Foundations of *PBIS*: What Scientists Know About Learning

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The design of *PBIS* has its roots in two strands of modern research on how people learn: the literature on the mental processes (cognition) involved in learning and the literature on engagement.

The Mental Processes Involved in Learning

The literature on the mental processes involved in learning tells us that people learn content and capabilities iteratively and incrementally,—a little at a time as a result of repeated and reflective practice. The literature on how people come to understand new concepts (e.g., Piaget) tells us that learning concepts is a process of iteratively and incrementally building mental models, revising them, and connecting them together. The literature on skill acquisition (e.g., Anderson; Schank & Abelson; Newell, Rosenbloom, & Laird) tells us that development of cognitive skills is a process of iteratively and incrementally refining, compiling, and automating ways of reasoning. This literature defines reasoning as a process of using mental models and cognitive skills to make sense of the world, achieve goals, and solve problems, and learning means constructing new mental models and skills by building on, revising, and connecting together what we already know (*Zone of Proximal Development*–Vygotsky). From this, we can conclude that learning deeply requires a great deal of reflection and interpretation—to recognize the need to learn and to troubleshoot and revise one's mental models and cognitive skills (e.g., Anderson, Bransford, Collins, Schank). In short, understanding anything deeply and learning enough to be able to apply what one is learning requires significant time and practice as well as reflection on, articulation of, and debugging of one's understanding and reasoning.

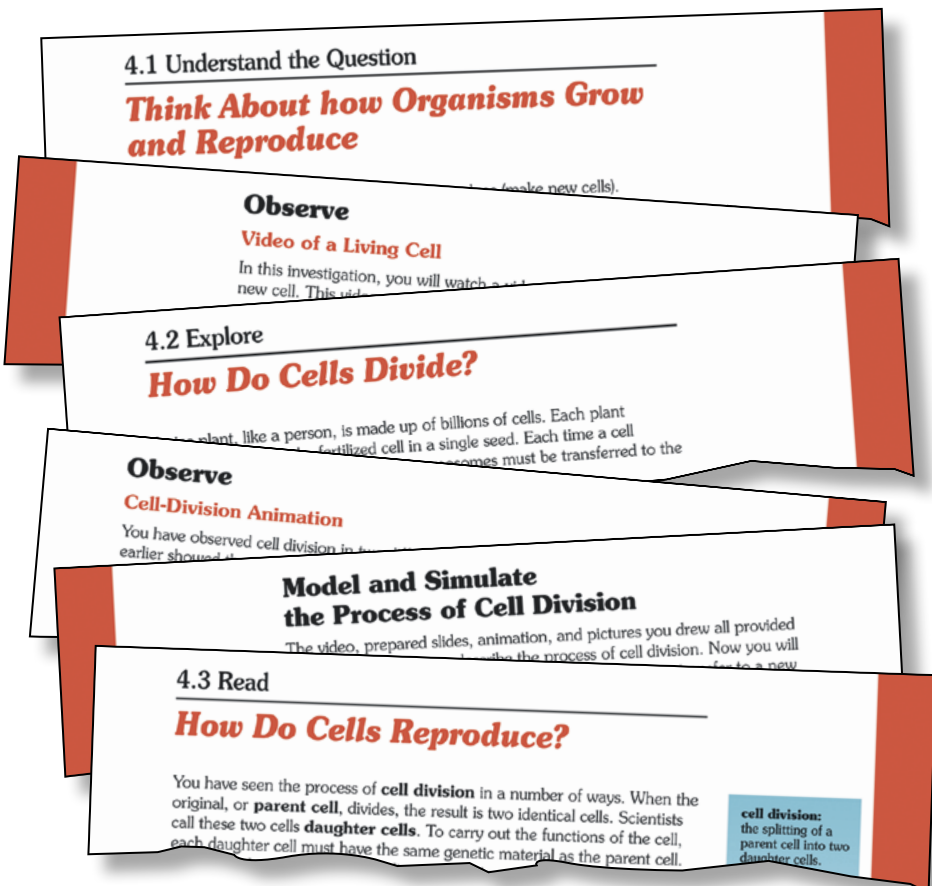
A **mental model** is one's mental representation (internal model) of something in the external world and includes everything one knows or thinks about something in the world—objects, ideas, processes, concepts, and people.

Iteration means working towards achieving a goal or desired result by repeatedly working toward achieving the goal or desired result, each time beginning with the previous result and using new knowledge or capabilities to achieve a better result each time.

When iterating toward a solution, one incrementally adds to the solution and to what one knows. An increment is a small increase. To incrementally add to a solution or what one knows means to add a bit at a time.

PBIS builds on five principles derived from this research:

- Learning is a process of iteratively constructing, revising, and connecting together mental models—models of what we know.
- Becoming fluid at reasoning skills is an iterative process of composing and debugging sequences of "how-to's"—mental logic for carrying out reasoning.
- This implies that we can only learn on the edges of what we already know.
- Learners know they need to learn something when a mental model or how-to sequence doesn't do the work they want it to do—they can't do something happens that they weren't expecting and can't explain (e.g. Anderson; Schank & Abelson; Newell, Rosenbloom, & Laird)
- A great deal of reflection and interpretation, and therefore time, are needed to recognize the need to learn and to troubleshoot and revise one's mental models.



These principles suggest that to promote learning well, activities in a curriculum should be sequenced so that learners have a chance to repeatedly practice using knowledge and skills they are learning in a variety of contexts and to iteratively and incrementally construct understanding, and that learners be helped to periodically reflect on their reasoning so that they become aware of the ways in which their understanding and capabilities need to be deepened or corrected.

These principles also suggest that the more learning activities are aligned to learners' goals, the more attention learners will put into building accurate, complete, and connected mental models. The principles further tell us that the better-aligned learning activities are with contexts in which mental models and skills will be used, the more accurate, complete, and connected the mental models and skills learners develop.

This research suggests to *PBIS's* designers five criteria we aimed to fulfill in *PBIS* units:

- Sequence activities in each unit so that learners have the opportunity to build up from what they already know (previously-acquired knowledge).
- Sequence activities so that learners have a chance to incrementally build up mental models and cognitive skills, try them out in a variety of contexts, and gradually make their mental models more accurate, complete, and connected to each other.
- Align unit challenges with the interest and goals of middle schoolers.
- Design unit challenges so that learners will be using targeted knowledge and skills in ways that match the ways they are used in the real world.
- Embed into units scaffolding that will provide reminders for learners of when and how to use skills and knowledge they are learning so that they can successful, and design the scaffolding so that it corresponds to what learners are familiar with and what we anticipate they might have difficulties with.

Engaging Learners and Sustaining their Engagement

The second of these criteria suggests that units should be long enough for learners to apply and debug the mental models and cognitive skills they are constructing several times. This, in turn, requires that learners remain engaged with learning activities for sustained periods of time. The literature on engagement sheds light on helping learners become and remain engaged. Some of the suggestions made by this literature are similar to suggestions that arise from the literature on mental processes involved in learning, and some are new.

Some research on engagement focuses on *personal meaningfulness* (e.g., Papert, Resnick, pianos not stereos). This literature tells us that people engage to the extent that they are interested and to the extent that they are able to be successful, suggesting, as the previously-mentioned literature does, that unit challenges should align with the interests and goals of middle schoolers and build on what they already know. This same strand of research suggests, further, that engagement will be sustained best when activities learners are engaged in are *richly authentic* (Shaffer & Resnick). According to this research, the most engaging learning activities align with the personal interests and capabilities of learners (personal authenticity), and in addition, are consistent with the activities of some set of people in the real world (disciplinary authenticity), give learners access to the same sorts of environments and resources as those who do these activities in the real world (real-world authenticity), and provide learners ways of assessing their own progress, understanding, and capabilities (assessment authenticity). Research by several of *PBIS's* developers (e.g., Krajcik, Edelson, Reiser) identifies particular scientific practices that can be made richly authentic for young science learners and how to achieve that. *PBIS* developers adopted these principles from this strand of research on engagement:

- Because we want learners to learn scientific reasoning, we should have learners engage in scientific reasoning as scientists would (disciplinary authenticity) using the tools scientist would use and having access to the same kinds of resources (real-world authenticity).
- Learners should be doing scientific reasoning in contexts that interest them and make sure to help them connect those contexts to what they already know (personal authenticity).
- Scaffolding in units should help learners gauge what they know and what they are stull unsure of (assessment authenticity).

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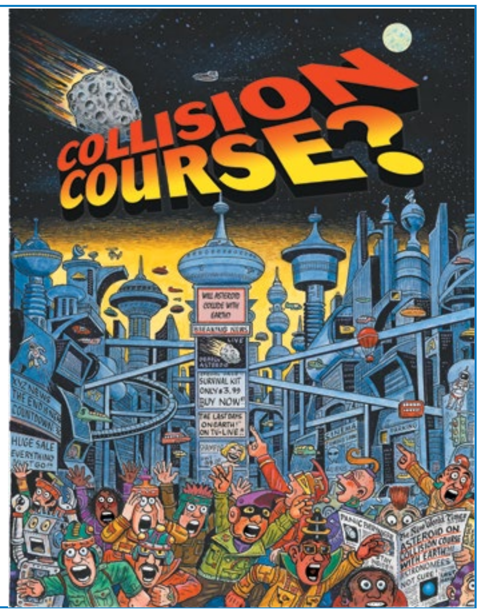
excerpt from *Astronomy* page 4



Other research on engagement focuses on agency (e.g., Holland). Agency means being in a position to exert power and make decisions. This research tells us that turning over agency to learners allows them to decide for themselves to participate. These researchers show that when learners have opportunities to make choices about how to participate, they engage more readily. Of course, it is important not to turn the classroom over to the students, and *PBIS* developers focused a lot of attention on which decisions might be turned over to students and on how the teacher and text could provide scaffolding that would help students make good decisions.

Still other research on engagement helped *PBIS* developers make those decisions—research the social and cultural conventions of *communities* of practice (Lave & Wenger). A community of practice is a group of people who share a set of goals—often those associated with an interest, profession, or craft. In a community of practice, those who are more capable often give of themselves to help others gain capabilities. Those who have more capability and who help others become more capable become more central to a community. Over time, shared values, ways of doing things, and ways of working together with each other evolve. Shared values and ways of working together, in turn, sustain the community. In her work on *Learning by Design*, one *PBIS* developer (Kolodner) showed how *Launcher Units* could be used to promote shared values and ways of doing (community) and that continued work together in the classroom sustains the classroom community.

From this research, *PBIS* developers developed these principles that are enacted in *PBIS*:

- Help learners and teachers together form classroom communities. The activities and sequencing in *Launcher Units* is Designed to help classes form a community of practice at the beginning of the school year, and the community of practice is sustained through repeated engagement in the classroom activities introduced in the *Launcher* throughout the year.
- Give learners opportunities to help each other understand and learn. Work in small groups, whole-class discussions, and presentations provide these opportunities.
- Provide scaffolding to learners that will help them be successful at working together and at helping each other learn. The text always includes hints and prompts to help students know how to participate and what to listen for or notice while working in small groups, engaging in whole-class discussions, and making presentations.
- Have learners identify what might come next before telling them what to do. This is achieved in the sequencing of units and the use of *Project Board* to keep track of questions they have raised and what they are learning.