The Quest for Deeper Understanding

Achieving a deep understanding of something can be challenging for many students, however the benefits can be transformative. **Tina Grotzer** shares some approaches for developing adaptive expertise and helping children become deeper learners.

Learning is like a geode. Its hidden gems are revealed to those who invest the effort to get beneath the surface, to look deeper and to get to know the internal structures.

The nature of understanding and how it relates to the enterprise of education has long been a focus of Project Zero research and for good reason. Understanding is elusive; it requires considerable investment, but the pay-offs can be significant for learners.

Fortunately, research has helped us to learn a lot about the nature of deep understanding and the challenges in developing it. In this article, I explain the main ideas behind what we have learned along the way and offer some implications for practice. First, I step back to consider the nature of understanding and to elaborate some principles that have guided Project Zero's work on understanding over the years.

Take a few minutes to think about something that you understand very deeply. What are the features of this understanding? In what ways does the understanding reveal itself? What is the emotional impact of having this type of understanding? Next, take a few minutes to contrast these features to something that you do not understand very well. What does the contrast illuminate about the nature of deep versus superficial understanding?

These are questions that my colleagues and I have long asked educators and other audiences. Their responses have highlighted how deep understanding is flexible, nuanced, empowering and often applicable in multiple contexts. It leads to a sense of confidence, engagement and often, a greater sense of humility about what is and is not understood. Interestingly, it typically leads to new questions and a willingness to work at the edge of one's competence to pursue new knowledge in a form of progressive problem-solving. Expertise begets more expertise.

What are some broad guiding principles of Project Zero's work related to the nature of deep understanding?

1. Depth of understanding is more empowering than broad, superficial coverage.

David Perkins has written extensively about how fragile, superficial knowledge hurts. It betrays the very promise of education—that what one learns will serve them in the real world. Often students learn isolated facts, information with gaps that leave it inactionable, or ritualised knowledge that is rigid and inflexible. In an information age, when facts can be readily acquired at one's fingertips, educating primarily for factual recall instead of deep understanding makes little sense.

2. Understanding is revealed through performances as opposed to what we know in our heads.

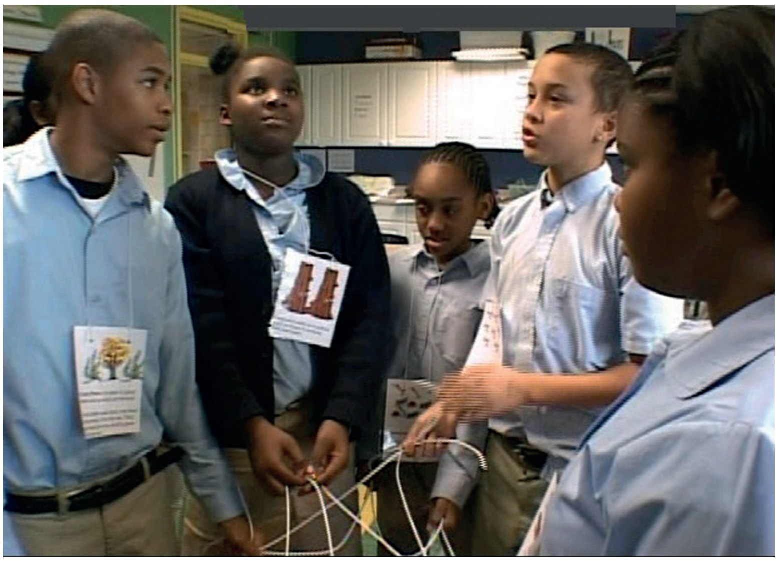
The ability to act with what we know is what matters. A Jeopardy-like command of facts can be helpful in limited instances, such as test-taking, crossword puzzles and game shows, but in general, it doesn't help us to live better lives. Actionable understanding is enabling and should be the goal of education. We need to be able to think flexibly and apply knowledge to new contexts. This requires recognising contexts to which it might apply and figuring out how to map it. One of the ways to make sure that students have the opportunity to gain actionable understandings is to engage them in scaled down versions of more expert endeavours—what David Perkins has called 'playing the whole game at a junior level.'[1]

3. Assessment should be on-going, based on authentic performances and interspersed with further opportunities to learn.

If understanding is revealed through performance, assessment must follow suit. When performance is high stakes, we typically do assess it in authentic contexts or in ones that closely adhere to the authentic features. Further, we offer on-going learning support, assess understanding and then provide further support in taking the next steps. We don't give a book exam on swimming and then toss kids into the pool. A written test for new drivers signals the beginning of the actual important learning that takes place with guidance behind the wheel. And the surgeon holding a scalpel had better have lots of guided experience before taking on solo surgery! Certainly these are high risk endeavours, but if what we are teaching truly matters, then performance-based assessment interspersed with supported learning experiences is warranted.

