Developing unfamiliar scientific practices in Singapore: A case study of a lactose intolerance argumentation activity for middle-school learners

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Introduction

Science as practice has been a major reform initiative in US science education over the last decade that has gained attention in other regions too (e.g. Korea, Singapore)

8 scientific and engineering practices (SEP) reflect authentic ways of thinking and doing science and engineering. SEP shows the iterative nature of research, problem-solving and procedural & epistemic work that was missing in the earlier emphasis on learning via inquiry

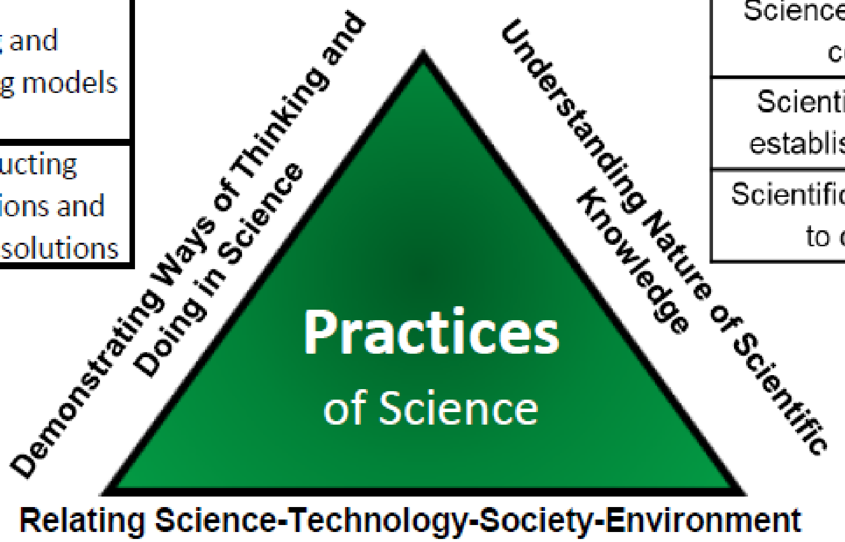
SEP-based instruction has to extend beyond a traditional linear process of the scientific method, or of mere transfer of facts from teacher to students

Set of established procedures and processes associated with scientific inquiry

Demonstrating WOTD		
Investigating	**Evaluating and Reasoning**	**Developing Explanations and Solutions**
Posing questions and defining problems	Communicating, evaluating and defending ideas with evidence	Using and developing models
Designing investigations	Making informed decisions and taking responsible actions	Constructing explanations and designing solutions
Conducting experiments and testing solutions		
Analysing and interpreting data		

How scientific knowledge is generated and established

Understanding NOS
Science is an evidence-based, model-building enterprise to understand the real world.
Science assumes natural causes, order and consistency in natural systems.
Scientific knowledge is generated through established procedures and critical debate.
Scientific knowledge is reliable, durable, open to change in light of new evidence.



Relating STSE
There are risks and benefits associated with the applications of Science in society.
Applications of Science often have ethical, social, economic and environmental implications.
Application of new scientific discoveries often drive technological advancement while advances in technology enable scientists to make new or deeper inquiry.

Application of Science in society

Our research

Designed a middle school scientific activity on lactose intolerance (LI) to foster productive disciplinary engagement (PDE) in argumentation (Engle & Conant, 2002):

1. **Productive**: Intellectual improvements/progress made in a disciplinary issue that students are engaged with that could include recognising a confusion or problem with an idea, making connections across ideas, or constructing a scientifically sounder argument
2. **Disciplinary**: Links between what students are doing and the issues and practices of a discipline's discourse. A diversity of what counts as disciplinary work
3. **Engagement**: Extent students contribute to a discussion about a topic in coordination with other students and continue to be involved attentively over a period of time and/or re-engage in the discussion promptly

