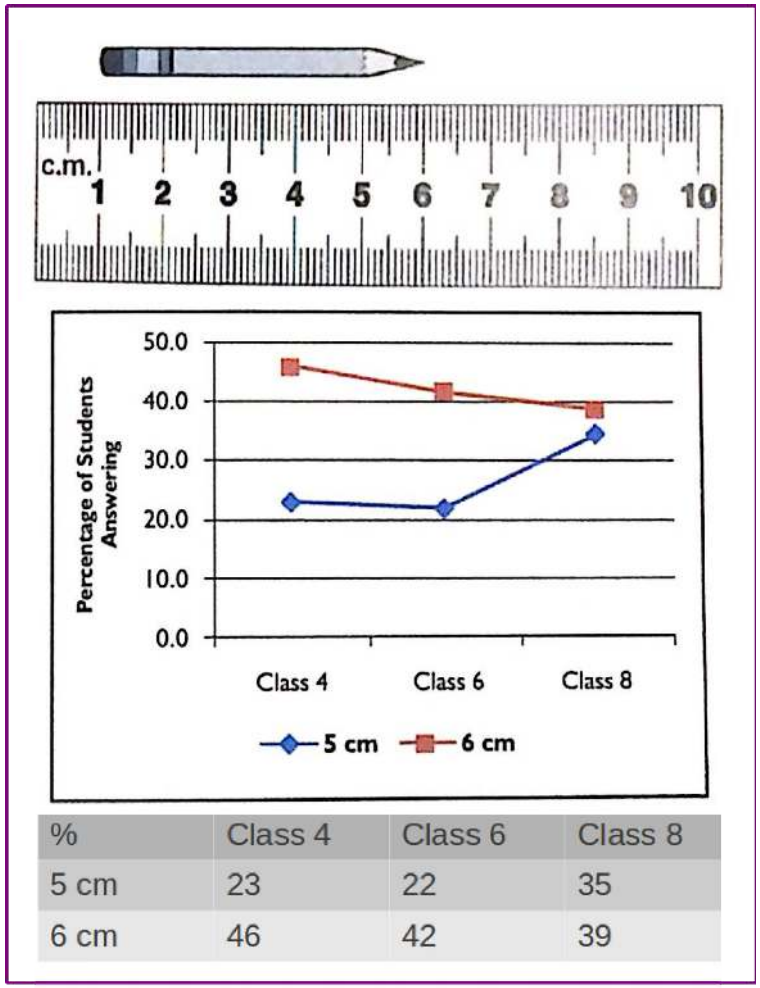


The reality of school

(Our) teaching methods are mercilessly stultifying, and it is a miracle that children survive them without entirely losing their creative abilities and independence of mind... (Public Report on Basic Education in India, 1998)

… load of non-comprehension… (Learning Without Burden, 1993)

…rote learning… misconceptions. (Educational Initiatives report, 2011)



%	Class 4	Class 6	Class 8
5 cm	23	22	35
6 cm	46	42	39

The reality of higher education

… Students passing out from institutions of higher education do so without obtaining the kind of skills they really need to work in a real-world environment. Among the drawbacks…

- lack of ability to analyze or solve problems,
- relate problems to different contexts,
- communicate clearly
- having integrated understanding of different branches of knowledge

(Report… on Renovation and Rejuvenation of Higher Education, 2009)

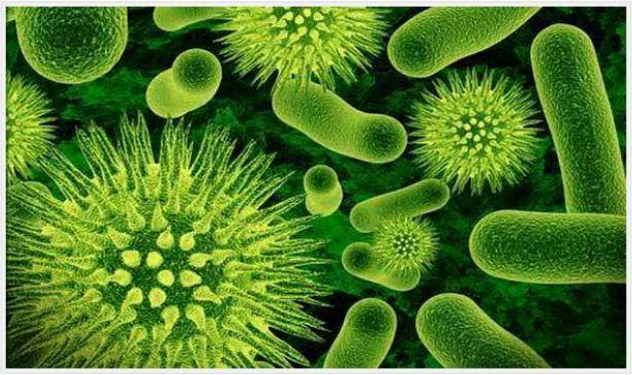
Doubts about science

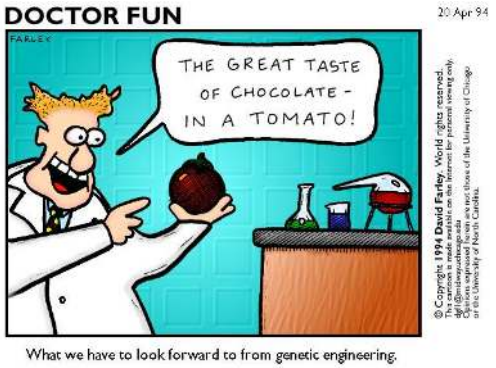
Antibiotic Misuse in Hospitals Raises Patient Infection Risk

Posted on March 5, 2014 - 11:09

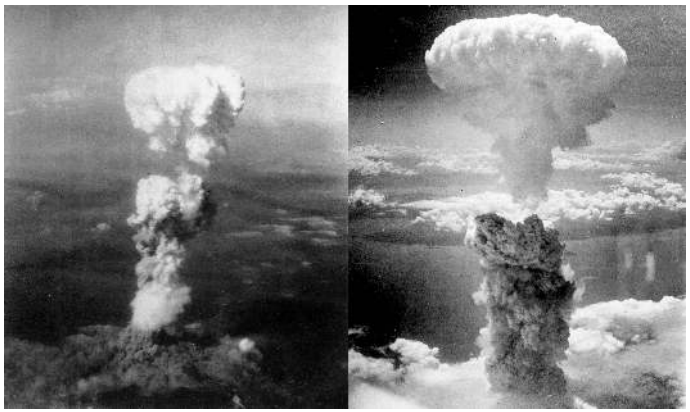
Source: www.livescience.com

By Rachael Rettner





What we have to look forward to from genetic engineering.



The release of atomic power has changed everything except our way of thinking ... the solution to this problem lies in the heart of mankind. If only I had known, I should have become a watchmaker – Einstein, 1945.

Yet, we do enjoy it!

Perhaps a good teacher inspired us!

Could we, in turn, inspire more?

Could we universalize our good experiences of learning science?

Could we address the real problems
of teaching and learning science?

This is what Science Education Research is about

… a quest for the Science of Science Education

Homi Bhabha Centre for Science Education
Tata Institute of Fundamental Research (A Deemed University)

Invites applications for PhD Programme in Science Education 2015

We are looking for young people with

- Interest in science education
- Flair for teaching and writing
- Curiosity about how students learn
- Critical and analytical skills
- Innovative approaches
- Commitment to improve education

To submit the form online, to download the form and for more information about the admission please visit: http://www.hbcse.tifr.res.in/admissions/

Note: This is a programme in education. It is not a pure or applied science research programme.

Scholarships
₹16,000 per month till registration
₹18,000 per month post-registration
Additionally, 30% HRA in lieu of on-campus institute accommodation
Annual contingency grant of ₹20,000.

Admissions are made initially for one year, renewable annually up to a maximum of five years.

To apply offline, send the completed form along with one passport size photograph and a demand draft for ₹400/- (non-refundable) to:

Graduate School Admissions - 2015,
Homi Bhabha Centre for Science Education, TIFR, V. N. Purav Marg,
Mankhurd, Mumbai 400088.

A written test for eligible applicants will be held at seven Centres around the country: Chennai, Bangalore, Pune, Mumbai, Delhi, Kolkata and Guwahati (provisional). Those who qualify will be called for an interview.