4. The focus of learning should be on topics or themes that have the potential to be generative and to contribute to understanding beyond the contexts taught.

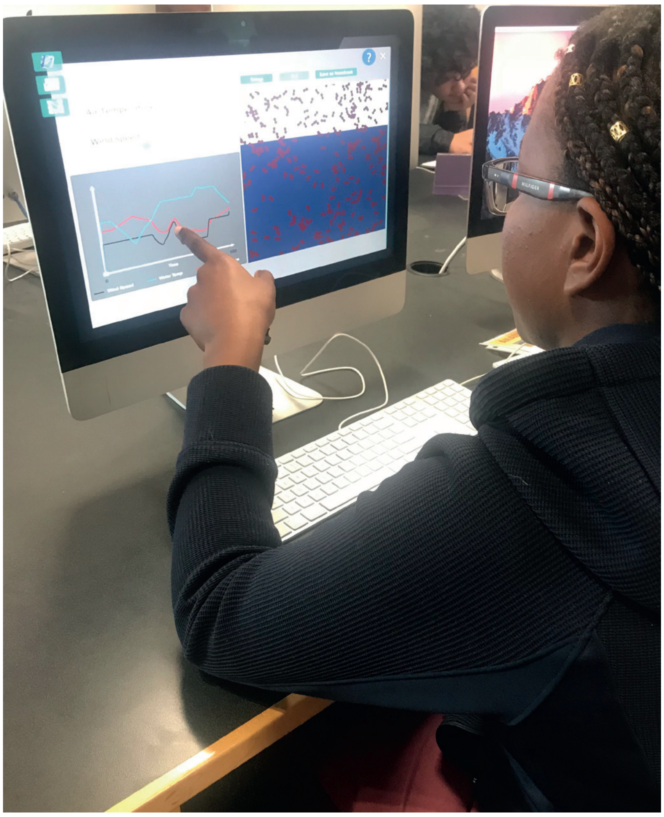
When teaching for deeper understanding, the impact of learning can be extended by focusing on topics that enable understanding beyond the specific content in which it is learned. For instance, certain topics in science, such as density and pressure, are viewed as fundamental concepts that open the door to concepts that build upon them. In the humanities, themes related to the nature of the common good, sources of conflict, and perspective-taking can be generative. Expansive framing refers to letting students know at the outset that what they are learning holds the potential to be widely helpful.[2] This does not mean that transfer happens automatically – one must still help students to extract the big ideas and to see how they can be powerful in other contexts.



What do we know about developing deep understanding? What do the research findings suggest?

Considerable research exists to inform the challenges and pedagogical implications of helping students to develop deeper understanding. This research spans cognitive science, neuroscience and the learning sciences. While there are a lot of nuanced implications to be drawn from the research, some overarching findings are as follows.

1. Deeper understanding is a journey not a destination. It involves trading up for increasingly more powerful explanatory models.



Research shows that students' understanding goes through an evolutionary process whereby they gain models that have greater explanatory power and that are more connected to other understandings. They don't necessarily let go of their earlier models – similar to how we think about Newtonian physics, these models may be useful in certain contexts.

A significant body of research in science, maths, social and historical perspectives has established that we hold robust views about how the world works based on our experiences.[3] Often, these views are limited by factors such as the perceptual evidence available to us, the ways the brain filters information to prevent overstimulation, and our ability to perceive and remember the data that we have access to. These views must be addressed in order to help students gain deeper understanding. It is not enough to bracket them. Students have to see the ways in which the models have explanatory power and in the ways in which they are limiting.

The process of helping students to evolve more powerful explanatory models can be supported by educators who understand the specific conceptual terrain (and what makes it hard) as well as the cognitive challenges that the mind has to grapple with in the new model. For instance, consider the challenges for students learning about the solar system. They need to imagine an earth in constant motion (though it certainly doesn't feel like it!), the location of the sun, the earth, the moon, etc., and put it all in dynamic relationship to one another. At the same time, they need to adopt the perspective of the scale of these astronomical bodies and their own relationship to it. A deep understanding of history involves holding a multitude of perspectives as different narratives are told, setting them in the context of the cultural milieu of the time, and trying to put oneself into a time scale that is typically many times the number of years that the students have been alive. Researchers have documented, particularly in science education,[4] the kinds of challenges involved and some typical paths that students' evolving understanding takes. This information can help teachers develop the provocations and supporting curriculum for students to navigate towards understanding.