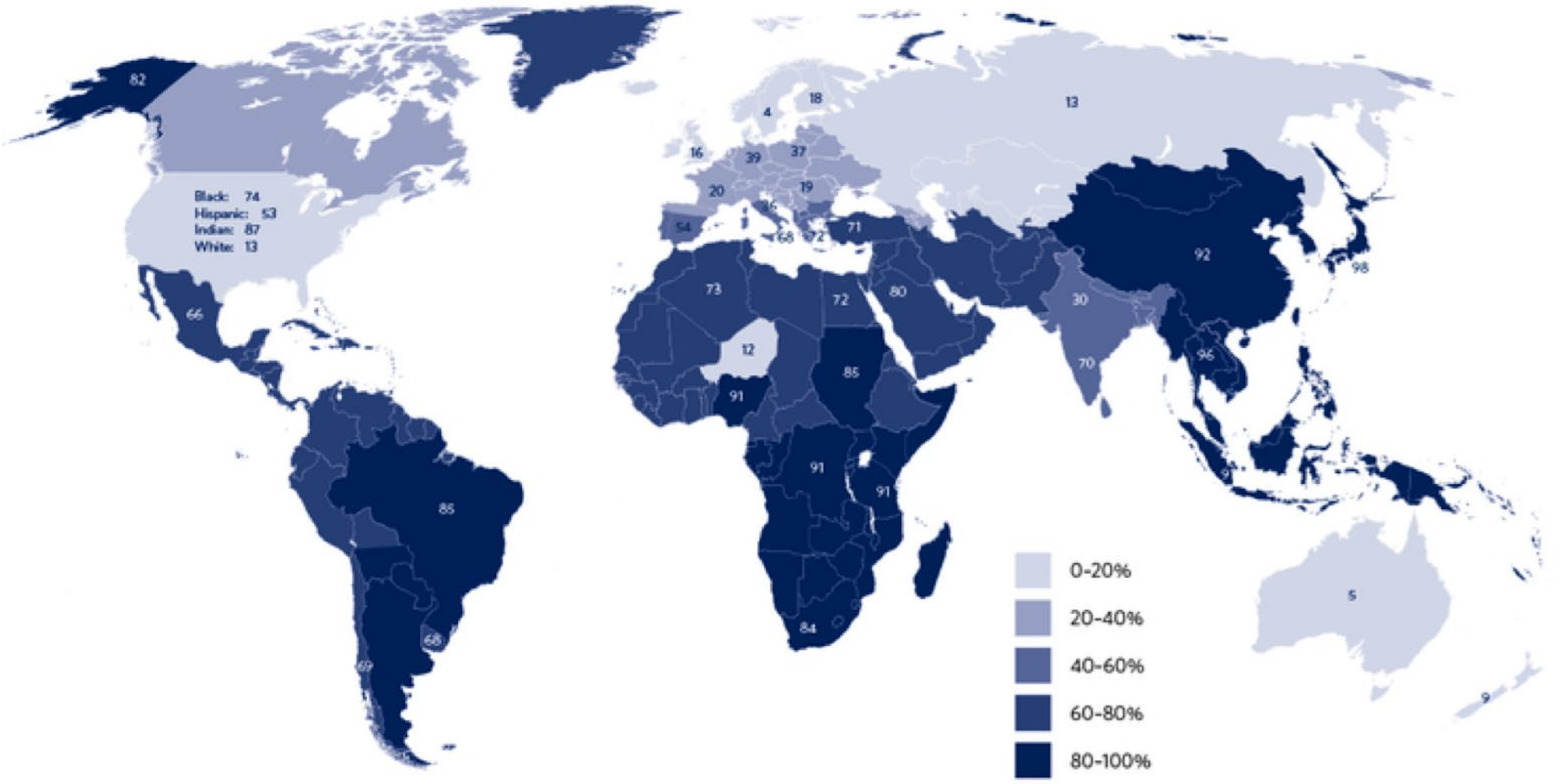
- Such perspective of PDE situates learning as a social experience and anchors the development of understanding on students' collaborative & interactive discourse as well as learning actions
- Argumentation is a very unfamiliar practice for students and teachers in Singapore ("middle sphere") that is a typical East Asian context. It is least successfully implemented and most misunderstood by many science teachers around the world