Areas Of Research

- Teaching and learning of science and mathematics from primary to undergraduate level
- Innovative curricula, laboratories, teaching and assessment methods
- Development of scientific and mathematical thinking in students at school and college level
- Design and technology in the curriculum
- Visual and spatial modes in learning
- Socio-cultural and gender factors in learning
- Structure and dynamics of knowledge

Eligibility

- M.Sc. (in any subject), M.S.W., M.A. (in Cognitive Science, Psychology, Education) or B.Tech./B.E./ M.B.B.S. or equivalent

Science and mathematics Teachers and Educators are also encouraged to apply. They would have to spend a minimum of two years at HBCSE and can do their research work while stationed at their parent institutions.

Exam Fee

- ₹400 to be paid online or through DD (in favour of Homi Bhabha Centre for Science Education, TIFR and payable at Mumbai).

Important Dates

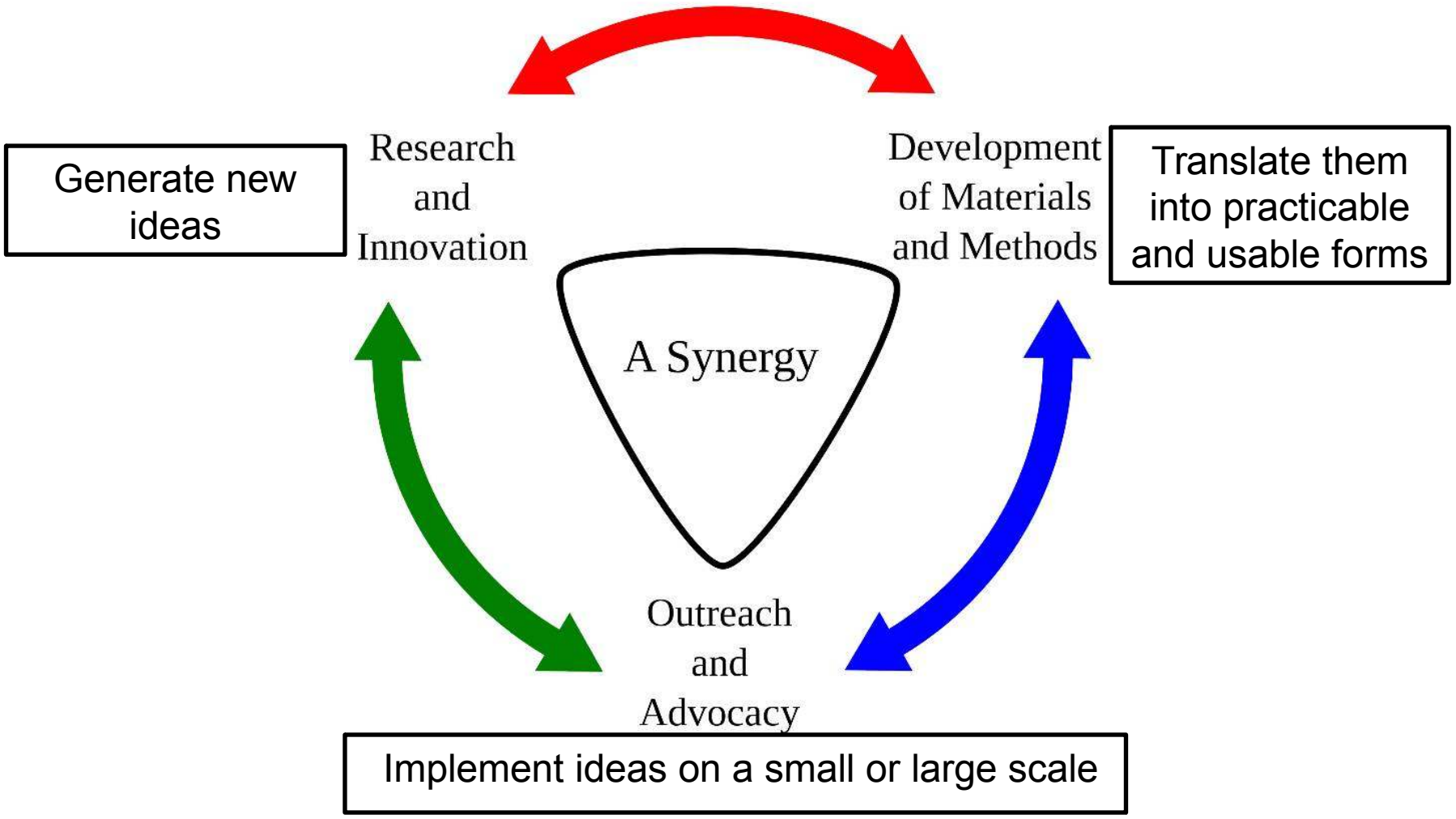
- Application Submission deadline: March 31, 2015
- Written test: May 17, 2015
- Interview: June 3rd week, 2015

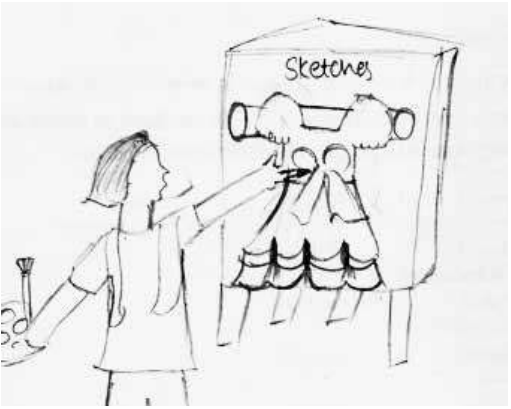
Phones: (022) 25072304/25072230; **Fax:** (022) 25566803; **Email: admissions@hbcse.tifr.res.in**

Note: This is a programme in education. It is not a pure or applied science research programme.

http://www.hbcse.tifr.res.in/graduate-school/gradschool

Homi Bhabha Centre for Science Education





Research and Innovation

Development of Materials and Methods

A Synergy

Outreach and Advocacy

हलका फुलका विज्ञान हलके फुलके विज्ञान

SMALL SCIENCE

Teacher's Book for Classes I & II

er's Book TextBook and WorkBook for Classes III, IV & V

Research areas at HBCSE

Students' conceptions

Design and technology

Out-of-school learning

Mathematical understanding

Learner-centred practices, collaboration, diversity

Concept mapping

Concept Inventories

Socio-scientific, ethical, moral issues

Model-based reasoning

Affective outcomes, student engagement

Visuo-spatial and embodied modes of reasoning

Testing and assessment

Motivations for research

- Developing better curricula, textbooks and teaching methods
- Effective teacher education
- Addressing conceptually challenging areas
- Questioning the assumptions

Motivation - Developing better curricula, textbooks and teaching methods

- Students' spontaneous conceptions
- Classroom Interaction, collaborative learning
- Process of Inquiry
- Experiments, projects: how do we learn from them?
- ICT in schools

An example: Visuospatial thinking

We use it every day

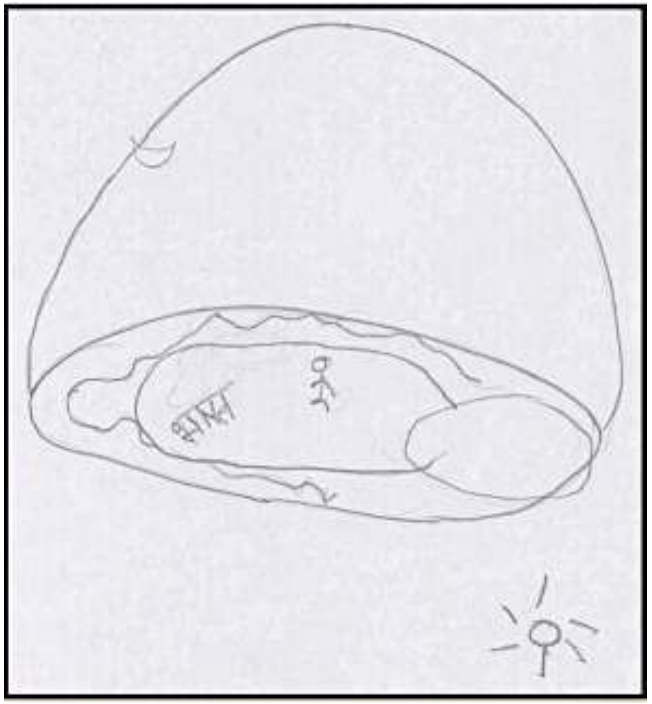
Shapes and arrangements; navigating through space; representing non-spatial entities in spatial metaphors: diagrams and graphs