However, a significant puzzle for education is that the evolving nature of deepening understanding is typically at odds with how schools structure units of learning. Units tend to have a finite endpoint and there are few opportunities to revisit concepts across and within school years. Teachers who attend carefully to students' current thinking as they begin a unit and shepherd them along the journey towards more powerful understandings of the world, may find that their efforts fall short in an unsupportive school structure.

2. Developing deeper understanding requires attention to structural knowledge. It involves restructuring tacit schemas that we hold and gaining a broader repertoire of schemas.

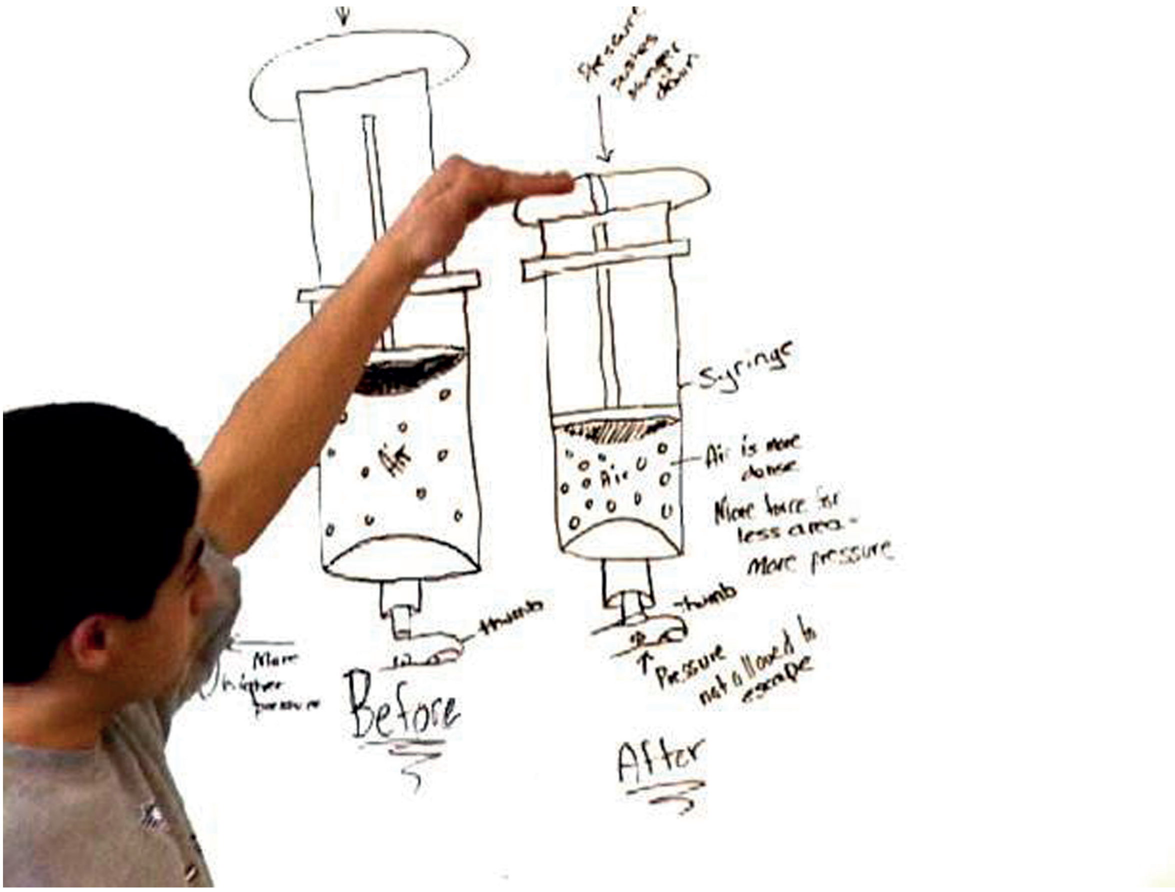
The journey towards deeper understanding requires careful attention to *how* students are structuring their models. Research shows that the implicit structures of our current understanding can limit and distort concepts. So, the process of achieving deeper understanding often requires deconstructing embedded structural assumptions that we are making. However, we may not even be aware that we are making them! For example, consider what happens when you drink from a straw. Students often think hold an agency-oriented, linear model that sounds something like, 'I suck hard on the straw and pull the liquid into my mouth.' However, a more sophisticated understanding of the fluid dynamics involves an implicit relational causality that sounds like, 'As I remove some liquid, I lower the air pressure in the straw and the higher ambient air pressure surrounding the liquid in the glass creates a differential so that the liquid moves up the straw.'[5]

My own work shows that most students adopt simple linear models such as these without knowing it. Researcher Michelene Chi has shown that students often adopt the wrong categories in their knowledge claims, for instance, they treat simply circuits as substance-like instead of process-like.[6] These structural assumptions are about the nature of the knowledge rather than the specific concepts.[7]

Building more powerful understandings requires rethinking these underlying structures and adopting schemas that lend greater insight. As educators, we often focus on what students know that they know or know that they don't know. Tacit knowledge such as this is much more challenging because it focuses on what students don't know that they know and we as educators may not readily realise the powerful pull that these schemas have on their understanding.

