Research at the Homi Bhabha Centre for Science Education
TIFR Deemed University

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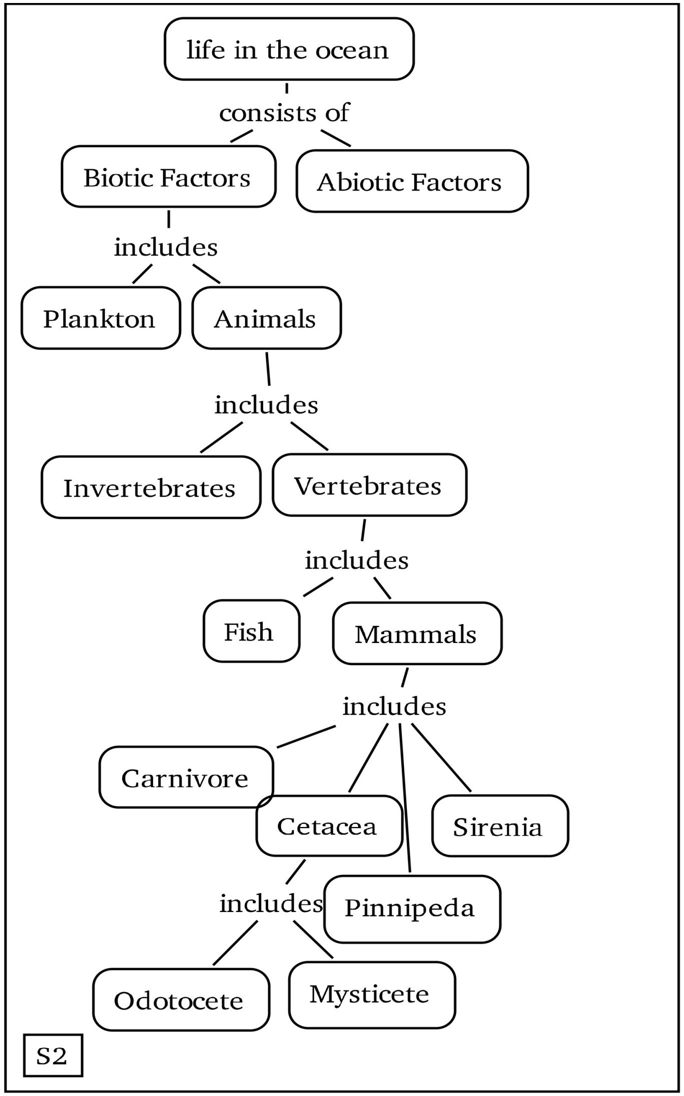
Cognitive Studies of Science and Mathematics Education

- Students' spontaneous conceptions (light, heat, matter, motion, life, human body)
- Mathematical understanding (algebra, fractions, multiplicative thinking, measurement)
- Concept mapping
- Model-based reasoning
- Visuo-spatial and embodied modes of reasoning.

"Refined Concept Map"



Sociocultural Issues in STME

- Classroom interactions, collaborative learning
- Inclusive education, diversity in the classroom
- Learner-centred practices
- Affective outcomes, student engagement
- Socio-scientific, ethical, moral issues
- Out-of-school learning

Visual, Spatial and Embodied modes of Learning

- Pictorial and schematic representations (light, motion, plants, human body, astronomy)