Scientists and Engineers use it

Models of molecular structures; Physical processes in the earth's crust; Planetary motions, structures of galaxies

Yet it is missing in textbooks and teaching…

Astronomy – some popular but false notions



- Pole Star is the brightest star in the sky.
- Venus is a star / Andromeda is a star.
- Shape of the earth is like a disk.
- Day-night occur because the earth moves around the sun.
- Phases of the moon are caused due to shadow of the earth falling on the moon.
- Seasonal changes are due to variation in the distance between the sun and the earth.

Padalkar, S., & Ramadas, J. (2011). Designed and spontaneous gestures in elementary astronomy education. *International Journal of Science Education*, 33(12), 1703-1739.

Some errors are corrected with experience…

- Polar star is the brightest star in the sky

  - Incorrect individual belief

- Venus is a star/ Andromeda is a star

  - Category mistake

Astronomy – flawed mental models

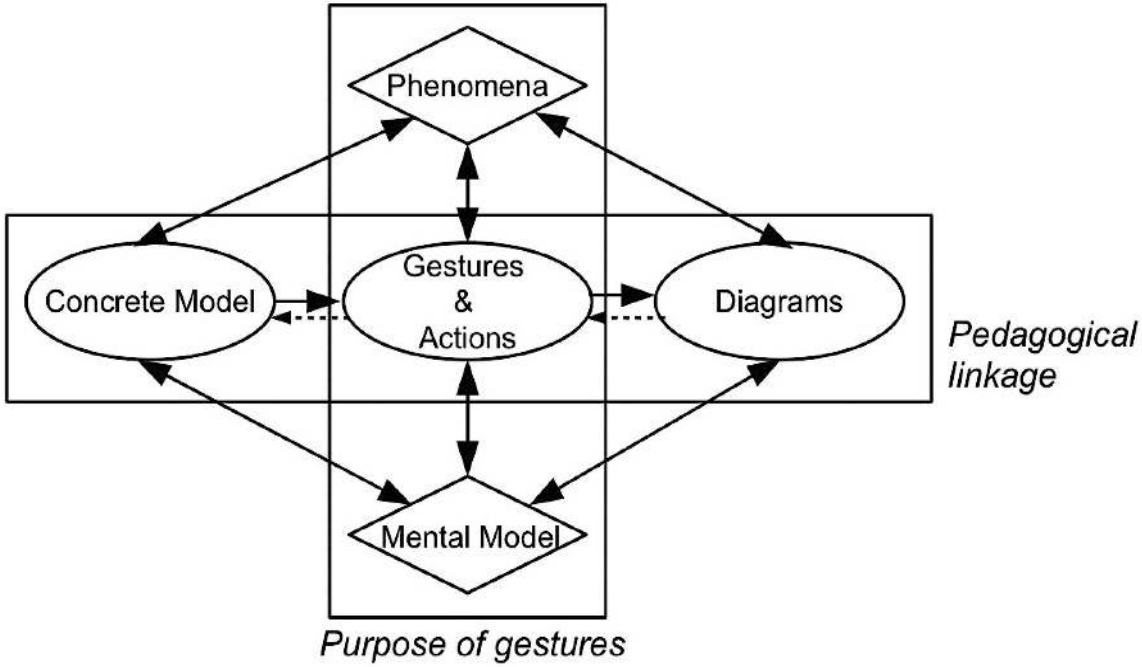
Shape of the earth is like a disk.
Day-night occur because the earth moves around the sun.
Phases of the moon are caused due to shadow of the earth falling on the moon.
Seasonal changes are due to variation in the distance between the earth and the sun.

The earth does appear disk-like.
It does revolve around the sun.
It does cast a shadow on the moon.
The sun-earth distance does vary over the year.

... Partly correct information, incorrect visuospatial reasoning

Tools for visuospatial reasoning

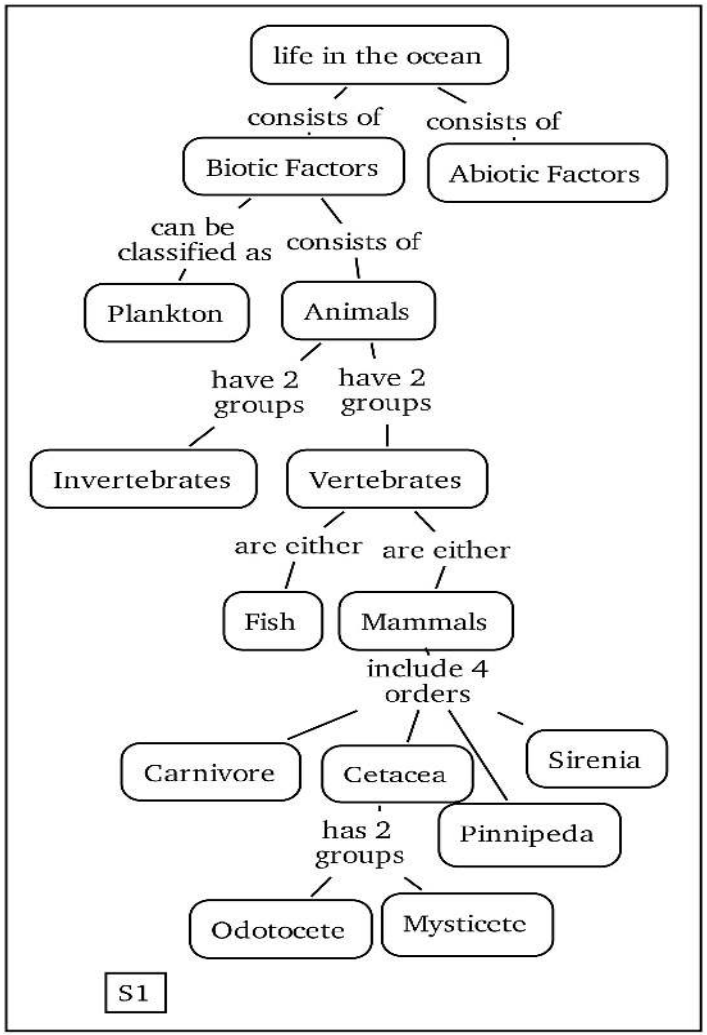
Diagrams, Gestures and Models: a powerful yet low-cost multimodal system to represent, communicate and reason about spatial information