So the quest for deeper understanding needs to attend to students' underlying structural knowledge, in addition to the conceptual and procedural knowledge that most classrooms focus on. What might this sound like in primary and secondary classrooms?

- In mathematics, students might discuss the assumptions of what it means to quantify or that base 10 is an invention—a design that has a history related to the number of digits we have on our hands but that one can use other bases and they may present advantages in some situations. Another example can be found in a video of a third grader named Sean grappling with the meaning of the terms odd and even in the University of Michigan Series.[8]
- In social studies, students might consider the perils of 20/20 hindsight and how hard it is to actually adopt the perspective of a given point in time as we look back to consider events from the perspective of those living in that time. Without realising the pull of 20/20 hindsight, we might believe that we are more intelligent than people from the past, that certain historical outcomes were inevitable and should have been obvious to the people of that time.
- In science, students might consider how climate change has many distributed causal agents and the emergent outcomes are unaligned with the intentions of those agents. They might discuss how the non-obvious greenhouse gases make it harder to think about inherent causal relationships.[9]



3. Our cognitive architecture presents challenges for developing deeper understanding. It requires reflective attention to the intersection between our cognitive tendencies, the conceptual terrain and the instructional approaches that navigate between them.

Research shows that a key way that humans develop understandings about how our world works is not through formal education but by summing across the wealth of our everyday experiences. We notice relationships and make connections between them in what has been referred to as a *Bayesian mindset*. We manage this process in a statistical rather than a deterministic manner. This means that if, most of the time, a certain outcome follows a certain impetus, we come to view them as related. This makes it possible for us to see patterns in our world.[10]

However, this process also means that we may miss critical, but uncommon distinctions that could drive our understanding towards deeper, more explanatory models. For instance, in the drinking through a straw example, most people have had the experience of drinking from a juice box and reaching a point at which they cannot get any more juice from the straw. However, we don't necessarily attend to this information and use it to drive towards more powerful models. There are many other examples like this in science. Further, once we think that we understand something, it actually becomes harder to see discrepant information. This is called confirmation bias. The neuroscience demonstrates that our brains react differently to information that confirms current beliefs than that which doesn't.[11] This work suggests that we bracket rather than attend to disconfirmatory information.

These tendencies make it difficult to see information that fits beyond our current understandings. We filter it away before we have a chance to reflectively consider it. This is the case in all learning—whether it is models in science, perspectives that we disagree with in our social and political world, or the argument that one just had over what happened on the playground. It is, in my

mind, the strongest case for supported opportunities in education to discover that which eludes us.

4. Students need to learn how to seek out deeper understanding. Learning how to learn new and challenging content—developing adaptive expertise—is necessary for helping students continue the journey beyond formal schooling. One of the most important things that teachers can do to support the development of lifelong learners is to help students know how to seek out and develop understanding. Learning for understanding is a special set of skills. For example, students need to develop sensitivity to when they are unclear on concepts, what steps might help them to gain clarity, and different ways to gain understanding. At Parker Charter School in Devens, MA, students decide when to petition to transition between divisions. The question of 'Do I deeply understand this material' is one that they regularly ask and reflect upon. They need to understand the value of flow states, the deep engagement that enables optimal learning and often, losing track of time, as the process becomes internally driven and motivated.[12]

In a Living Curriculum Pedagogy, schools take learning for understanding even further.[13] Understanding is an on-going quest carried out by the learner. The curriculum is living in that it is about real world, authentic learning that is dynamic and changeable—responding to what is relevant at that time, but most importantly, it is developed with teacher support by the one living it. It focuses on having the ability to gain deeper understandings—on developing adaptive experts—more than on a particular set of understandings. Instead of viewing themselves as the ones who chart the journey towards understanding, teachers at Tremont School, a Living Curriculum School in Lexington, MA, help students in this role in a form of negotiated curriculum. Students learn things such as being sensitive to how clear concepts feel, knowing how to operationalise their questions into inquiry paths, and considering what forms of resources and expertise they can build upon as they set and revise their learning paths. As the content to think with, students in Living Curriculum schools often learn as many facts as students elsewhere, yet they also emerge as better learners and innovators.

