Teaching and Learning Science through Inquiry at the Middle School Level

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HBCSE

Middle school curriculum development

Primary concerns:

- What to teach

    (*“why?” is implicit*)

    (*“what not to teach” is important!)*

- When (at what grade level)

- How to teach it

Interlinked!!

What to teach

The big picture: Focus on foundational concepts

Details: Through intensive classroom work

With inputs from:

- History of Science (HOS)

Children's conceptual development parallels historical development of concepts

Incorporating HOS is a good *pedagogic* strategy

- Literature documenting student difficulties

(of course, this cannot be exhaustive)

Also:

- Pointers from one's own day to day experience

- Self reflection

Material thus arrived at, woven into a coherent curriculum

When to teach it

What, to us, may seem trivial is often hugely difficult for school students

Just one grade level may make a difference: particularly in middle school (grades 6 through 8), a huge jump across grade levels in cognitive readiness

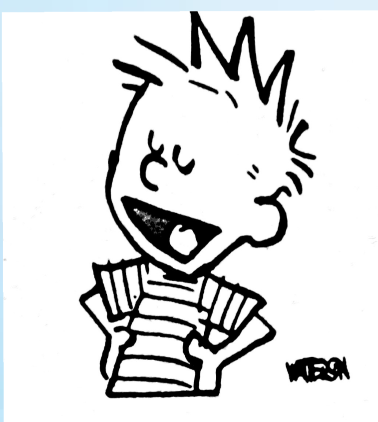
General effort: to introduce material the earliest they can be

How to teach it

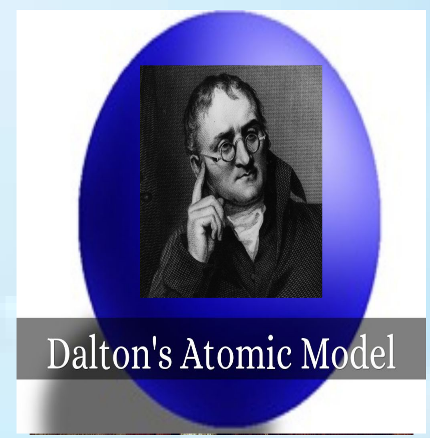
Conceptual Change Framework

Students' concepts → Scientifically correct concept

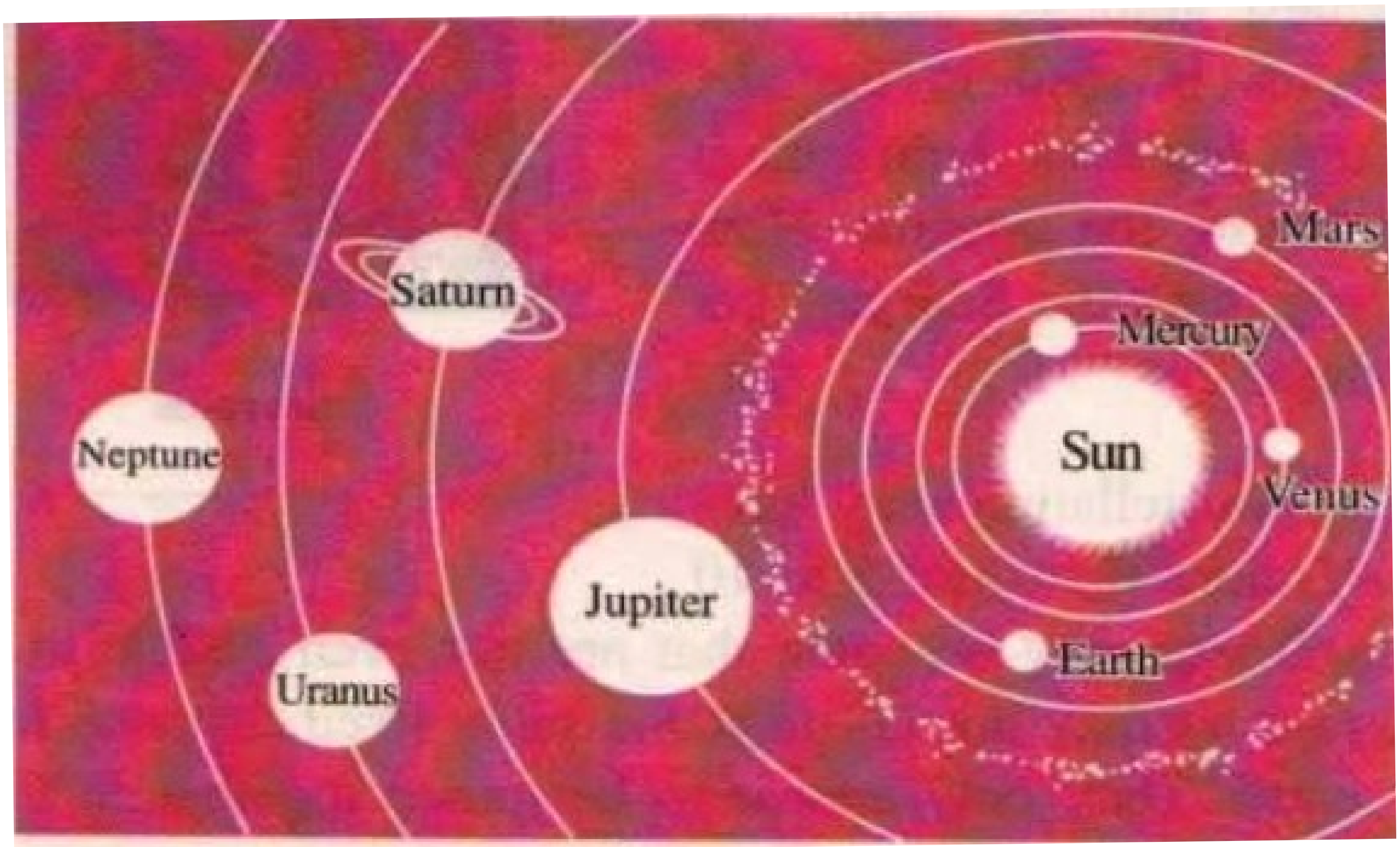
?