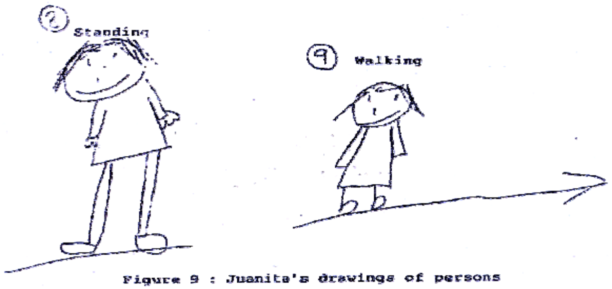


Figure 9 : Juanita's drawings of persons

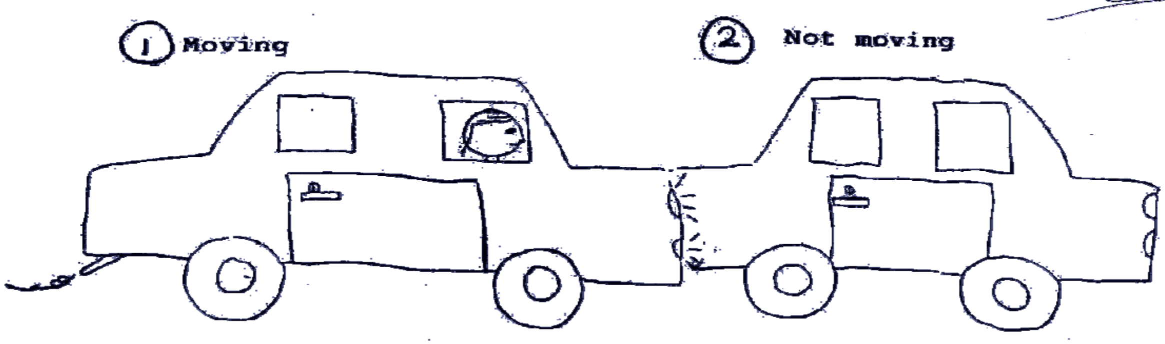
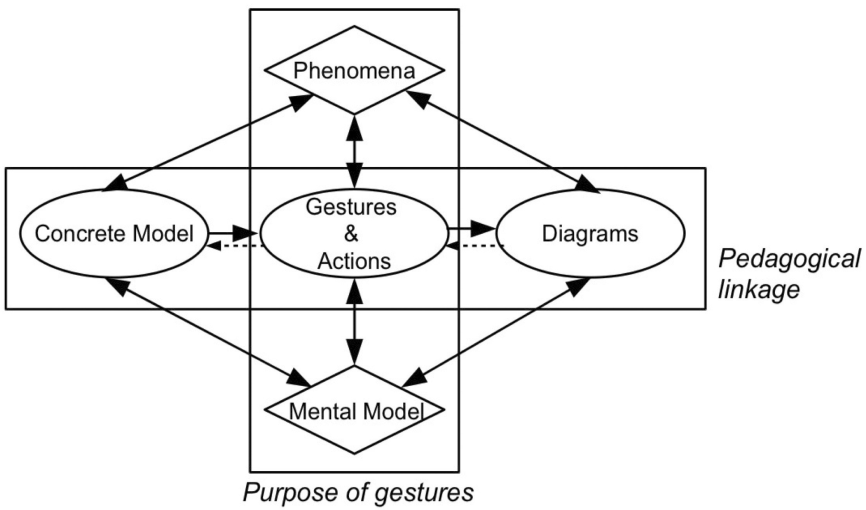


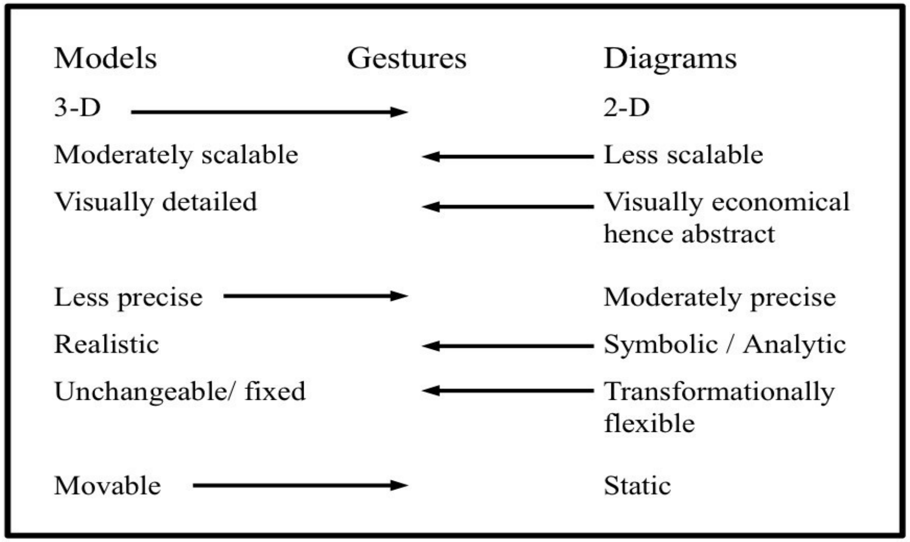
Figure 3 : Susan's drawing of cars

- Mental visualisation, transformational reasoning, mental simulation
- Gestures as a mediating device

Role of gestures in learning



Purpose of gestures in linking phenomena with mental models and their pedagogical role in linking concrete models with diagrams

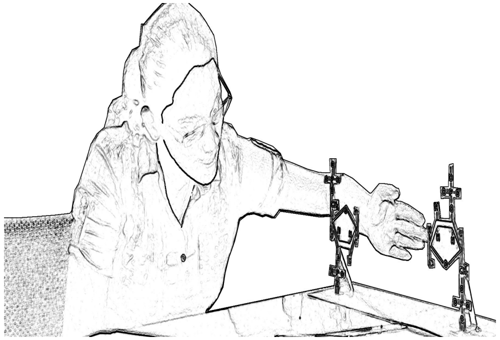


Gestures can be used to link concrete models with diagrams: Arrows denote the properties that gestures share with either concrete models or diagrams.