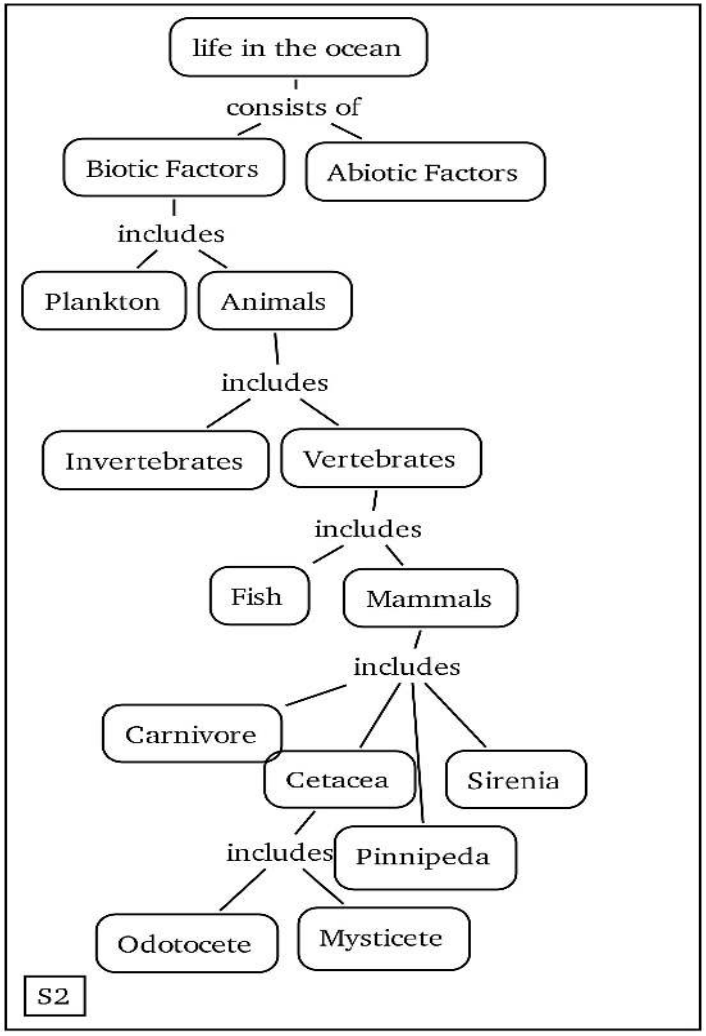
Padalkar, S. and Ramadas, J. (2011). Designed and spontaneous gestures in elementary astronomy education. *International Journal of Science Education*. 33(12), 1703-1739.