Often incorrect but
coherent!



Incorrect but coherent: ***The mind seeks coherence!***



Class 8, General Science Maharashtra state board

A coherent picture: Not just from lived experience, but brought in from folklore, amalgamating own ideas with hazily perceived lessons in school

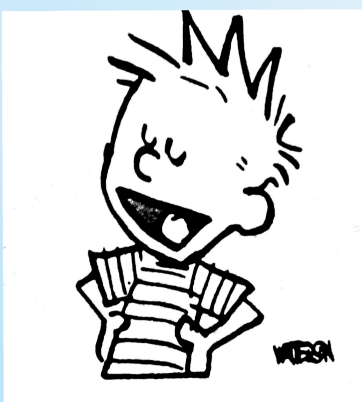
How eating sweets leads to intestinal worms

Plausible scenarios

Eat sweets → germs form
fuse together → to form a worm

Eat sweets → react with stomach acid
↓
form worms

Coherent within the range of their knowledge/understanding



Conceptual change involves several interwoven issues that are **complex** and **non-transparen**t*

- The ways in which knowledge is misconceived
- Its resistance to change
- Ways of designing instruction that promotes conceptual change. **Examples of how this is to be achieved in practice are few****

*Chi, 2008
**Berry and Milroy, 2002

How do we go about bringing this change?

Involving students in the process of discovery

However, 2000+ years of scientific discoveries cannot be replicated in a few years by novices in middle school on their own

↓

Guided inquiry


Non inquiry
Open inquiry

Improved inquiry grid	**Inquiry skill areas**				
Level	1: Scientifically orientated questions	2: Priority to evidence	3:Explanations from evidence	4: Explanations connected to knowledge	5: Communicate and justify
3: Open inquiry	Learner poses a question	Learner determines what constitutes evidence and collects it	Learner formulates explanations after summarising evidence	Leaner independently examines other resources and forms the links to explanations	Learner forms a reasonable and logical argument to communicate explanations
2: Guided inquiry	Learner selects amongst questions, poses new questions	Learner directed to collect certain data	Learner guided in process of formulating explanations from evidence	Learner directed towards areas and sources of scientific knowledge	Learner coached in development of communication
1: Structured inquiry	Learner sharpens or clarifies question provided by others	Learner given data and asked to analyse	Learner given possible ways to use evidence to formulate explanation	Learner given possible connections to scientific knowledge	Learner provides broad guidelines to use to sharpen communication
0: Confirmation/ verification exercises	Learner engages in question provide by others	Learner given data and told how to analyse it	Learner provided with evidence	Learner provided with precise connections	Learner given steps and procedures for communication

From Bevins and Price, 2016

Procedural dimension

This “Question-Procedure-Result-Interpretation” (QPRI) model “*organises a messy, complex and dynamic process which has many twists, turns and reversals into a neat simple sequence of independent procedures*”

The QPRI model is an inadequate description and open to interpretations

Our effort – to present the complexities with data* from actual classrooms and our attempts at teaching the curriculum as it was developed

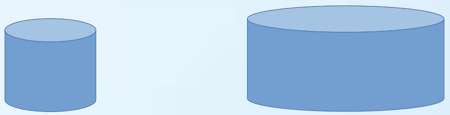
*Video records, student worksheets, students' writings, teachers' diaries

Measuring rain

In mm (how odd!)

Does the cross sectional area of the gauge matter?

Does its shape matter?



Does where it is placed (within a few meters, say) matter?

Are rain drops all of the same size?

A key concept: Time average

1. Students were given brown paper and a transparent sheet

2. They sprinkled water on the brown sheet

3. Keeping the transparent sheet on top of the brown sheet, they marked the drops on it

4. All transparent sheets were stacked together

The key is to have open discussions in class and identify what students can inquire into, and infer. Usually these are smaller components of the main topic being taught