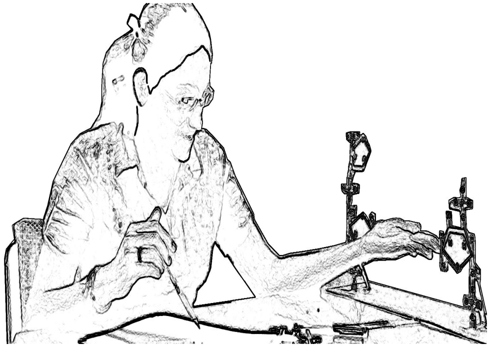
Padalkar, S. & Ramadas, J. (2010). Designed and spontaneous gestures in elementary astronomy education. International Journal of Science Education. DOI: 10.1080/09500693.2010.520348

Gesture and mental simulation as learning device

Name of the student	No. of '+' ve transitions	Context of the transitions
Anuja	3	1. [1]**Ladder analogy with mental simulation**; 2. reminder about gesture against M1; 3. reminder about orientation.
Sharada	2	1. **Ladder analogy**; 2. palm gesture.
Nitin	7	1. **Ladder analogy with mental simulation**; 2. palm gesture; 3. palm gesture; 4. reminder of earlier orientation; 5. reminder of earlier orientation; 6. ladder analogy with mental simulation; 7. ladder analogy with mental simulation.
Sandhya	8	1. **Ladder analogy with mental simulation**; 2. **ladder analogy**; 3. reminder about base positioning; 4. reminder about earlier gesture; 5. palm gesture; 6. ladder analogy with mental simulation; 7. ladder analogy; 8. reminder about the base placement.
Aakriti	4	1. Ladder analogy; 2. ladder analogy; 3. **ladder analogy with mental simulation**; 4. **ladder analogy**.
Total	**24**	Ladder analogy (6), ladder analogy with mental simulation (7), palm gesture (4), reminder (7)



a) Incorrect ('-' ve) palm gesture



b) Correct ('+' ve) palm gesture

[1]All context(s) which had direct bearing on the "Aha!" moment of the student are given in bold font.

Physics Education Research (PER)

- From commonsense insights and intuition
- To systematic investigation in depth and detail.
- Major journals: American Journal of Physics (AJP), European Journal of Physics (EJP), International Journal of Science Education (IJSE),
- Physical Review ST PER (PRST), The Physics Teacher (TPT), Physics Education (PE).
- Indian journals: Physics Education, Resonance
- Major theoretical influence: Work of Jean Piaget – Personal cognitive construction.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Major Trends in PER and HBCSE's contribution

- STUDENTS MISCONCEPTION / ALTERNATIVE CONCEPTIONS
- Robust and do not easily yield to formal instruction - Parallels with history.
- HBCSE Works: Students conceptions about light and motion by J. Ramadas.
- Alternative conceptions in Galilean relativity by J. Ramadas, A. Kumar, others (In IJSE)
- Students conceptions in general relativity by A. Bandopadhyay and A. Kumar (In EJP, PRST)

Concept Inventories

- Carefully crafted set of MCQ's on a concept or topic aimed at probing and assessing student understanding.
- Particularly relevant to Indian scenario.
- Well known inventories: FCI, MBT developed by Hetsenes et al.
- HBCSE Works: FRBI by P. Pathak and V. Singh
- Ongoing work in rotational kinematics by K. K Mashood and V. Singh (In EJP)

PER In Laboratory Settings

- Developing innovative experiments
- Help students learn important experimental skills.
- HBCSE Works: Ongoing work in heat and thermodynamics by R. Khaparde and S. Pathare.
- Part of the work pub. In PE.

