SCIENTIFIC INQUIRY WITH KNOWLEDGE BUILDING AND VIRTUAL LABORATORIES
Thong Chee Hing, Anselm Premkumar Paul, Lye Sze Yee and Chia Pei Xian

WHAT

Scientific inquiry invites students to connect prior knowledge to new ideas and experiences, explore and form new understandings, and formulate explanations about observed natural phenomena. Students study the natural world by asking questions, and designing and conducting investigations to collect the evidence needed to answer those questions.

Knowledge Building and virtual laboratory simulations can be used to support students in their scientific inquiry. During Knowledge Building (Bereiter, Scardamalia, Cassells & Hewitt, 1997), students work as a community of learners to collectively problematize the task by raising and pondering questions in Knowledge Forum (KF). They explore and engage in KF discussions (Figure 1) to understand the given context, define the task’s variables and constants, elaborate their experiment procedures, and later evaluate, explain and discuss the experimental results.

Students can iteratively test and refine their procedures and apparatus using a virtual laboratory (Figure 2) which can simulate various experimental conditions. They can then share their experimental approach and results with their peers in KF for additional feedback and further discussion.

Figure 1: Students’ discussion in KF

Figure 2: A virtual laboratory

WHY

Students tend to perceive scientific inquiry as a solitary, single-attempt endeavour. Thus students may not appreciate the role Science plays in societal progress, or recognise how Science is relevant to daily life (Goh, Chai & Tsai, 2012). To address these misconceptions, teachers should design learning experiences that involve the iterative and negotiative nature of doing Science, much like what scientists themselves experience in constructing scientific knowledge (Lin, Goh, Chai & Tsai, 2013). Understanding the nature of scientific inquiry can help students “learn science content with more depth” (Deng, Chen, Tsai & Chai, 2011).
In addition, this approach to scientific inquiry enables students to develop essential 21st century competencies such as critical and inventive thinking, and information and communication skills. Students are given ample opportunities to share their understanding with peers for improvement, discuss ideas using empirical data, and pull arguments together to form new concepts, and refine experimental designs and explanations (Goh, Chai & Tsai, 2012).

Knowledge Building and virtual experiments encourage students to explore multiple perspectives of their designs and iteratively refine their experimental procedures. Virtual laboratories present results dynamically in multiple representations such as graphs and data tables based on students’ inputs. These representations help students to focus their attention on elaborating the underlying theories or constructing concepts.

**COLLABORATIVE LEARNING**

Effective group processes
- Students negotiate and set common understanding
- Students interactively contribute own ideas and consider other points of view objectively
- Students seek clarifications and offer constructive feedback
- Students take on roles and tasks responsibly to achieve group goals
- Students reflect on group and individual learning processes

Individual and Group Accountability of Learning
- Students rely on each other for success
- Students work towards completing individual task as well as helping group members achieve their goals

**SELF-DIRECTED LEARNING**

Ownership of learning
- Students articulate and identify gaps of understanding

Management and Monitoring of Own Learning
- Students formulate questions and generate own inquiries
- Students explore alternatives and make decisions
- Students reflect on their doing and use feedback to improve
- Students plan and manage their time and workload

**HOW**

In the Problematization phase (Figure 3), a teacher posts an authentic and ill-structured task that involves a discrepant event to motivate and engage the students in generating a diversity of ideas. In groups of 3 or 4, students post their initial ideas about the task on KF, then clarify and improve these ideas to lead to a collective understanding of the problem. The teacher facilitates each group discussion with prompts such as “What do we know and want to know about this task?”, “What do we know about …?”, and “How do we know …?”
Figure 3: Phases of scientific inquiry with knowledge building and virtual laboratories

During the **Experimentation** phase, each group member designs his experimental procedure, identifies the dependent or independent variables and constants, and formulates the hypotheses and assumptions. The student then tests the workability of his or her procedure. Through building and testing simulated experiments, students are able to plan and monitor their progress.

In the **Consolidation** phase, group members post their experimental data and graphical analysis in KF. They share and negotiate between differing ideas, and provide justifications for their propositions. They work collectively to synthesise and consolidate the group’s understanding of the investigation based on the robustness of the experimental evidence. During this social negotiation process, students deepen and broaden their understanding of the authentic task and of their knowledge gaps.

During the **Reflection** phase, the teacher facilitates group discussions with students to reflect on areas for improvement in terms of experimental design and Knowledge Building processes.

These 4 phases make up the approach to scientific inquiry with Knowledge Building and virtual laboratories.

Last but not least, it is important to lay ground rules for students to work collaboratively. Hence, structures must be put in place to ensure full participation by students. Examples of participation structures are getting students to listen to each other actively, share personal responses, consider alternative points of view, and question ideas politely. In addition to providing sufficient time and space, the teacher must also create a safe environment for students to share, reflect and synthesise ideas with one another.

**TECHNOLOGIES**

**Knowledge Forum**
http://www.knowledgeforum.com/

**Virtual Laboratories**
https://phet.colorado.edu/en/simulations/category/physics
https://phet.colorado.edu/en/simulations/category/chemistry
http://onlinelabs.in/chemistry

**ETD PROJECT SCHOOLS**

Beatty Secondary
Chung Cheng High (Main)
Regent Secondary
Yishun Town Secondary
RESOURCES


PARTICIPATION

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The design principles for creating lessons that involve scientific inquiry with Knowledge Building and the use of virtual laboratories are presented in the table below. We have also provided an exemplar which integrates the principles into a coherent Physics lesson flow.