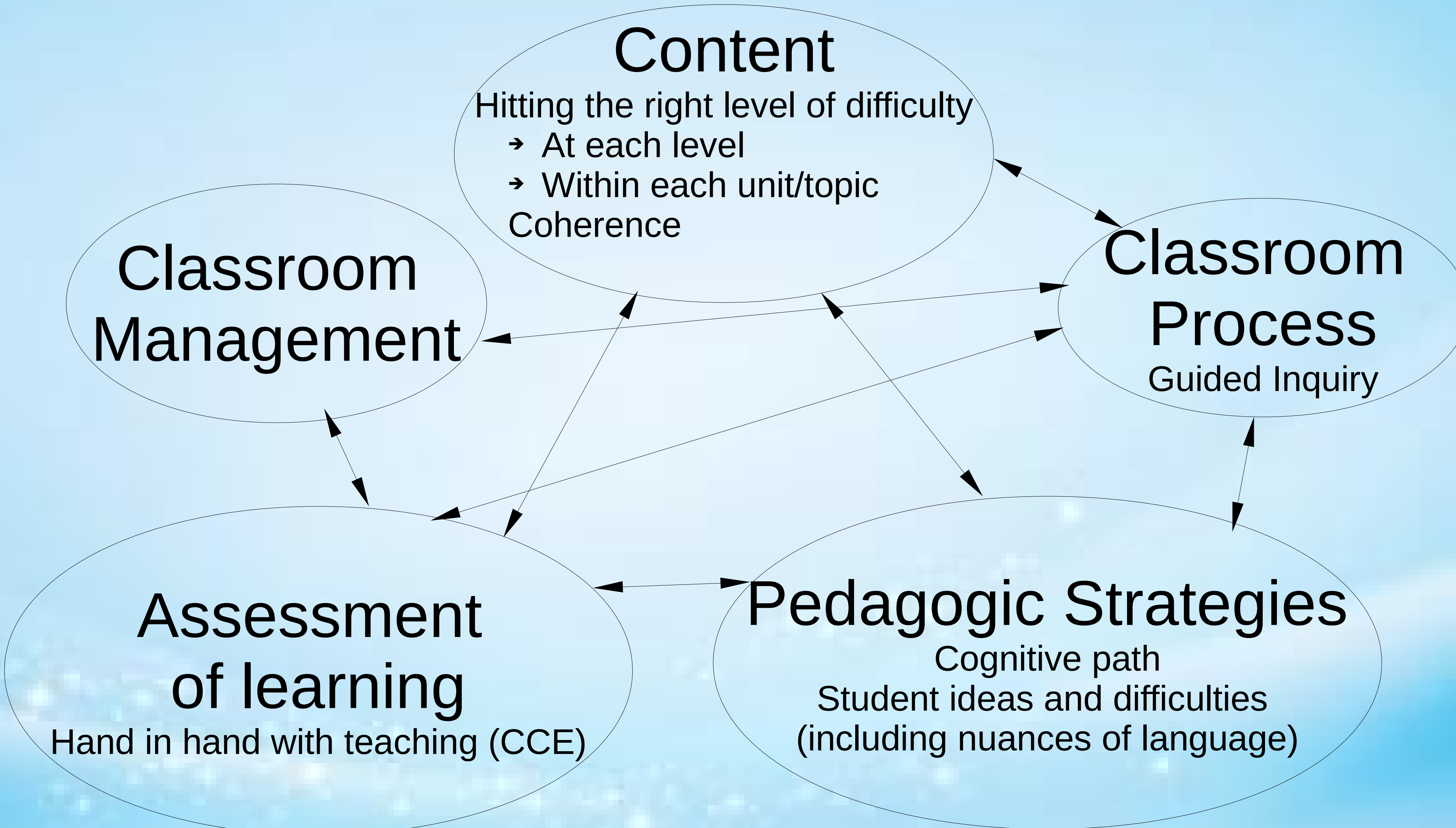
Note that the teacher is involved in his/her own inquiry

Adults easily see the logical flaw in a student's reasoning/understanding, and tend to address it directly

In the process they fail to address all the complexities of the misconception, and, more importantly, to give students the opportunity to deal with them and engage in the *process* of science

/home/hbc-8464/Desktop/JV SEMINAR/Clip 1.ogg

What teaching involves



The Teacher's role

In “Traditional” (Commonplace) teaching:

Teachers’ responsibility is to expound clearly

Teacher explains the concepts with the help of demonstrations and hands-on verification activities

In Inquiry teaching:

Teachers’ responsibility is to elicit, challenge and scaffold student thinking and encourage wider responses from the class

Teacher engages and guides students through investigations, making observations and arriving at explanations

Kawalkar and Vijapurkar 2013

Classroom discourse

In Commonplace classes:

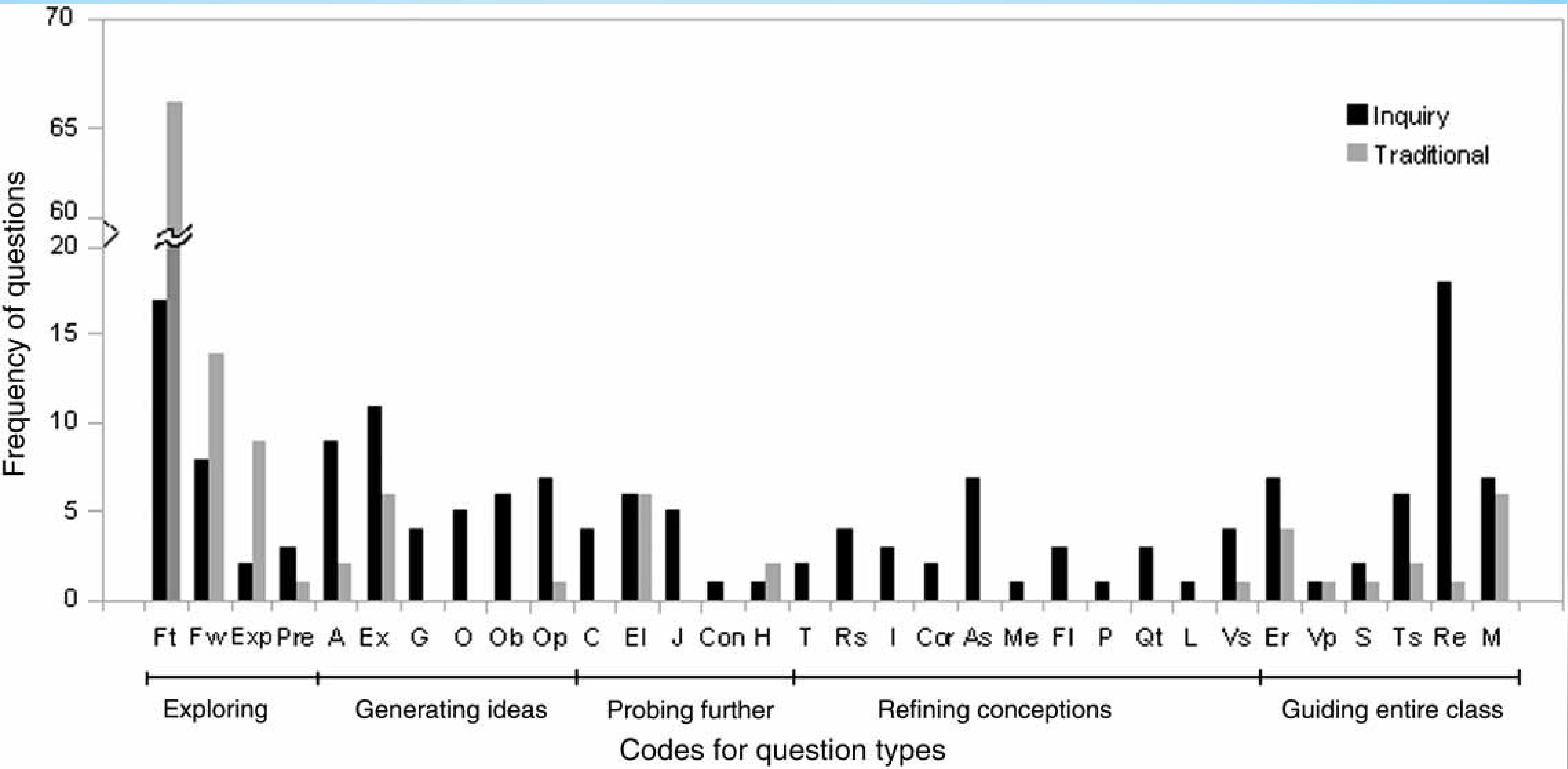
Teacher engages students in questioning that does not lead to discussions; teacher goes through a sequence of questioning, accepting, or correcting answers where necessary but rarely follows up with further probing

Students’ utterances are often in response to teachers’ questions and usually consist of single, detached words, many a times in chorus

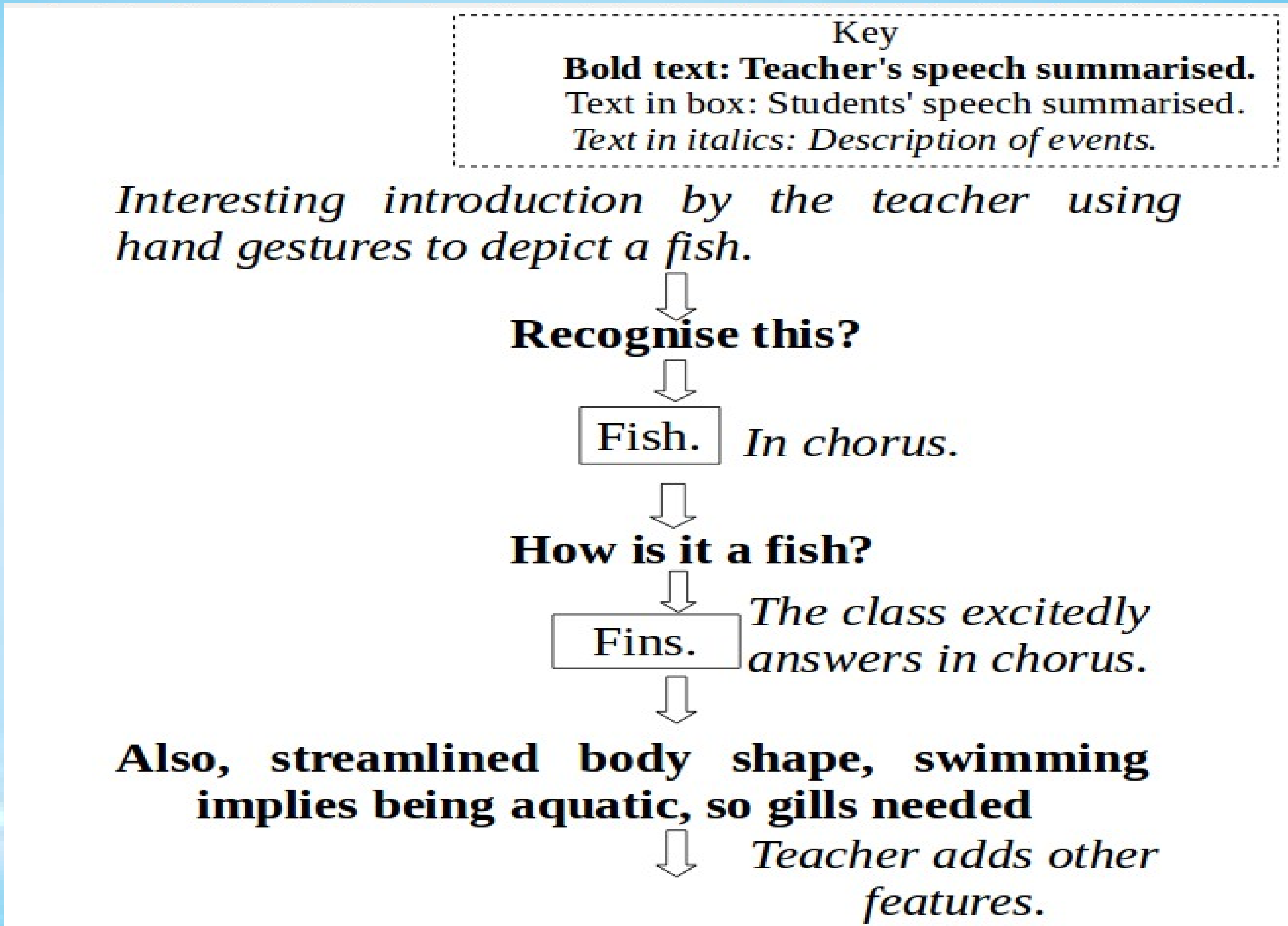
In Inquiry classes:

Teacher consistently engages students in open ended questions, often leading to discussion and debate where observations, assumptions and reasoning are challenged by the teacher or other students

Students' utterances are not restricted to direct answers to teachers' questions, are expressed in whole phrases/ sentences and may be tentative



Comparing teachers' questions in inquiry and traditional



'What makes a fish a fish'

Teacher shows some fishes (fresh specimen of pomfret and sardine and a preserved one of the seahorse) as well as a prawn and a starfish.