ICT in PER

- Development and implementation of simulations
- Interactive learning softwares.
- Studio class rooms.
- HBCSE Works: Gnowledge lab led by G. Nagarjuna and A. Dhakulkar is involved in ICT related works.
- Graphicacy using SUGAR OS.
- OLPC
- Promoting Free and Open Source Softwares
- [FOSS] for educational purposes.

Mathematics Education Research (MER)

- Mathematics as part of core curriculum by 18th and 19th century
- MER as an independent field established with the founding of *International Commission on Mathematical Instruction* (1908)
- Revitalising MER in 1960's
  - International Conference on Mathematics Education started in 1969
  - International group for the Psychology of Mathematics Education established in 1976 in ICME 3, Germany
- Journals: Educational studies in Mathematics (ESM), Journal for Research in Mathematics Education (JRME), Journal of Mathematics Teacher education (JMTE), The Mathematics Teacher (India)

Some Important Themes in MER

- Fundamental shifts in conceptions of learning
  - From behaviourist measurement to cognitivist analysis of tasks
  - Role of belief-systems and affective issues
  - Learning as enculturation
- Integrating research on learning and research on teaching
  - Studies on teacher thinking, pedagogical content knowledge, classroom instruction, teaching experiments
- Research Paradigms
  - Realising limits of experimental methods lead to use of qualitative methods (e.g. in depth case studies)

MER at HBCSE

- Study of students' learning and development of teaching approaches
  - Algebra: developing a teaching learning sequence for transition from arithmetic to algebra (Rakhi Bannerjee and K. Subramaniam)
  - Fractions for understanding ratio and proportion (K. Subramaniam and Shweta Naik)
  - Measurement using gestures, tools and out of school/indigenous activities and its connection with multiplicative thinking (Jeenath Rehman and K. Subramaniam)
  - Integrating everyday mathematical knowledge and out of school mathematical practices with school learning for developing multiplicative reasoning (Arindam Bose and K. Subramaniam)

MER: In-service teacher Professional development

- Going beyond transmission model of “Teacher Training” through
  - Situatedness in the work of teaching
  - Offering challenges to teachers to revisit their knowledge and beliefs
  - Developing a sense of belonging to a community
- Opportunities for teacher leaning through
  - Analyzing teaching and its artifacts
  - Developing content knowledge integrated with pedagogy
  - Bridging research - practice divide
- Research Focus:
  - Supporting teacher learning of students' mathematical thinking through designing “classroom based tasks” (Shikha Takker and K.Subramaniam)
  - Developing suitable model of professional development for teachers of mathematics for using learner - centered approaches (Ruchi S. Kumar and K.Subramaniam)

Project Based Learning

Motivation

- HBCSE's work on inquiry and activity-based learning

HBCSE Primary science curriculum (Ramadas, Vijapurkar et al.); Activity-based STS foundation course (Natarajan et al.), Student action research (Mahajan and Nair), Design and technology curriculum (Khunyakari, Mehrotra, Ara, Chunawala, Natarajan et al.)