Representing static propositions

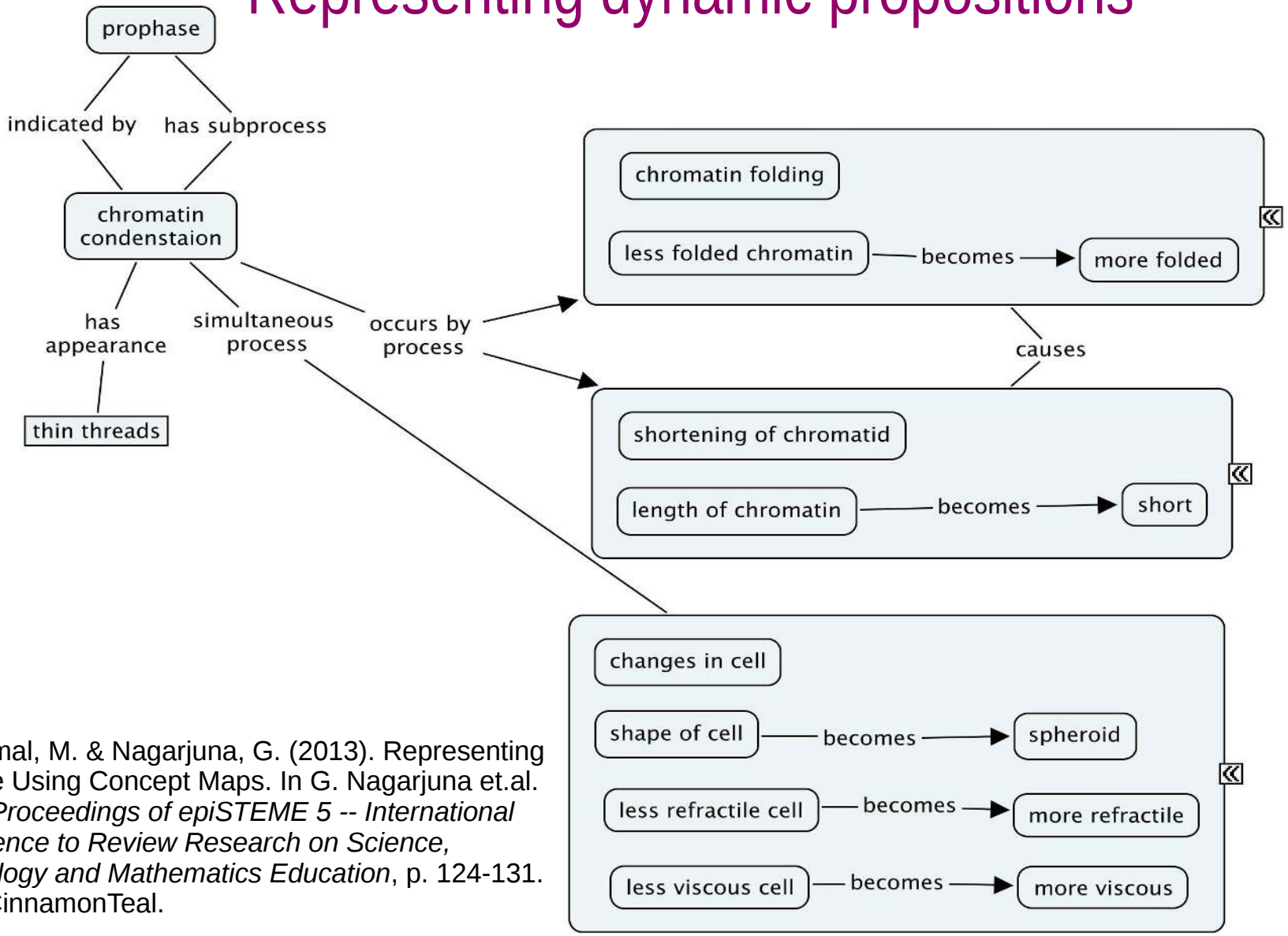
Traditional concept map



Refined concept map



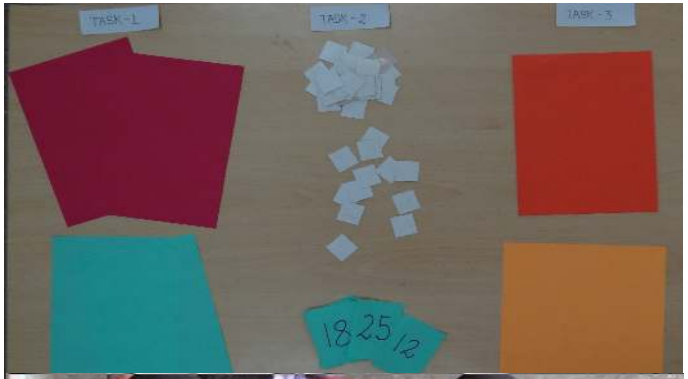
Representing dynamic propositions

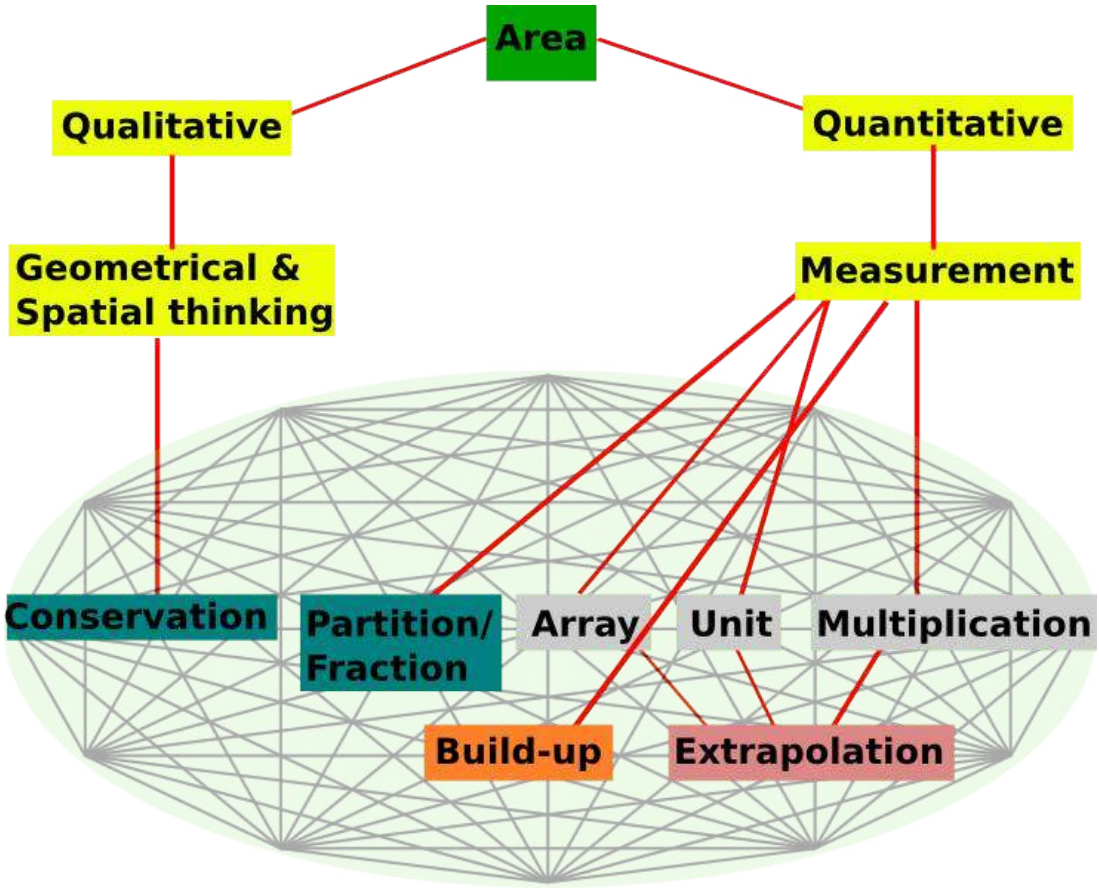


Kharatmal, M. & Nagarjuna, G. (2013). Representing Change Using Concept Maps. In G. Nagarjuna et.al. (Eds.) *Proceedings of epiSTEME 5 -- International Conference to Review Research on Science, Technology and Mathematics Education*, p. 124-131. India: CinnamonTeal.

Network model of area measurement

Area-measurement connects space and number





Rahaman, J., Subramaniam, K. & Chandrasekharan, S. (2013). A network model of the mathematical concept of area . In Nagarjuna G., A. Jamakhandi, and E. M. Sam (Eds.) *Proceedings of epiSTEME-5: Third International Conference to Review Research on Science, Technology and Mathematics Education*. pp. 300-306, Margao, India: CinnamonTeal Publishing.

An ICT rich world!

What is the potential of ICT in the low-technology, low resource context of rural India?

Rafikh, S., Nagarjuna, G. & Chandrasekaran, S. (2013). Socialising mathematics: collaborative, constructive and distributed learning of arithmetic using a chat application. *In Nagarjuna G., Arvind Jamakhandi, and Ebie M. Sam (Eds.) Proceedings of epiSTEME-5: Third International Conference to Review Research on Science, Technology and Mathematics Education.* pp. 321-327, Margao, India: CinnamonTeal Publishing.

Motivation - Effective teacher education (TE)

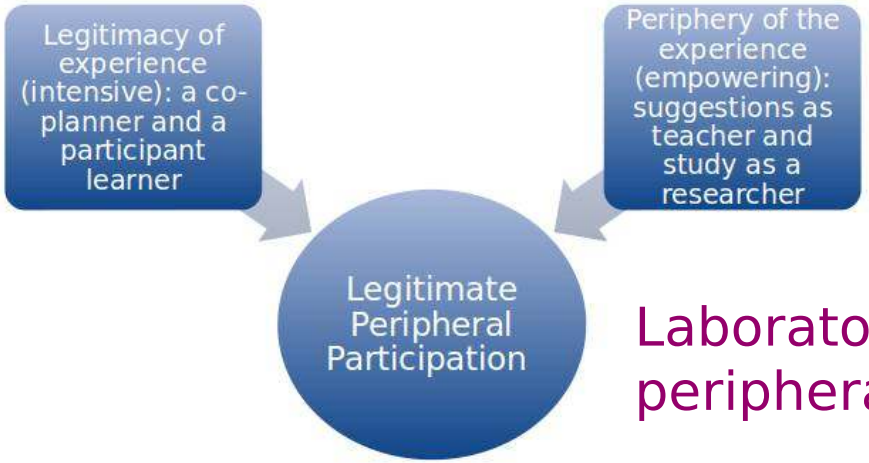
Practice-based settings for effective TE

Project-based learning to bridge gap between reform and practice

A site for collective work on teaching…

In a laboratory setting

- deliberate collectively on teachers' decision making
- develop and discuss teaching experiments
- diverse participants, various "lenses"



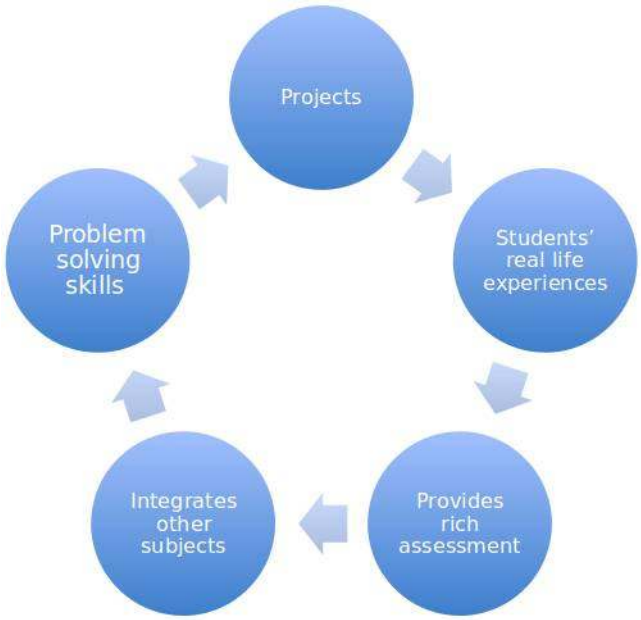
We found that teachers…

- position as co-planner
- provide concrete suggestions
- experience shared accountability

Laboratory creates a space for legitimate peripheral participation of teachers!

Naik, S. & Ball, D. (2012) Teacher learning through organized experiences, In proceedings of *International congress of mathematical education 12*, ICME: Korea.

Bridging the gap between reform and practice



- Teachers' understanding of goals of education and of content
- Time constraint
- Inflexibility of school towards reforms

Project based learning: A pedagogy to bridge the gap

Development of PBL in collaboration with teachers

Shome, S. & Natarajan, C. (2013). Ideas of and Attitudes towards Projects and Changing Practices: Voices of Four Teachers. *Australian Journal of Teacher Education*, 38(10), 64-81.

Conceptually challenging areas in undergraduate science

- Chemical reactions
- Structure of DNA
- Photosynthetic pigments in non-green leaves
- Rotational kinematics
- Gravitational and inertial mass
- Visuospatial reasoning in astronomy
- Optical black box – Physics olympiad

Understanding chemical reactions

Balance the chemical reaction with correct stoichiometric co-efficients.

$N_2 + H_2 \rightleftharpoons NH_3$

Student's response in examination

$N_2 + 3H_2 \rightleftharpoons 2NH_3$ Correct!