⇩

Which are fish? And which are not fish?

⇩

Seahorse is not a fish. *In chorus.*

⇩

Teacher explains how prawns and starfish are not fish while seahorse is a fish.

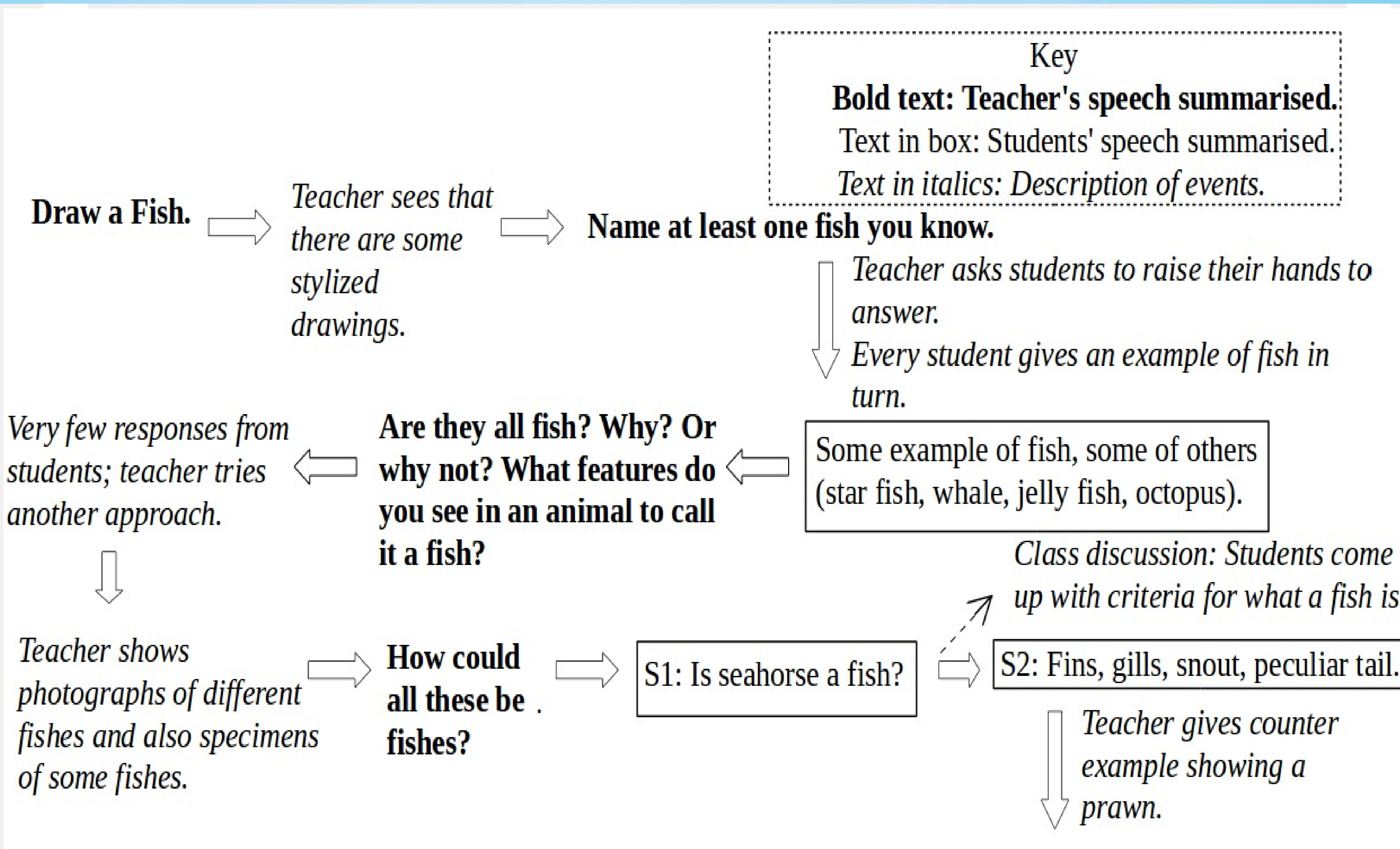
⇩

Teacher explains features of fish (such as gills, scales, different kinds of fins) with the help of a labelled picture of a goldfish.

⇩

For being a fish what are the important features? *Teacher assigns homework.*

'What makes a fish a fish'



'What makes a fish a fish'

A brief student generated discussion on what is meant by dorsal and ventral sides and sense organs in aquatic animals.

Teacher gives counter examples: for a particular criterion there would be some fishes that don't clearly have it and some other animals that do. Students too add to such examples. Class ends.

Next class: **Some fish, like the seahorse, do not have a streamlined body; some fishes have lungs too...**

S1: Some salamanders have gills and retain them for life; some reptiles have scales.

Class discussion leading to more questions.

S4: Are dolphins, fish or not? Why?
S5: What about jellyfish? What will we call tadpoles – they have many of these features?

S6: If jellyfish and starfish are not fish, why are they named that way?

Questions tossed back to students.

Teacher answers with history of classification of animals.

S3: Gills, scales, cold blooded. S6: Streamlined body. S4: Lateral line. [S?][*]: Snouts, tail.

Summing up of the criteria.

Exceptions: some larger fishes like white sharks can maintain higher body temperature.

'What makes a fish a fish'

Common in our classes for students:

To not want to stop for a break

To not want to be told the answer

To challenge authority

To ask for time to think

To argue their stance with supporting data

To stay engaged with a question or idea for long periods even outside of class

To ask questions

Method

Multiple trials in the classroom during the school year as well as vacations

Simultaneous testing across grades

A strong longitudinal study component

Duration of participating in the program	**Number of students**
1 year	9
2 years	8
3 years to 4 years	14

Detailed records of classes

Video/audio

Diaries by the teacher written immediately after class show a lot of self reflection (Teaching and classroom management methods refined through self reflection)

Diary entry: content (cognitive aspect)

“Class started with a discussion of homework - How would the sky appear if there were no atmosphere?

a) in the day and b) at night

A majority of students had said it would be white in the day... After much discussion, it emerged that the points of confusion/ contention were:

1. The sun is larger than Earth so light from 'all directions' falls on small earth washing it with light, so to speak. So the sky must look white. (Vipul had said that the ground would be bright but sky would be dark. Perfect!!)

2. The sun is far away.

After I addressed these points the class (all but 3 kids) concluded that the day sky would be dark except for the brightness in the sun's direction.

Some of the arguments were really of very high quality, and this was one thing they would never be able to test so they had to rely on logic to satisfy themselves of the correctness of their answer...”

Also, records of affective changes in students started to emerge in these diaries

“...Jatin volunteered to show Pythagoras theorem on the board... I have seen Jatin improving since we paid him a little attention before, but today his interest and participation was noticed as markedly different from that of the boy sitting in the back corner staring out of the window”

Our first study on affective outcomes

Our observations in class

+

Informal voluntary reports from students

↓

Post-intervention questionnaires

Students | Parents | Peers

↑ Follow up interviews (Students)

↑ Follow up interviews (Peers)

Kawalkar and Vijapurkar, 2011

In general, calls for more emphasis to be placed on affective aspects in science education research have not been met adequately*

To ignore the affective domain is to exclude consideration of a seminal part of the learning that takes place in science learning**

*Alsop, 2003
**Watts and Alsop, 2000

Outcomes of inquiry teaching

Outcomes for students - a wide range of changes

(Conceptual, Affective and Epistemic)

Now I love physics, I didn't like it earlier.

I used to hate science but now I like it much better than earlier.

I started paying attention to biology classes.

After attending HBCSE classes,topics like Newtons' law has become very interesting and has become one of the best topics to chat about with friends.

I now realise that biology is not just about remembering *[facts]*, there is so much more to it.

Biology experiments made difficult concepts easy to understand.

Chemistry is not visible; got more idea after learning here...

I started appreciating people who contributed to science... Actually *[earlier]* I did not take it as a creative thing or something on which we have to concentrate. It was a formality, you're going to school and you have to read it. But now I respect them *[scientists]* and I am inspired by them.

I imagined scientists as mixing two chemicals but now realise that there are different sorts of work that scientists do.

Earlier I didn't like it *[physics]* much and found it hard but after coming here I learned that it is all about our daily observations - force, momentum... if you see it practically then you can understand more.

Normally, earlier I used to mug up – social studies or science it made no difference to me. From the textbook I used to learn the definitions. Now after coming here when I learn something new I discuss with my friends, the first thing I do is <u>discuss</u> with my friends that I found something. <u>Then if they find any mistake they tell me, if there is a problem we discuss and come over it *[sic]*. That's how we learn Science.</u>

Yes, first we used to just mug up and teachers used to explain and we used to never question them. But now I learned to *question* and *reason*.

Also, they reported

- Higher achievement in other subjects, particularly in maths
- Higher confidence – started asking questions in class, lost fear of speaking in public, started participating in activities and anchoring events etc.
- That parents were getting involved...vacation trips were planned so as to not clash with our classes
- Enjoying HOS component
- That they started respecting rules

And....some negatives:

- Did not like dwelling for long on the same topic
- Did not like worksheets

Students reported these changes after an intervention period that was a small fraction of the time they spend in school

Limitation:

No control group… was the intervention per se responsible for some of these changes?

↓

A more rigorous study with a control group undergoing commonplace teaching initiated: A Ph. D project (Aisha Kawalkar)

More rigorous study on outcomes for students

Two similar cohorts underwent intervention at the same time, in the same place, taught the same topics. Each group had two different teachers.

Maintained diaries (open ended writings) about what they learned and their feelings about it

Kawalkar and Vijapurkar 2015

Students' diaries have the potential to:

Reveal what students have understood, and their understanding *as it evolves*

Expose what they have not

Reveal the teaching practice *as perceived by students*

	Units	Number of classes	
		Inquiry group	Comparison group
Biology Units	Fish	15	14
	(Circulatory and Respiratory system) [a]	(8)	(4)
	Structure of living cells	-	3
	Total	15	17
Physics Units	Density	20	9
	(Volume) [a]	(3)	(1)
	Electricity and Magnetism	-	7
	Total	20	16

Number of classes taken by teachers of the two groups for different units

[a] *These were sub-topics that differed considerably in terms of time taken to transact them.*

Results

- Content learning

  Traditional teaching (47 instances of lack of conceptual clarity, of which 21 were related to density)

Objects which are not heavy will float, heavy objects will sink.

We learned today that density of object = mass/ volume.

