Content, Assessment and Pedagogy: An Integrated Design Approach for OBE at the Course Level

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Workshop Layout

• Welcome & Overview
• Update on Engineering Accreditation
• Integrated Course Design (CAP Model)
  – Content
  – Assessment
  – Pedagogy
• Integrated Course Design Approaches
• Wrap-up and Next Steps
Session Objectives

• Participants will be able to describe key elements of:
  – Integrated course design – CAP model
  – Variety of integrated course design approaches
  – Teaching and Learning assessment strategies

• Participants will begin applying key elements to the design/re-design of a course
Background Knowledge Survey

• Level of Familiarity with
  – International Accreditation Outcomes
  – Approaches to Course Design
  – Assessment Strategies
  – Pedagogy

• Responsibility
  – Individual course
  – Program
  – Accreditation
What is Accreditation?

Accreditation is intended to provide programs with a credential. The credential is used by the programs and their constituencies - the general public, students and prospective students, employers, industry, and governmental bodies - to assess the quality of the program and the extent to which it achieves its own goals as well as agreed-upon educational standards. The process of accreditation also serves to foster self-examination by learning institutions; it develops a dialogue between constituents of educational programs on content, methods, and outcomes; and to encourage continuous improvement of academic programs.

Accreditation often plays a role in decisions about enrollment in school, hiring of employment seekers, and licensing of professionals by governmental bodies. Accreditation of a program is sometimes used as an indicator that graduates of the program received education that qualifies them to be employed as professionals at a certain level (e.g., entry level) or to become candidates for a professional license.

In this site we focus on accreditation of academic programs in engineering, engineering technology and computing.

To explore information about IEEE's involvement and support of accreditation worldwide, view this PowerPoint presentation.

Historical Developments
- Boeing – Employee Checklist
- Global Engineer

NAE Engineer of 2020 – Successful attributes

Purdue Future Engineer
It could well be that faculty members of the twenty-first century college or university will find it necessary to set aside their roles as teachers and instead become designers of learning experiences, processes, and environments.

James Duderstadt, 1999 [Nuclear Engineering Professor; Dean, Provost and President of the University of Michigan]
Integrated Course Design (Fink, 2003)

Initial Design Phase

1. Situational Factors
2. Learning Goals
3. Feedback and Assessment
4. Teaching/Learning Activities
5. Integration
The Key Components Of INTEGRATED COURSE DESIGN

Learning Goals

Teaching and Learning Activities

Feedback & Assessment

Situational Factors

A Self-Directed Guide to Designing Courses for Significant Learning
CAP Design Process (Shawn’s Model)

Start → Context → Content → Cloud of alignment → Pedagogy → Assessment → End
Resources

- Bransford, Vye and Bateman – Creating High Quality Learning Environments
  http://books.nap.edu/openbook.php?record_id=10239&page=159

- Pellegrino – Rethinking and Redesigning Curriculum, Instruction and Assessment
  http://www.skillscommission.org/commissioned.htm
Designing Learning Environments Based on HPL (How People Learn)
Backward Design
Wiggins & McTighe

Stage 1. Identify Desired Results

Stage 2. Determine Acceptable Evidence

Stage 3. Plan Learning Experiences and Instruction

Content Resources


**Figure 1.1. Decoding the Disciplines: Seven Steps to Overcome Obstacles to Learning**

1. **What is a bottleneck to learning in this class?** Identify a place in the course where many students encounter obstacles (bottlenecks) to mastering the material.

2. **How does an expert do these things?** Explore in depth the steps that an expert in the field would go through to accomplish the tasks identified as a bottleneck.

3. **How well are students mastering these learning tasks?** Create forms of assessment that provide specific information about the extent of student mastery of the particular learning tasks defined in Step 2. Are there other bottlenecks?

4. **How will students practice these skills and get feedback?** Construct assignments, team activities, and other learning exercises that allow students to do each of the basic tasks defined above and get feedback on their mastery of that skill.

5. **What will motivate the students?** Consider principles of student motivation that will enhance the learning environment.

6. **How can these tasks be explicitly modeled?** Show the students the steps that an expert would complete to accomplish these tasks.

7. **How can the resulting knowledge about learning be shared?** Faculty who have gone through the first six steps share what they have learned informally with colleagues or more formally in SOTL articles and presentations.
Worksheet for Designing a Course/Class Session/Learning Module

<table>
<thead>
<tr>
<th>Learning Goals for Course/Session/Module:</th>
<th>Ways of Assessing</th>
<th>Actual Teaching-Learning</th>
<th>Helpful Resources: (e.g., people, things)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>This Kind of Learning:</td>
<td>Activities:</td>
<td></td>
</tr>
<tr>
<td>2.</td>
<td></td>
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<td>3.</td>
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<td>4.</td>
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<td>5.</td>
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<tr>
<td>6.</td>
<td></td>
<td></td>
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</tbody>
</table>
Backward Design

Stage 1. Identify Desired Results

Filter 1. To what extent does the idea, topic, or process represent a big idea or having enduring value beyond the classroom?

Filter 2. To what extent does the idea, topic, or process reside at the heart of the discipline?

Filter 3. To what extent does the idea, topic, or process require uncoverage?

Filter 4. To what extent does the idea, topic, or process offer potential for engaging students?
Understanding Understanding

Stage 1. Identify Desired Results
Focus Question: What does it mean to “understand”?

Stage 2. Determine Acceptable Evidence
Focus Questions: “How will we know if students have achieved the desired results and met the standards? What will we accept as evidence of student understanding and proficiency (Wiggins & McTighe)
Understanding Misunderstanding

A Private Universe – 21 minute video available from www.learner.org

Also see Minds of our own (Annenberg/CPB Math and Science Collection – www.learner.org)

1. Can we believe our eyes?
2. Lessons from thin air
3. Under construction

The Interaction Between the Science Content Knowledge of Teachers and Their Students

What do we know now?

1. Misconceptions often unchanged after taking science. Necessary step in learning
   The standards are hard to master.
2. Teachers are knowledgeable, but does not assure student learning.
3. Teachers do not know their students’ misconceptions, but should.
4. Teacher knowledge builds slowly.
5. Professional development must be
   • targeted to specific standards at grade levels
   • evaluated with relevant tools.
6. AP courses help the most if they focus on quantitative science, conceptual labs, fundamentals.

We find that teachers are knowledgeable, and they have more content knowledge than a lot of people let on.
Taxonomies

*Bloom’s taxonomy of educational objectives: Cognitive Domain* (Bloom & