

Content	Questions/Thoughts
Introduction/Structure/General reading Book = personal realization (through reading) that some practices (direct instruction (di)) more effective than others (discovery learning), includes concrete suggestions/shared language. Book is theory light/ helpful/practical/science-specific. Part 1: Substance Chapter 1: Where to start? Curricula can be low specificity, decide core qs (CQs) you want answered, differentiate school subject knowledge (SSK) from pedagogical content knowledge (PCK) AND procedural K (K how) vs declarative K (K that), CQs good for declarative K. Chapter 2: Which knowledge matters? Science can be hierarchical; always need to identify what they need to know to access CQs = prerequisite K (PK), write questions to identify if it's there (PKQ) Chapter 3: Starting the learning sequence Ss are not blank slates. They have domain knowledge (DK), need to check the correct DK, get data at the start with PKQ = retrieval practice (RP.) – tell them rationale for RP. Clarify means of participation (MoP) → notes/where do answers go/what if they don't know/full sentences/write q? Build a culture of participation. Chapter 4: Books, mini-whiteboards (MWB) or oral response – what works when? For PKQs: bookwork (participation ratio high, hard to get whole-class data, MWB), targeted qs (encourages high level language, only a few Ss, see Lemov Cold Call/Wait Time/No Opt Out), MWB (quick, full participation, need routines) Chapter 5: Types of question Need range of qs: short answer (SA) (can be simple declarative, or application), T/F/MCQ (quick but recognise ≠ reproduce, data you get is limited, calculations take time, use diagrams with care). Chapter 6: The challenge equation $CHALLENGE = \frac{task\ quantity}{DK + support}$ Task quantity (TQ) = no. of things in the question, DK = fluid/changeable, support = cues, keywords, can be verbal, written, diagrammatic. Chapter 7: Many birds, one stone Spacing aids retrieval, quiz with range of spaced qs + go over as whole class = settles, routine of long-term learning (has benefits re. self-determination theory - see Ryan & Deci), then MWBs for PK. Chapter 8: Going over your retrieval quiz – the basics 2 type of question: monosemic (single correct answer e.g. where is bile produced?), polysemic (multiple correct answers e.g. what is an atom?). Sample Ss answers, clarify what/why it's correct, write correct answers on the board, Ss mark own work. Chapter 9: Going over your prerequisite quiz What if PKQs on MWB show weak understanding of PK? Re-teach/explain weak areas then more (detailed) qs on MWB to check for understanding (CfU).	
Part 2: Explanations Chapter 10: Explaining science Use the CHALLENGE equation to guide route through. Experts (teachers! (Ts)) have knowledge that is organized differently, can struggle to understand issues novices face (curse of knowledge). Chapter 11: Sequencing examples needs: careful planning including non-examples → elicit boundary conditions to concepts. Chapter 12: The multimedia effect = learn more from images + verbal info at the same time (dual coding explains this). If separate → split-attention effect e.g. recipes. Listening + reading → redundancy effect e.g. reading from slides. Both avoided by building up diagrams in real time. Chapter 13: Making the abstract concrete Need to amend: $CHALLENGE = \frac{TQ + abstraction}{DK + support}$. Ss have limited working memory (WM), easily overloaded, hard to make mental image of abstract concept. Chapter 14: Explanations in action - digestion → see book for detailed example (live diagrams) Chapter 15: Analogies have: source (what is known), target (new thing), inference that links the two. Use them when: Ss are familiar with source, the source → target not too much stretch/believable, not distracting (no celebs), doesn't promote misconception, is necessary! Chapter 16: Directions of travel (DOT) like concrete → abstract or familiar → unfamiliar. 1. Wood → Trees → Wood (aka Zoom Out/In to see bigger picture, the 'why') 2. Simple → Complex (learning the complex can take years) 3. Example → Principle → Example (can concretize the principle faster to vary order) 4. Explanation → Definition (definitions can be v. unfamiliar/off-putting) 5. Hinterland → Core (can set the stage/ make connections to Core easier) 6. Conflict → Resolution (set up as a story). Chapter 17: Misconceptions are plausible/predictable, better to think 'misconception character' (high: sun goes around Earth/low: respiration = breathing/not: ribosomes contain DNA). Little solid practical advice from research. Know what they are, mitigate effect by dealing with abstraction. Chapter 18: Explanations in action - diffusion see book for detailed example (using CQs/non-examples). Chapter 19: Explanations in action – the heart see book for detailed example (simplifying complex live drawing). Chapter 20: Introducing new vocabulary Remember simple → complex DOT, use explanation → definition DOT a lot to teach meaning then define after. Chapter 21: Explaining equations Solving equations = transferrable skill, understanding meaning of equation is not; needs quantitative AND qualitative approach by 1. Teaching what variables mean 2. Start with concrete variable 3. DOT → abstract variable 4. Do simple ratios/diagrammatically/build to simple numbers 5. Use accumulations (e.g. energy = power x time, distance = speed x time) Chapter 22: Solving equation problems Care with cognitive overload, significantly reduce TQ at the start (whole numbers, broken down, small steps), view as building a skill set over the long-term. Pick a method that works (READ about it before you use it!). Chapter 23: Engaging explanations Remember attention is fragile: care when asking questions during explanation (increases participation ration, can be disruptive), jokes/personal stories (use carefully, can split attention).	

Part 3: Building Understanding Chapter 24: What is understanding (U)? Ill-defined, can be: subjective feeling (but reject self-reporting of feeling = K), perception of deep structure (can be superficial), integration of new K with old K (into a 'schema' = organizational structure of K in LTM). U = solidifying new K + extent of connections to prior DK → a spectrum. Teacher moves Ss along spectrum by: PKQs, explanation, CfU, independent deliberate practice. Chapter 25: Check and consolidate New K is initially hazy/ephemeral, do not understand <i>enough</i>. Explanation → CfU → consolidation (make new K <i>solid</i>) by verbalizing/writing (e.g. Turn & Talk, sampling via MWB). Chapter 26: The 'quick and dirty' – check and consolidate (QDC&C) → E.g. remove labels from diagram, replace w/a, b, c etc. Ask qs about each (name/purpose/differences/why/what if)	•
Part 4: Independent Practice Chapter 27: Practicing procedural knowledge - equations Evaluate practice qs with the CHALLENGE equation, need careful design/sequencing (not 'easy' → 'hard', <i>all</i> should produce learning). Increase challenge by: TQ (unit conversions/more steps/finding data), reducing support, care with decimal numbers → increases abstraction. Chapter 28: Interleaving = mixing qs from different topics (vs. blocked practice = same topic). Works to: break algorithmic routine (when blocked), space retrieval, elicit similarities/differences. Chapter 29: Practicing procedural knowledge in action - speed see book for detailed example (teaching equations, CfU, consolidation). Chapter 30: Practicing declarative knowledge → More challenging than procedural K, less variation possible. Techniques: 1. Spacing slightly varied repeat. 2. Contrast concepts (e.g. SHC/SLH) 3. 'If it didn't...' (elicit structure & function e.g. if a sperm didn't have a tail) 4. Give a wrong answer + ask why. 5. Because/but/so (e.g. metals conduct...). Interleave for same reasons as in procedural K. Chapter 31: Expertise reversal → Effect = what is effective for novice Ss (NS) (chunking, worked examples, direct instruction etc.) is less effective for expert Ss (ES). Think CHALLENGE equation: as Ss move along spectrum: NS → ES support ↓, TQ ↑ as DK&U ↑.	•
Part 5: Assessment and Feedback Chapter 32: Assessing understanding A 'literal' test checks one bit, can't test everything they should have learned, need to give 'representational test' – sufficient qs to infer K of the whole. Can also use QDC&C to get data – assuming level of challenge is right. Chapter 33: Feedback On a spectrum: directive (instantaneous, work-focused) → non-directive (time-lagged, student-focussed). Directive at the start → non-directive with time/teaching. Chapter 34: What to do after an exam Plan 'going over the test' with care. Do question level analysis (QLA) to see patterns/issues - note down what to reteach/put in RP/do differently next year Chapter 35: Marking and whole-class feedback Comment based marking inefficient (and arguably ineffective without class time given for action). Instead, Whole Class Feedback (WCF) efficient/effective: get info from: 1. Noticing issue in indep. practice 2. Sampling some books, see common errors 3. Short test/assessment then go over/CfU/continue. Chapter 36: Reviewing independent practice Don't just give out the answers: Cold Call/no need for Wait Time/Bounce to other students/keep thinking ratio high/write longer answers on board/sample numerical answers/require listening	•
Part 6: Practicals Chapter 37: The art of the demo Ask 'why am I doing this demo?' 1. Awe & wonder: links to 'unexpected', helps to set up conflict → resolution DOT 2. Teach content: make the abstract → concrete, narrative approach, support with diagrams alongside, follow with QDC&C. Chapter 38: Problematic practicals (Ps) Benchmarks: 1. School needs policy re. purpose/place of Ps within other learning 2. Ts should know how to do Ps effectively. Many reasons for Ps. Problems: high TQ & abstraction/low DK of Ss/hard to support. Chapter 39: The Slow Practical 1. Break down P into smaller steps 2. Combine Ss P activity with T demo. Benefits: all manageable, easier to see issues/risks, can continue to explain throughout, learning is clearer to Ss.	•
Part 7: Building Brilliant Scientists: Chapter 40: Mary, and why we teach science Learning science → 'new' DK that gives alternative perspective, deepens/enriches experience of the world, produces tech achievements, glimpse of how scientists think, informed citizenship. Chapter 41: Motivating scientists Engagement is a poor proxy for learning. We can help motivate by 1. Explaining the why of learning (the more you know the easier it is to learn) 2. Giving success → breed confidence → motivating. Chapter 42: A culture of retrieval RP is a long-term strategy that is contained in 1. Fixed-point quizzing (see Ch1) 2. Before/during explanations (see Ch9) 3. During practice (see Ch28) 4. Homework (builds a Culture of Retrieval – see Carousel Learning for easy-to-use system with excellent feedback for teachers: https://www.carousel-learning.com/)	•
Conclusions Happy Science Teaching! Advice from FAQs: 1. Don't try everything from this book – do a chunk at a time. 2. Differentiation – not useful term, use CHALLENGE equation instead 3. Curriculum sequencing – very time consuming. 4. Student talk: answering qs, Turn and Talk, whole class reading, paired quizzing are good places to start. 5. Lesson Objectives (LO) never: grade them/use all/most/some/differentiate by command work/have Ss spend ages copying them/say them at the start. 6. Frequency of assessment: frequent CfU/C&C, infrequent tests. 7. Getting Ss to read the q. 8. Exit tickets: don't teach to the bell. 9. Metacognition: what does it mean? 10. Taking notes: should not be copying 11. Projects: time-consuming, can learn little 12. Hands-on learning: hard to know what learning is happening 13. Working scientifically: not different to other K, needs explicit teaching using CHALLENGE. 14. RP starter takes too long: Ss don't have enough DK for your qs, build slowly. 15. Is this book everything I need? No, but great start... now read some more!	•