(Entry on the next day) I learned more about density. We understood the formula to find density.

Inquiry teaching (11 instances of lack of conceptual clarity)

We had to find out the volume of the object from the water displaced. *As per my observation,* the volume depends on the size of the object, but in one case it was not true.

- Affective aspects

Traditional

The class was very interesting.

It was a very exciting class.

Inquiry

The question started hot debate. We said *[sic]* and *convinced the teacher about our answer*.

It was great to get a chance to present our views in the debate.

It was a good and tricky sum *[problem]* but we tried our best.

Today teacher brought some objects, she dropped them in water and *through this experiment* we learned that there is no effect of air in making an object float or sink.

- Epistemic aspects

Expression of own involvement	No. of instances in inquiry group	No. of instances in comparison group
Statements explicitly showing a sense of shared epistemic authority	35	-
Statements showing modification of conclusion/tentative solutions	7 + 6*	1 + 11*

** responses to a question framed as 'give your guess' and explicitly asking why it may or may not be correct*

We were deciding which kinds of objects float and which ones sink...Then we raised doubts *[sic]* which **teacher** and **we answered**

Students internalised the inquiry approach to learning science -

"We did this experiment to find out if...", "...after much discussion we concluded that...", or that "we convinced the teacher of our answer..."

Epistemic difference in how students perceived learning science – whether it is "explained nicely" or "thinking how" and "to find out" was reflected in their diaries.

Studies on students' ideas

Students' notions of spontaneous generation of life

We first encountered these ideas in our classes

Were also aware that many adults in the general population held these ideas

Students given 3 situations:

- Mosquito life
- Appearance of moss in the monsoon
- Intestinal worms from eating sweets

Historically significant contexts!

Vijapurkar and Konde, 2014

HOMI BHABHA CENTRE FOR SCIENCE EDUCATION
Summer camp 2008
WORKSHEET FOR STUDENTS

Name: [redacted] Date: [redacted]

Class: VIII School: [redacted]

Before seeing a worm in a PEA. There is always a hole on that pea. So may be the worm makes a hole on that pea and then enters into that pea and start eating it.

Sometimes there is no hole, but still a worm is found inside that pea. So my imagination is that maybe after many days ~~that pea~~ inside the pea, the peagwin ~~may~~ must be damaged and then some reaction maybe taking place and a worm is formed.

Lice ~~[illegible]~~ are formed on the head due to other people. It is a spreading action.

175 (98 boys and 77 girls, age 12.3 years) middle school students (grade 8) from two schools.

In their schools had learned about mosquito, silkworm and butterfly life cycles, and about spores.

Two steps process

Step1. Written questionnaires – 175 students.

Step2. Interviews – 54 of 175 students.

Results

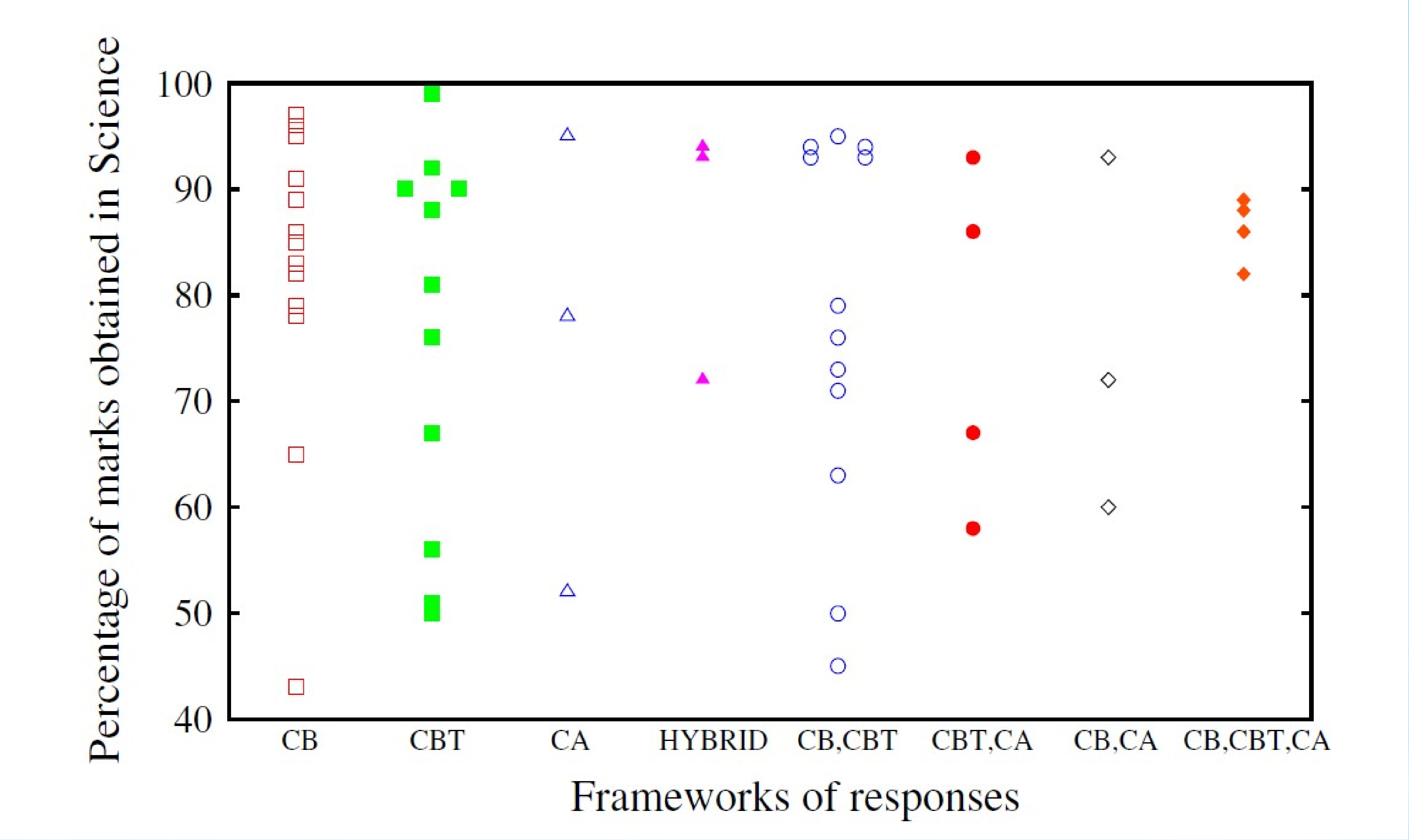
Students' explanations:

- Included the idea that one species can transform to another.

- Worms in vegetables and fruits → Intestinal worms.

- “Hybrid” a new category of explanation identified by this study.

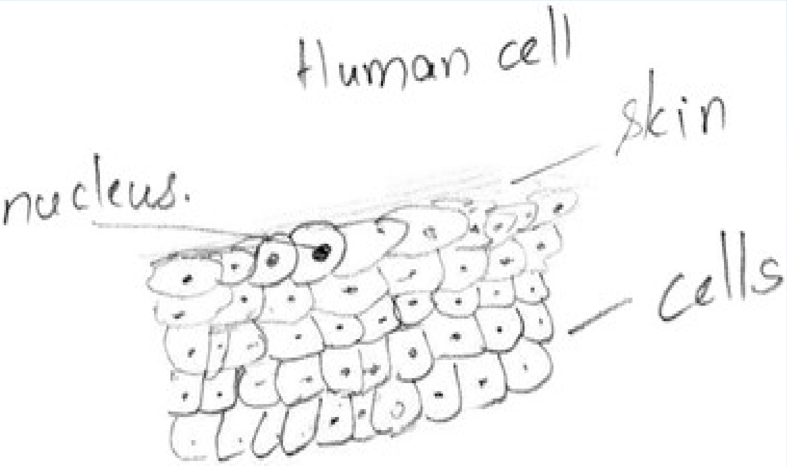
Students were using more than one framework across 3 questions and within questions.



Students’ academic achievement plotted against frameworks of responses

2-D visualization of the biological cell

Used models to diagnose and track students' evolving conceptions



Vijapurkar, Kawalkar and Nambiar 2014

From a researcher:

"Last year, I had initiated a project on exploring children's ideas with my undergraduate students. They in turn examined children of different age groups for their ideas on variable scientific issues, such as, child birth, shadows, rivers, earth etc. I found that although there is plenty of research on exploration of ideas, scant work is being published on how to bring about conceptual change. Your article was certainly an eye opener in this regard"

Outcomes for researchers

- Insights on curriculum and on classroom processes
- Innovative teaching strategies usable in a resource poor environment
- Making explicit the tacit strategies used by the teacher
- Unearthing students' (mis)conceptions
- Models of inquiry

- Significant contributions to science education literature (2013 paper among top 10 papers in IJSE, > 3260 downloads)
- Teacher workshops
- Articles for teachers
- Inputs to national/state level statutory bodies

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References

- Alsop, S. (2003). Science education and affect. International Journal of Science Education, Special issue: Affect, 25 (9), 1043-1047.
- Berry, A., & Milroy, P. (2002). Changes that matter. In J. Loughran, I. Mitchell, & J. Mitchell (Eds.), Learning from teacher research (pp. 196–221). New York: Teachers College Press.
- Bevins, S., & Price, G. (2016). Reconceptualizing inquiry in science education. International Journal of Science Education.
- Chi, M. T. H. (2008). Three types of conceptual change: belief revision, mental model transformation, and categorical shift. In S. Vosniadou (Ed.), Handbook of research on conceptual change (pp. 61–82). Hillsdale: Erlbaum.
- Kawalkar, A. & Vijapurkar, J. (2011) Several Lines of Inquiry Into Inquiry Teaching and Learning: Exploring the Affective Outcomes of Inquiry-Oriented Science Teaching. In D. Mogari, A. Mji and U. I. Ogbonnaya (Eds.), Proceedings of ISTE International Conference on Mathematics , Science and Technology Education, p. 265-276. South Africa: University of South Africa.

- Kawalkar, A., & Vijapurkar, J. (2013). Scaffolding Science Talk: The role of teachers' questions in the inquiry classroom, International Journal of Science Education, 35:12, 2004-2027, DOI: 10.1080/09500693.2011.604684
- Kawalkar, A., & Vijapurkar, J. (2015). Aspects of Teaching and Learning Science: What students' diaries reveal about inquiry and traditional modes, International Journal of Science Education, 37:13, 2113-2146, DOI: 10.1080/09500693.2015.1067933
- Vijapurkar, J., Kawalkar, A., Nambiar, P. (2014). What do Cells Really Look Like? An Inquiry into Students' Difficulties in Visualising a 3-D Biological Cell and Lessons for Pedagogy. Research in Science Education, 44:307–333. DOI 10.1007/s11165-013-9379-5
- Vijapurkar, J., Konde, P. (2014). *"Omne Vivum Ex Vivo"?* A Study of Middle School Students' Explanations of the Seemingly Sudden Appearance of Some Life Forms. Research in Science Education, 44:885–902. DOI 10.1007/s11165-014-9406-1
- Watts, M., & Alsop, S. (2000). The affective dimensions of learning science. International Journal of Science Education, 22(12), 1219-1220.

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