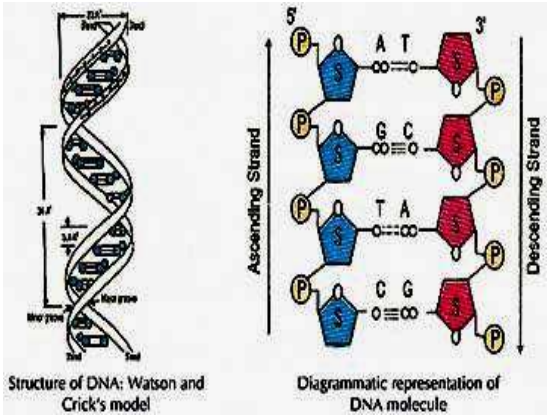
Represent the reaction pictorially, with N and H

Student response 1

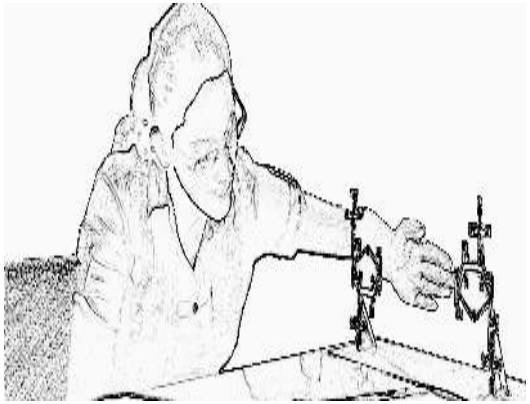
Student response 2

Have these students really understood?

Understanding an apparently simple aspect of DNA structure



a) Textbook representation of DNA structure

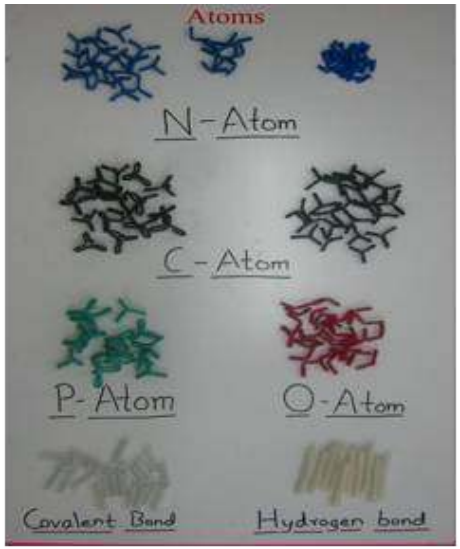


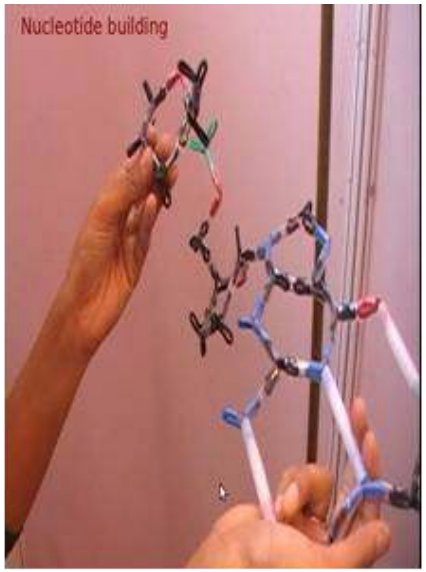
b) Student's initial representation of base pair orientation

Use of analogy, gesture and mental simulation leads to change in student's representation

Srivastava, A., & Ramadas, J. (2013). Analogy and Gesture for Mental Visualization of DNA Structure. *In Multiple Representations in Biological Education* (pp. 311-329). Springer Netherlands.

Structure of DNA

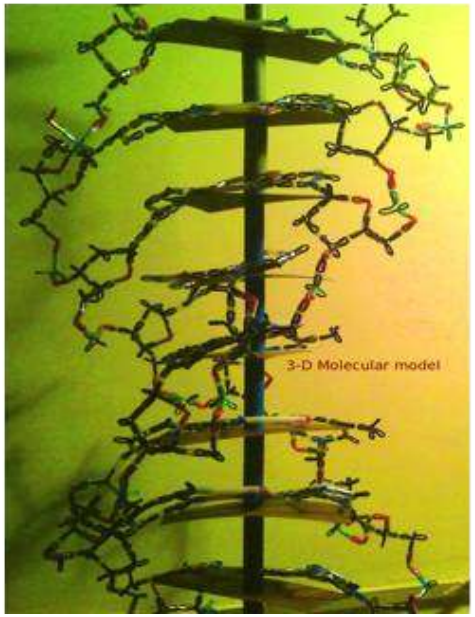


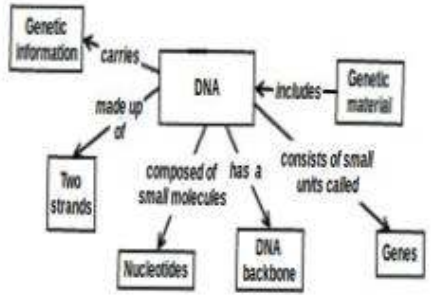


Atoms to model:

Does model building improve conceptual linkages?

Can we quantify conceptual understanding?





Photosynthetic pigments in non-green leaves

Students' hypotheses:

A. Red leaves contain a pigment other than chlorophyll that performs photosynthesis (40%)

B. Red leaves do not contain chlorophyll (28%).

C. Red leaves contain very small amounts of chlorophyll compared with red pigment. Hence the leaves do not appear green (16%).

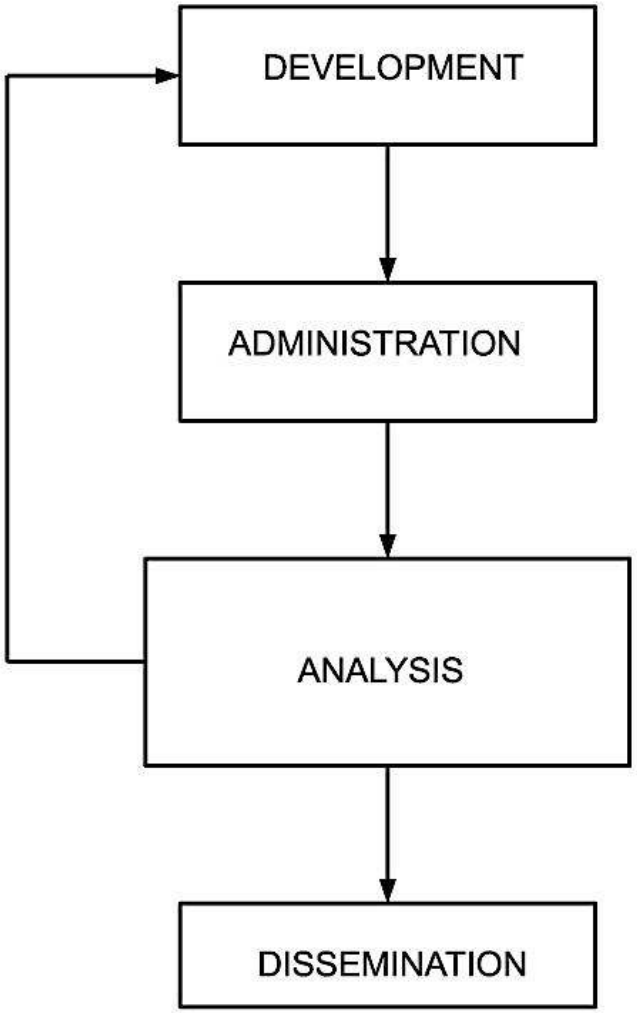
D. The green parts of the plant such as the stem take over the function of the leaves (4%).