4 design principles of PDE

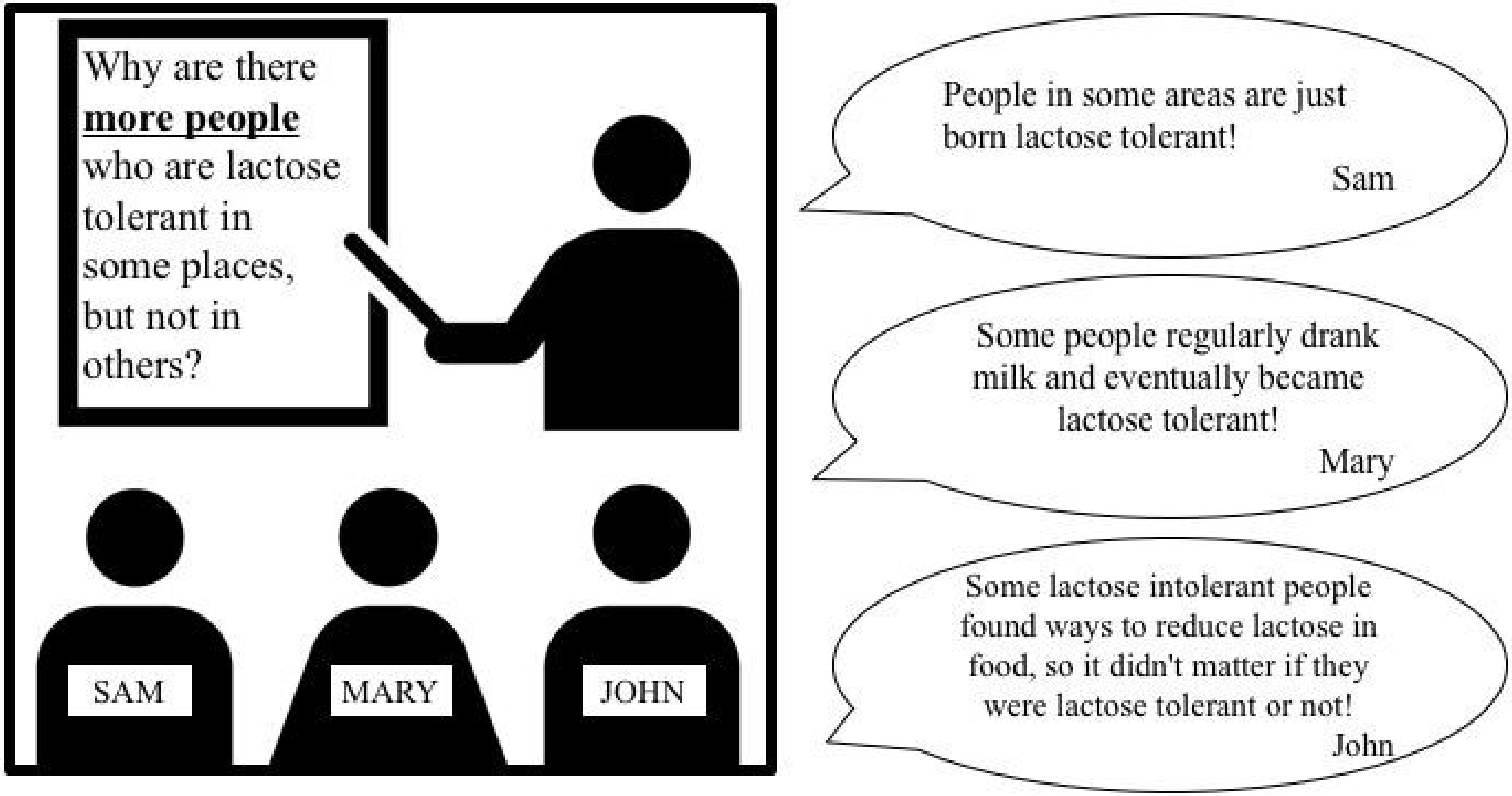
1) *Problematising: S*tudents work on a problem that is meaningful to the disciplinary community, i.e., the scientific community in our case
2) *Resources:* Such as sufficient time or materials, access to relevant information, and relevant scaffolding
3) *Authority:* Learners define, address, and solve the problem. They assume more active roles such as stakeholders, contributors, and experts that encourages them to be producers of knowledge
4) *Accountability: S*tudents would be responsive towards other perspectives, especially those holding differing perspectives. They have to reconcile why their ideas differ from others' valid ideas, including authoritative disciplinary ideas. In the context of argumentation, it includes holding ideas accountable to epistemic criteria or ideals valued by scientific communities such as the notions of reliability and validity

Study site

- Data came from a larger project that sought to develop new science activities based on SEP for middle-school students in Singapore.
- Used video- and audio-recordings of lessons, teacher pre- and post-activity interviews, field notes, student focus group discussions (FGD), and completed worksheets/artifacts. Teacher interviews for both pre- and post-activity to elicit their views about the aims, learning goals/opportunities, and the implementation issues surrounding the activity. FGDs with 12 students per class (students were divided into two groups of six)
- The argumentation segment of the LI activity was implemented over 1 hour in each class, which was the average time for a secondary science lesson in Singapore.
- LI activity took place at a school with two Grade 7 classes consisting of 38 (Class A1) and 39 (Class A2) students respectively. Secondary school (Grades 7 to 10) for girls in the north-eastern part of Singapore that was founded by a religious order and was considered academically average among secondary schools



Problem: "Why are there more people who are lactose tolerant in some places, but not in others?"