What are some implications for educators?

The research findings support that it is challenging to develop deeper understanding. However, we know a lot about why and how to help us get there. Here are some main take-away messages:

- Start with what learners know.
- Try to understand how learners are making sense and help them to see the tacit structures in their sense-making.
- Help learners experience where their current understandings work and where they fall down.
- Help learners to gain models of what more expert understanding looks like.
- Look for critical distinctions and disconfirmatory evidence that will drive learners towards more powerful conceptions.
- Position learning as a journey, not a destination.

Despite the challenges, the pay-off for the quest for understanding can result in deep and big understandings that David Perkins has called, 'lifeworthy learning'. The promise of education should offer no less!

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Knowledge Trails

1. **Fostering Deep Thinking In The Primary Classroom**
   Is it ever too early to teach children how to think? Researchers Russell Grigg and Helen Lewis say it's not. Here they report on the strategies uncovered during an action research project in South Wales to extend and deepen pupils' thinking – even from a very young age.
   https://library.teachingtimes.com/articles/fostering_deep_thinking_in_the_primary_classroom
2. **Learning In Depth: A Curriculum Innovation**
   Deep knowledge of one topic has the potential to transform the schooling experience of nearly all children, says Kieran Egan. https://library.teachingtimes.com/articles/learning-in-depth-cross-curriculum-projects
3. **Project Plan - Learning In Depth**
   A Cross Curriculum Project with a difference. The rationale is that learning about one topic for the whole of their school career will radically change students' understanding of the nature of knowledge.
   https://library.teachingtimes.com/articles/project-plan-learning-in-depth
4. **The Young Researchers**
   Ryan Hughes argues the case for Learning in Depth - a casual, yet effective, mode of teaching and learning.
   https://library.teachingtimes.com/articles/ctl6-4-the-young-researchers

Notes

1 Perkins, D. N. (2010). Making learning whole: How seven principles of teaching can transform education. NY, NY: Jossey-Bass.

2 Engle, R.A., Lam, D.P. Meyer, X.S., & Nix, S.E. (2012). How does expansive framing promote transfer? Several proposed explanations and a research agenda for investigating them. Educational Psychologist 47(3): 215-231. http://www-tandfonline-com.ezp-prod1.hul.harvard.edu/doi/full/10.1080/00461520.2012.695678

3 See for example, Driver, R., Guesne, E., & Tiberghien, A. (eds.) (1985). Children's ideas in science. Philadelphia: Open University Press.

4 Driver et al. (1995).

5 A website with curriculum to help teachers assist students in assessing and revising their causal schemas can be found at www.causalpatterns.org.

6 Chi, M.T. (1992). Conceptual change within and across ontological categories: Examples from learning and discovery in science. In Giere, R. (ed.), Cognitive models of science: Minnesota studies in the philosophy of science (pp. 129-186). Minneapolis, MN: University of Minnesota Press.

7 Grotzer, T.A. (2002). Expanding our vision for educational technology: Procedural, conceptual, and structural knowledge. Educational Technology, March-April: 52-59.

8 Mathematics Teaching and Learning to Teach, University of Michigan (2010). SeanNumbers-Ofala. http://hdl.handle.net/2027.42/65013

9 Grotzer, T.A. Derbiszewska, K., Gramling, M.D., Solis, L.S., & Bialik, M. (2015). Becoming responsible individuals: Understanding distributed causality. Causal Learning in the Classroom (CLIC) Modules. Cambridge, MA: President and Fellows of Harvard College. https://clic.gse.harvard.edu/

10 The reasons that we accept probabilistic causation are a matter of continued discussion and may include an inability to process so much information, to hold it in mind (cognitive load) and/or forgetting in contrast with an understanding of statistics and probabilistic outcomes. See Grotzer, T.A., & Tutwiler, M.S. (2014). Simplifying causal complexity: How interactions between modes of causal induction and information availability lead to heuristic driven reasoning. Mind, Brain, and Education, 8(3), 97-114.

11 Petitto, L.A. & Dunbar, K. (2004, October). New findings from educational neuroscience on bilingual brains; scientific brains, and the educated mind. Presented at the conference on Building Usable Knowledge in Mind, Brain, and Education, October 6-8, 2004, Harvard Graduate School of Education, Cambridge, MA.

12 Csikzentmihalyi, M. (2008). Flow: The Psychology of Optimal Experience. New York: Harper Perennial Modern Classics.

13 Grotzer, T.A., Vaughn, D., & Wilmot, W. (in press). Living curriculum: How does it change how education is defined? Independent School Magazine, March 2019.