E. Chlorophylls are present in these leaves but they are masked by the red pigment (2%).

Exploring these hypotheses in the laboratory through an inquiry based approach.

Vartak, R. (2006). Photosynthesis in plants with non-green leaves, *Journal of Biological Education*, 40(4).

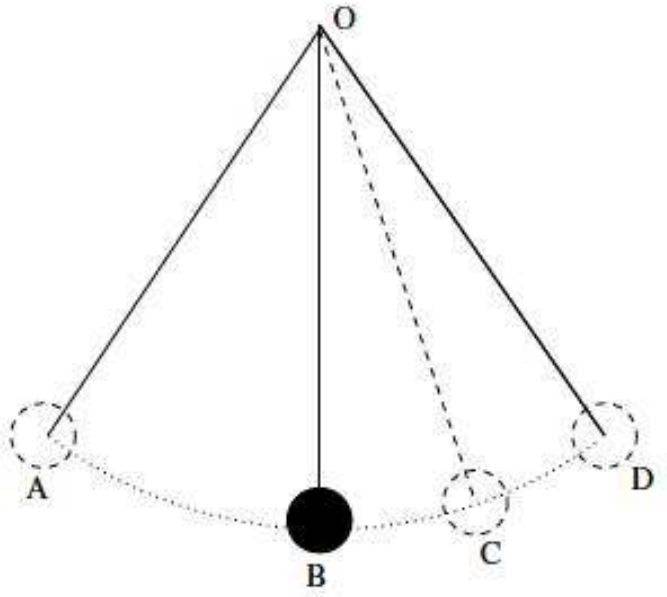
Concept Inventory (CI)



- Carefully crafted multiple choice questions aimed at probing students' misconceptions and eliciting ill suited reasoning patterns

- Played a crucial role in stimulating research-driven education reforms in US (Hake, 2011)

CI in rotational kinematics



Misconception: Angular acceleration mimics angular velocity…

Throughout the motion of the bob from A to D, the magnitude of the angular acceleration of the bob

(a) remains the same (19%).

(b) keeps on increasing (11%).

(c) first increases and then decreases (54%).

(d) first decreases and then increases (15%).

Mashood, K. K., & Singh, V. A. (2012). Variation in angular velocity and angular acceleration of a particle in rectilinear motion. *European Journal of Physics*, *33*(3), 473.

Conceptual vulnerabilities – m_I and m_G

Experimental fact:

Gravitational field produces the same acceleration for all bodies (irrespective of the mass, composition or state of motion of the body).

Most students appreciate this characteristic of a gravitational field, which is in contrast to electric and magnetic fields.

Students also know Newton's 2nd Law:

(Force) = (inertial mass) x (acceleration)

"Inertial mass" m_I, a characteristic constant of the body, is a quantity that "resists the force". Now "gravitational mass" m_G is defined by

Gravitational force = (gravitational mass) x (intensity of gravitational field)

… Vulnerabilities – m_I and m_G

m_G is a characteristic constant of the body that determines the 'coupling' of the body with gravitational field. Conceptually, m_I and m_G are distinct. However, the experimental fact above shows that the ratio m_I / m_G is a universal constant (=1, by choice).

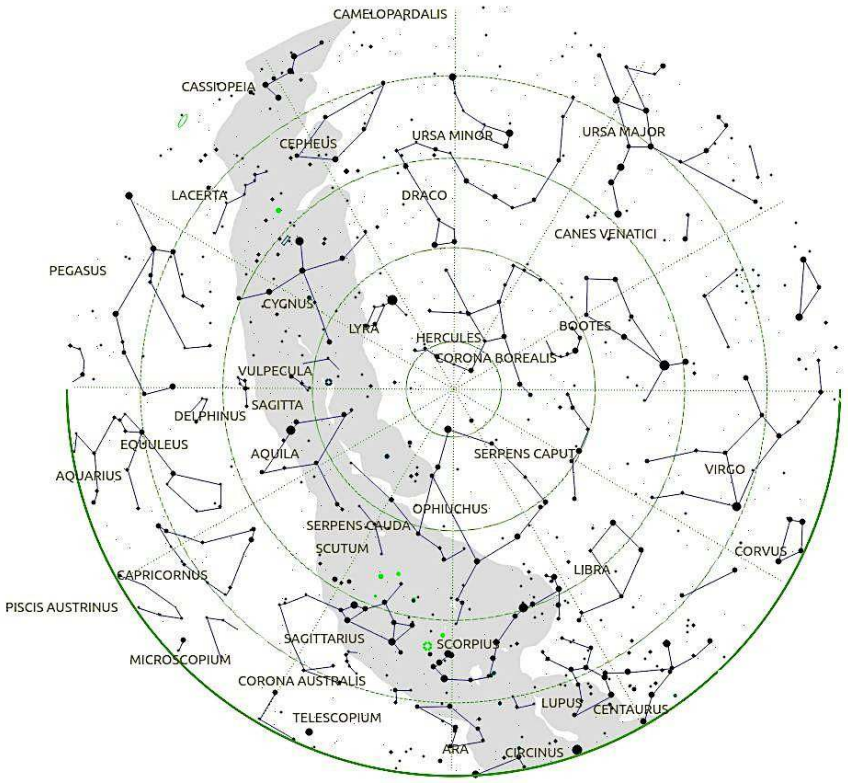
Students' view of m_G

m_G is the quantity that "resists" gravitational force!

Gravitational mass is viewed as instantiation of inertial mass in a gravitational context.

Bandyopadhyay, A., & Kumar, A. (2010). Probing students' understanding of some conceptual themes in general relativity. *Physical Review Special Topics-Physics Education Research*, 6(2).

Universalizing the universe!*



*Phrase coined by Sabyasachi Chatterjee in 2008, in preparation for IYA 2009.

A problem from INAO 2014

Mark Polaris; show boundary of circumpolar stars; draw the celestial equator; mark the ecliptic; mark the approximate position of the Sun.

Yesterday was a new moon day; mark the current position of the moon. Which star was very close to the Zenith at 06:00 am today? Draw a line across sky showing the horizon as at 07:00 am today.

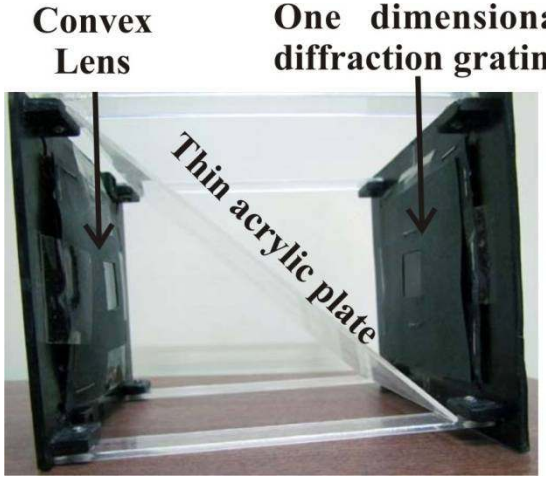
Training experiment for the physics olympiad

Identify three optical elements placed inside the optical black box from the following list:

1. Thin plane mirror
2. Double convex lens
3. Double concave lens
4. Thin plane parallel glass plane
5. Equilateral triangle prism
6. Plane one-dimensional diffraction grating

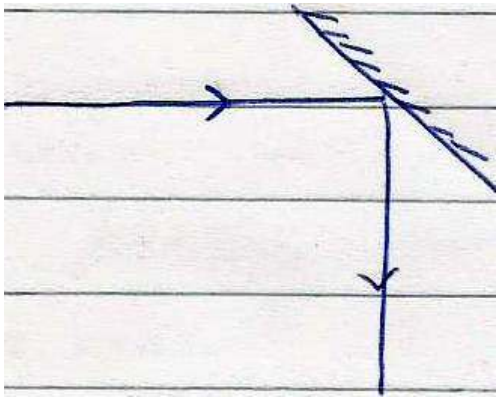
Seeing through the black box… using laser source, screen

