Detailed List of Headings and Notes (with Page Numbers)

1 What Is Teaching? 1

2 What Is Science? 3

Purposes of Science 3 Hallmarks of Science 5 Note: The Scientific Method 6 Note: Creativity and Science 6 Dealing with Creationism and Other Nonscientific Beliefs 6 Note: Teaching Evolution 8 Note: Teaching about Global Warming 8

3 One Key to Student Success 9

Learning requires effort and study. Note: What Counts as "Study" 9 The State of U.S. Education 10 K-12 Education 10 Note: Study Expectations Vary Greatly Among Schools 10 Note: Options for Increasing Study Time 10 College Education 11 Note: Validity of the Decline Claim 11 Note: There Is Less Decline in Science 12 Note: Reversing the Decline Trend 12 Multitasking 13 Note: Technology Can Be Beneficial 14 Note: Distracted Drivers 14 Consequences to Education — The Pressure to "Dumb Down" 14 Note: The Common Core Standards 14 Note: Digital Textbooks 15 Consequences for Society 16 Changing the National Conversation 16 Note: An Equation for Success 17

4 Three Big Picture Ideas about Teaching 19 Big Picture Idea 1 19 You can't actually "teach" anything to anybody; you can only help people learn for themselves. Note: The Importance of Modeling Behaviors for Your Students 20 Big Picture Idea 2 20 Brains are brains. Note: "Knowing" Things That Are Not True 20 An Example of "Brains Are Brains" 21 Note: More on Visualization 22 Note: Nearly All Scientists Can Do Well Speaking to Children 23 "Today's Students Learn Differently" 23 Note: Old Teaching Strategies Can Still Work 24 Note: Learning and Age 24 Big Picture Idea 3 24 People have known how to teach successfully for thousands of years. The Art of Teaching 25 Note: The Art of Teaching Can Be Studied Scientifically 25 Teaching Today 26 5 Five General Suggestions for Successful Teaching 27 General Teaching Suggestion 1 27 Above all, try to ensure that your students study. Time on Task 28 College Education 28 Note: Students Do Not Know the Rule of Thumb 28 Note: For Science, the Main Issue Is in Nonmajor Courses 29 K-12 Education 29 Note: The Homework Debate 29 Note: Helping Students Who Lack Home Support 30 Educating Students about Time-on-Task Expectations 30 College Education 30 Note: Students for Whom the Rule of Thumb Cannot Fit the Actual Number of Hours in a Week 31 Note: Policy Changes to Allow Students More Time to Graduate 31 Note: It's OK to Take Longer 32 Note: Students Who Complain about the Rule of Thumb 32 K-12 Education 33 Implications of Time on Task 33 Note: On "Teaching to the Test" 33 Note: The Value and Limitations of Educational Research 34 Note: The Value and Limitations of "Flipped Classrooms" 34

General Teaching Suggestion 2 35

Provide structure and assignments that will help your students study sufficiently *and* efficiently.

Class/Direct-Contact Time 36 Share your enthusiasm 36 Use demonstrations, props, and experiments 37 Note: Discrepant Events 37 Note: Role Playing 37 Move when you talk 38 Be Socratic 38 Note: Clickers and Attendance 38 Promote controlled interaction 39 Note: Use Cooperative Learning Strategies 39 Note: More on Classroom Control 40 Don't expect to cover everything 40 Provide feedback 40 Note: Application to Online Courses 40 Note: On Self-Paced Learning 41 Note: On MOOCs ("Massive Open Online Courses") 41 Assignments 42 Reading 43 Homework/Independent Assignments 43 Activate the brain 44 Practice and drill (but don't kill) 44 Note: There's No Such Thing as "Dumb Mistakes" 44 Note: Games Can Help 45 Return again and again 45 Mix it up 45 Note: Problem-Solving Strategies 45 Note: On Grading Selected Problems 46 Note: Prompt Feedback and Record Keeping 47 Exam Preparation 47 Tests should help students learn 47 Note: Pros and Cons of Multiple Choice 48 Tests should reflect assignments 48 Note: What to Test in Introductory Courses 48 Tests should be cumulative 49 Frequency of tests should be "just right" 49 Get students to review their tests 49 Note: "Exam Rebates" 49 Grading 50 Note: The Problem of Grade Inflation 50

General Teaching Suggestion 3 50

Teach for the long term by focusing on three linked goals for science teaching: education, perspective, and inspiration. Education 51 Perspective 51 Inspiration 52 Note: The Unfortunate Decline of Field Trips 52 Monetary Inspiration 52 Elementary School Inspiration and Attitudes toward Science 54 Note: Don't Be "Bad at Math" 54 Note: How Much Science Should Elementary Teachers Know? 54 Inspiring Girls and Young Women and Other Underrepresented Groups 55 Confidence issues 55 Note: Perceptions of Study and Effort 56 Hidden biases 56 It's an American issue 56 Role models 57 Note: Bring Role Models to School 57 General Teaching Suggestion 4 57 Have high but realistic expectations, and spell them out clearly. Setting High but Realistic Expectations 58 Guidepost 1 58 Guidepost 2 58 Note: The Guideposts and Fear of Science 59 Note: The Guideposts and Negative Attitudes toward Science 59 Note: Using the Guideposts with Different Audiences 59 Making Your Expectations Clear 60 Note: Behavioral Expectations 60 Note: Sample Syllabus 60 Grading on Your Expectations 61 General Teaching Suggestion 5 61

Be human.

You can't reach everyone 62 Note: Help Your Students Get Help 62 Show empathy 62 Make your teaching a two-way dialogue 63 Note: Homework Evaluation 63 Don't let the turkeys get you down 63

6 Seven Pedagogical Strategies for Success in Science Teaching 65 Strategy 1 65

Begin with and stay focused on the big picture. Note: We Can't Expect Students to Know What They Haven't Been Taught 66 Identifying the Big Picture 67 Opening with the Big Picture 68 Note: Choose an Effective Order of Presentation 68 Note: On the Lifelong Learning Goal 68 Maintaining Focus on the Big Picture 69

Strategy 2 69

Always provide context. Mental Binning 70 Astronomy 70 Biology 71 Geology 71 Mathematics 71 Climate science 71 Relevance 72 Note: Relevance and Curiosity Are Not Opposed 72 Planetary science/Geology 73 Biology 73 Physics/Engineering 73 Mathematics 73 Astronomy 74

Strategy 3 74

Emphasize conceptual understanding.
Use the Concepts to Guide Your Selection of Facts 74 Note: On the Next Generation Science Standards 75 Simplify but Don't Lie 75 Note: Think of "Extracting" Rather than "Simplifying" 76 Beware of the Pressures of Testing 77 K-12 Education 77 College Education 78

Strategy 4 78

Proceed from the more familiar and concrete to the less familiar and abstract.

"Bridges to the Familiar" 79

Note: The Counting Example with Elementary Students 80 Context-Driven versus Content-Driven Teaching 80

Strategy 5 81

Recognize and address student misconceptions. Recognizing Misconceptions 82 Dispelling Misconceptions 82 Note: Age Effectiveness of the Paper-and-Rock Demonstration 82 Note: Eggs on the Equinox 83 Seasons 83 Note: At Least They Knew Something 83 Note: The Importance of Scale 84

Weightlessness 85 Note: Why I Don't Say "Microgravity" 85 Note: On "Apparent" vs. "True" Weight 85 Gravity on the Moon 87 Note: It's a Super-Bowl-Class Misconception 88 Note: Heavy Boots 88 Strategy 6 89 Use plain language. Note: Jargon Reduction Is Not "Dumbing Down" 90 Note: Please "DNUA" 91 Translate When Possible 91 Note: A True Story 91 Seek Simpler Choices (of jargon) 92 Note: Pay Attention to Jargon in the Media 93 Note: When Jargon Is Unavoidable, Point Out Word Roots and Etymology 94 Note: Please Don't "Type"-Cast Science 95 Note: A Dwarf Quiz 95 It's Nice to Honor Them, But... 96 Be Accurate, But Not Persnickety 97 Note: When Earth Wasn't a Planet 98 Be Clear When Jargon Conflicts with Common Usage 98 Note: Why I Still Like the Term "Theory" 98 Don't Make a Bad Jargon Situation Worse 99 "The God particle" 99 "The Goldilocks zone" 99 "Ice giants" 102 Note: So What Should We Call Uranus and Neptune? 102 "Flipped classrooms" 103

Strategy 7 103 *Challenge your students.*

7 Putting It All Together 105

Appendices 107

Appendix 1: How to Succeed Handout 109 Appendix 2: Sample Syllabus 114 Appendix 3: A Dwarf Quiz 120

Excerpts 123

Excerpt 1: What Makes It Science? 123 Excerpt 2: Evolution in the Classroom 143