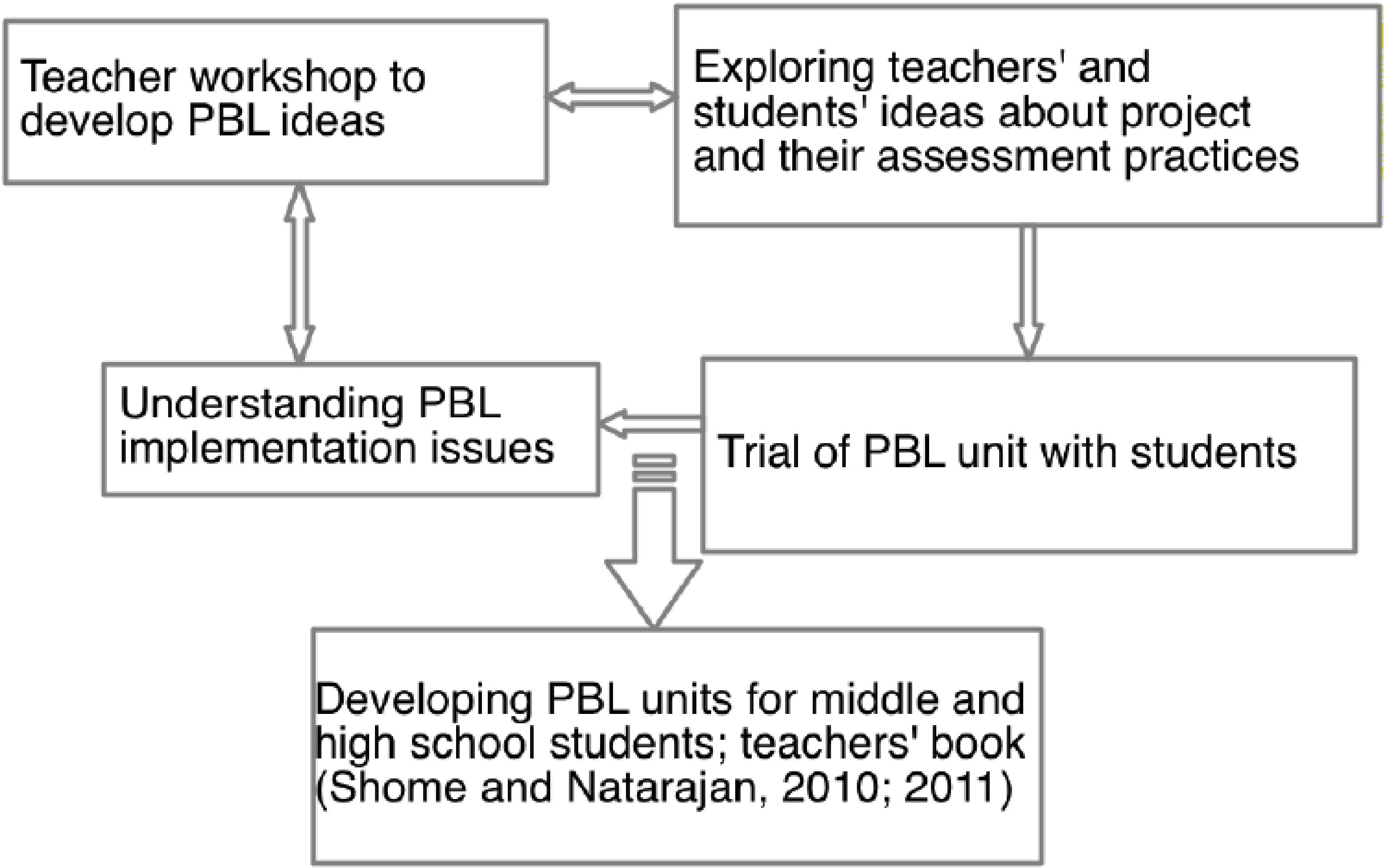
- National curriculum framework and position papers (NCERT) advocated projects at school level, connecting real world experience, integrating formative assessment.
- Present practice of school projects:
  - Most projects in schools reduced to mere rituals
  - Difficulties setting learning goals; integrating assessment and real world connection; subject integration; resource management, etc.

What is Project Based Learning?

- Project based learning (PBL) organizes learning around projects:
  - projects are central to curriculum
  - starts with a driving question
  - engages students in authentic & constructive engagement
  - set in real world contexts
  - provides autonomy to students
  - allows to integrate formative and summative assessment.
- Hence collaboration with teachers to develop meaningful PBL projects for middle school

Project Based Learning

Brief Outline of the work



Affective Aspects of Learning Science

Beyond cold conceptual change

- Learning as ‘conceptual change’ (1980s)
  - Learning not as expansion and accumulation of knowledge but restructuring of conceptions
- Learning embedded in emotional and social context (1990s)
- The context for learning has to be designed in a way that supports the cognitive, rational processes

Affective Aspects of Learning Science

Research on affect in science education

- Affective factors in learning: interest, motivation, attitudes, beliefs, self-confidence, self-efficacy, identity, scientific attitudes and attitudes towards science and scientists
- Could affect be an important learning outcome?

Affective Aspects of Learning Science

Previous attitudinal research at HBCSE

- Attitudes towards mathematics (1992-1995)
  - (Sugra Chunawala and H.C. Pradhan)
- Students' ideas about Science and Scientists (1995-1998
  - (Sugra Chunawala and Savita Ladage)
- Relevance Of Science Education (2003-2005)
  - (International Project, HBCSE collaboration)