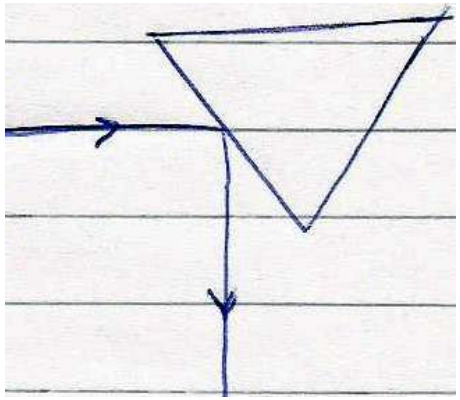
Honing one's observational and analytical skills…



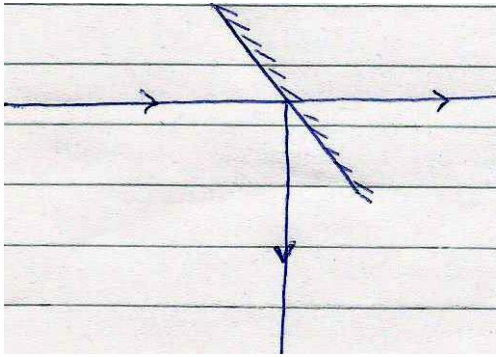
Used in Olympiad Camp 2004

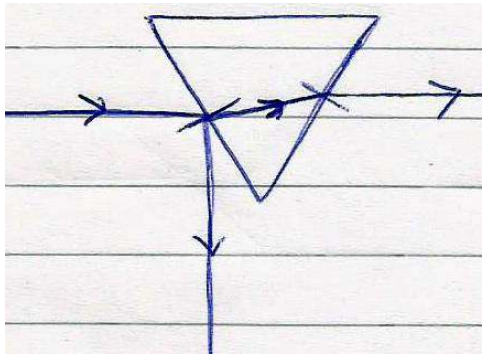
Hypotheses made by four students





Ignoring data to fit the theory





Changing the theory or principle to fit data

Questioning the assumptions

- Is science education all about following good textbooks and improved teaching of the products and processes (concepts and methods) of science?

- Why teach science?

  - To produce scientists and technocrats?
  - To place students in the job market?
  - To produce informed and critical citizens?
  - All of these?
  - Anything else ?

Assumptions of science and science education

- Values in science (ethical, social and scientific values)
  - Reproductive health, commercial surrogacy, MTP
- Hegemony of normality
  - Science and maths pedagogy for the blind
- Relationship between modern science and other knowledge systems, e.g., farmers' traditional knowledge
- Development issues in science education
  - Management of natural resources
- Gender biases through omission and commission in textbooks

Connecting out-of-school knowledge…

Work context enhances maths learning

When currency used as a cue…

- 981 ÷ 9 = 19 rectified as 109

Measurement (garment, leather, etc)

- Templates used in work context help in transitioning non standard to standard units, construction of new units

Bose, A., & Subramaniam, K. (2011). Exploring school children's out of school mathematics. In *Proceedings of the 35th Conference of the International Group for the Psychology of Mathematics Education.* V(2), pp. 177-184.

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http://www.hbcse.tifr.res.in/admissions/

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Last date of submission
March 31, 2015

Application form filling requisites

- 2 passport size photographs
- A demand draft of Rs 350 /- payable at Mumbai, in favor of “Homi Bhabha Centre for Science Education”

Filled form should be sent to

The Dean
Science Education Faculty
Homi Bhabha Centre for Science Education
TIFR, V. N. Purav Marg, Mankhurd
Mumbai 400 088.

Where our alumni went...

- Tata Institute of Social Sciences, Mumbai, Hyderabad
- Azim Premji University, Bangalore
- Srishti School of Art, Design and Technology, Bangalore
- Spatial Cognition Lab, UCSB, USA
- QUEST, Wada, Maharashtra
- National Institute of Education, Singapore

Students' visits to universities

- Abhijeet Bardapurkar: Cambridge University, UK (2006).
- Swati Mehrotra: Virginia Tech University, USA (2006).
- Meena Kharatmal: University of North Carolina at Wilmington, USA (2006); Institute of Human and Machine Cognition, Florida, USA (2006); Mimos, Semantic Web Technology Lab, Kuala Lumpur, Malaysia (2010)
- Arindam Bose: State University of Sao Paulo, Rio Claro, Brazil (2011); David Yellin College of Education, Jerusalem, Israel (2011); Curtin University, Perth, Australia (2010).
- Anveshna Srivastava: Columbia University, NJ, USA (2011).
- Shikha Takker: University of Colorado, Boulder, USA (2011).
- Mashood K. K. : University of Washington, Seattle, USA (2013); Harvard University, USA (2013).

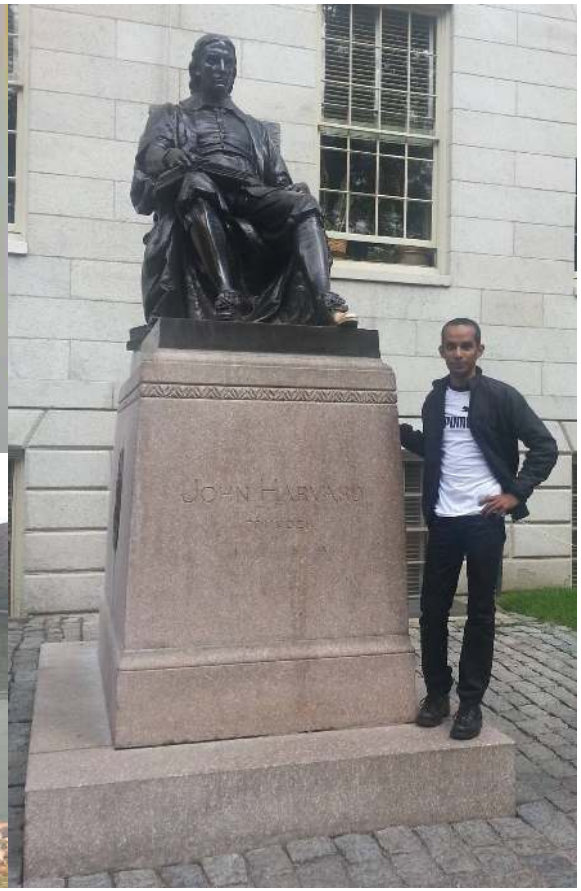
Students' representation in conferences

- Psychology of Mathematics Education
- International Conference on Mathematics Education
- International Conference on Physics Education
- International Conference on Concept Mapping
- International Conference on Conceptual Structures
- Gordon Research Conference VisSciEd
- PATT conference
- Mathematics Education Research Group of Australasia
- CogSci conference

Visiting Ph.D. students

- Renato Marcone, University of Sao Paulo, Brazil
- Dheeraj Kumar, Patna University, India
- Senthil Babu, Jawaharlal Nehru University, India
- Shweta Gupta, Indiana University, USA
- Tim Gaard, Maastricht University, Netherlands

Graduate students' moments at HBCSE



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A presentation by the
Ph.D. students at HBCSE*
in consultation with
HBCSE faculty and alumni

Thank you!
Hope to see you soon at HBCSE!

*Special thanks to Shweta, Rafikh, Anveshna and Jeenath for version 1.0 of SER_What_Why.

This Version is suggestive and not comprehensive. It is free to HBCSE members to modify and use. Please share any significant modification or new slides on the HBCSE intranet.