As a group, choose whose explanation you think is the most well supported by evidence. Your group may choose more than one explanation if you can provide enough support! [*Authority & Accountability*]

6 Evidence cards [*Resourcing*]	Description of each card
1	a written statement of the history of the lactose tolerance gene
2	a map of the genetic heritage of some regions
3	a summary of a scientific research study on the effect of daily lactose feeding to the symptoms of lactose intolerance
4	a map of the distribution of global milk consumption
5	a table of percentage of lactose content in some dairy products
6	a map of the distribution of global milk production

Data analysis

- Used **three-dimensional student outcomes of PDE** to evaluate the LI activity. Hence, students must be shown to critique and construct of arguments using appropriate evidence & scientific reasoning especially how the balance of student authority & accountability is achieved
- **Video recording** of the lessons served as the primary source of data here to capture how the two teachers presented the argumentation problem, the claims and the evidence cards to the students (problematising and resources) and subsequently guided the students' engagement in argumentation (accountability and authority)
- **FGD video/audio** recordings to gain insights into how groups proceeded with the LI activity. We also reviewed students' **worksheets** to assess the quality of students' arguments and peer critique as a further measure of their demonstration of the argumentation practice

Findings

- Students did not engage in scientific argumentation productively as intended – why?
- At the whole class level and small group presentations of their arguments, both teachers were satisfied after *students constructed and presented but students did not engage in critical discussion of various arguments put forth by their peers*
- So we found *absence of peer critique of arguments based on epistemic criteria*; not a surprising situation as it has also been reported elsewhere
- Teachers also *did not reconcile any differences in students' choice of evidence cards* to support the same claim across different groups
- In the end, *class did not decide which claim (A, B, or C) best explained the global distribution of lactose tolerant populations*, which was the driving question of the argumentation activity. Thus, groups only proposed their **own** argument without reaching a consensus on which is the best or most scientifically sound argument.

Discussion

- The teachers had modified the nature of the problem and thus reduced the extent of scientific argumentation intended by our LI activity design.
- Too much time and effort was dedicated to students understanding the evidence cards and they ended up working on the less critical task of matching evidence cards to their selected claim without "rising above" to answer the main question of about population distributions.
- Additionally, the lack of appropriate resources to support students in evaluating their own argument during group discussion led to a lack of accountability of students' ideas.
- This was exacerbated as the teachers also did not adequately hold students' arguments accountable when the groups shared their arguments at the class level.
- Teachers were overly reliant on the information provided in the Teacher Resource document to critique students' arguments. Teachers were eager to highlight responses that agreed with those in the document but downplayed or dismissed responses that were not mentioned in the document.

- The LI activity as implemented might have given students the impression that all arguments presented were equally good and valid, as mentioned above.
- Without "rising above" to the task of reaching a consensus on the most scientifically sound explanation for the observed phenomenon (i.e., lactose tolerant populations distribution) among the science classroom community, students (and teachers) might have missed the goal of engaging in scientific argumentation through peer critiques of evidence and scientific reasoning.

Implications

- Need to have extended PD of an unfamiliar scientific practice (i.e., argumentation). Teachers in our study might have inadvertently underestimated the challenges of facilitating argumentation
- The reliance on teacher resources, which we had provided, might have given teachers a false sense of security that they would be able to facilitate an unfamiliar scientific practice by simply reading the resources or thinking that the LI activity was yet another confirmatory practical
- Our experience underscores the point that engaging in learning scientific practices are non-trivial— they are not just a re-naming of old science process skills, which some teachers seemed to think
- Furthermore, it is unlikely that a one-hour engagement in scientific argumentation would enable students to become good at this practice. There is a need for us to persuade teachers that more instructional time should be spent on worthy activities such as the LI activity