<table>
<thead>
<tr>
<th>Phase</th>
<th>Activity</th>
<th>Participation Structures</th>
<th>Social Surround</th>
</tr>
</thead>
</table>
| Problematization | 1. Post an authentic and ill-structured problem which involves a discrepant event to generate diversity of ideas  
2. Improve initial ideas to lead to a collective understanding of the problem | Provide opportunities for learners to oscillate between self-directed reflection and collaborative learning in support of the iterative and negotiative nature of scientific inquiry | Create a classroom environment for learners to take on the role of thinking like scientists and encourage student-centred ideation to advance learning |
| Experimentation | 1. Identify parameters to set up a virtual experiment to address the problem:  
a. dependent/ independent variables and constants  
b. hypotheses based on identified variables  
c. assumptions made  
2. Test workability of experimental approach(es)  
3. Extract empirical data to either support or oppose propositions to address the problem |                                                                                     |                                                                                 |
| Consolidation  | Generate a rise-above to synthesise group understandings of the problem with reference to:  
a. robustness of experimental evidence  
b. comparison of similar and contrasting perspectives |                                                                                     |                                                                                 |
| Reflection     | Engage in meta-discourse analysis to highlight areas for improvement in terms of Knowledge Building behaviours |                                                                                     |                                                                                 |
# Lesson

<table>
<thead>
<tr>
<th>Level</th>
<th>Secondary Two Express/ Normal (Academic)</th>
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</thead>
<tbody>
<tr>
<td>Topic</td>
<td>Optics – Lenses</td>
</tr>
<tr>
<td>Learning Outcome</td>
<td>To investigate the relationship between object distance and image distance of a converging lens</td>
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<td>Setting the context</td>
<td>Inviting students to share their views on their perception of what Science is, what Scientists do, and the difference between learning about Science and learning Science</td>
<td>Encouraging students to research and reflect on the dispositions of a Scientist. Providing space for students to share with one another their research as well as stories of how Scientists have shaped the world.</td>
<td>Pervasive Knowledge Building. Making connections between the task and students’ lives outside the classroom, and encouraging them to do the same.</td>
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<tr>
<td></td>
<td>Inspire students with stories of how Scientists (e.g. Galileo Galilei) have shaped our views of the world</td>
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<tr>
<td>Problematisation</td>
<td>Negotiating with students regarding the set of expectations and ground rules for productive Knowledge Building.</td>
<td>Encouraging students to think about expectations and ground rules that would enrich their scientific inquiry with knowledge building. Providing space for students to consolidate expectations and ground rules for the group.</td>
<td>Community Knowledge, Collective Responsibility. Focusing on shared goals and value the contributions of every student in helping to advance the knowledge of the class.</td>
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<td>Posting Inquiry-Based Investigative Task</td>
<td>Providing space for pupils to first reflect before individually posting their initial thoughts on the problem.</td>
<td>Real Ideas, Authentic Problems. Encouraging students to focus on problems that matter.</td>
</tr>
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*It is selfie time! Tim received a camera with this funny number 18 ~ 55 mm as a gift. You are to design an experiment to explain what*
| **Experimentation** | Allowing students to work out an experiment to demonstrate the outcomes of the numbers 18–55mm, and **Guiding students in identifying and establishing:**  
- dependent and independent variables, and constants  
- hypotheses based on identified variables  
- experimental procedures  
- assumptions made or limitations of ideas  

Guiding students in:  
- Testing the workability of experimental approach(es). For example, they could investigate the relationship between object distance and image distance.  
- Investigate irregularities/ambiguous results at any point of the inquiry process,  
- Explore different experimental approach(es) using different sets of variables, apparatus, material and virtual laboratories.  

| **Epistemic Agency** | Giving pupils the independence and encouragement to own and manage their learning.  
- Providing the space for students to share and negotiate between differing ideas, opinions and views, (within or across groups)  
- Encouraging learners to share with one another any irregularities/ambiguous results and assumptions made or limitations of ideas. |
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<tr>
<th><strong>Consolidation</strong></th>
<th>Instructing students to build on the post-experimental postings of group members. Using pre-experimental and post-experimental postings to facilitate a rise-above, to synthesize group understanding with focus on understandings of the problem and ways to achieve class goals.</th>
<th>Encouraging students to continue building on one another’s ideas using their own experimental findings. Inviting learners to discuss with one another on similar and/or contrasting ideas in reference to their pre- and post-experimental postings.</th>
<th><strong>Immovable Ideas</strong></th>
<th>Cultivating an environment where students feel safe in taking risks—revealing ignorance, voicing half-baked notions, giving and receiving criticism. After all every idea is a work-in-progress.</th>
<th><strong>Rise-Above</strong></th>
<th>Consciously pulling out similar or contrasting ideas and encouraging pupils to form a deduction.</th>
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<td><strong>Reflection</strong></td>
<td>Summarising past lessons by reflecting on learning gleaned both from the discourse and meta-discourse.</td>
<td>Facilitating dialogue between students and teachers not only on what they have learnt, but also on the meta-processes that have helped them learn better.</td>
<td><strong>Pervasive Knowledge Building</strong></td>
<td>Making connections between the task and pupils’ lives outside the classroom, and encouraging them to do the same.</td>
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