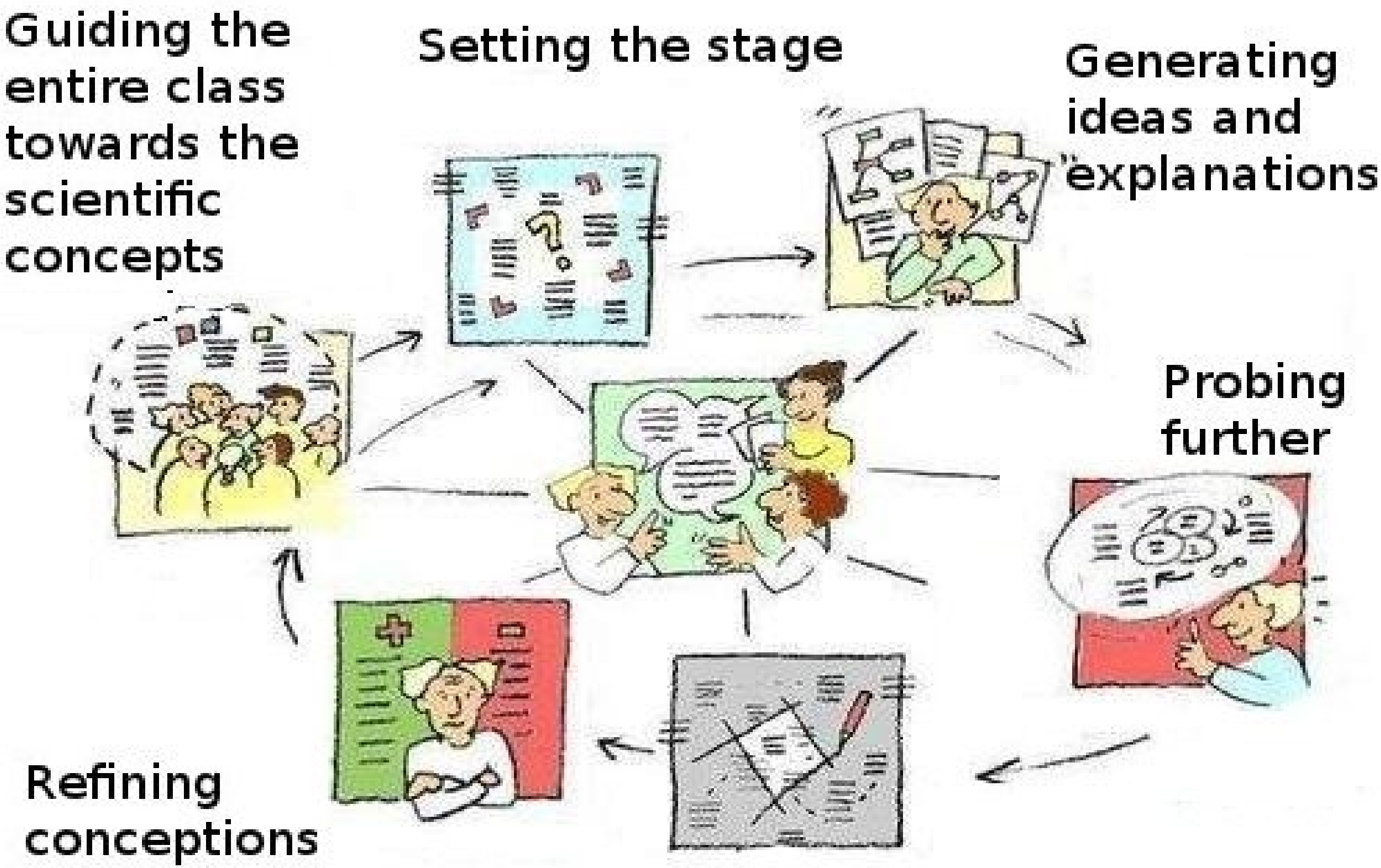
Affective Aspects of Learning Science

Ongoing research in this area

- Developing an innovative, inquiry-oriented science curriculum at the middle school level (Jyotsna Vijapurkar)
- A related doctoral thesis on characterising teaching science as inquiry and affective outcomes of learning through inquiry (Aisha Kawalkar)

Affective Aspects of Learning Science

Characterising inquiry in the science classroom



Kawalkar & Vijapurkar (2011a,b)

Graphic icons from Hakkarainen and Muukonen (1998)

Affective Aspects of Learning Science

Wide-ranging outcomes: Results from pilot study

Increase in students' interest in Science

Change in how students view science and scientists

Increased participation in their science classes at school

Change in the way they study science

Increase in students' self-confidence levels

Improvement in English and mathematics

Behavioural and personality changes

Improved achievement in science at school

Kawalkar & Vijapurkar (2011c)

Thank you!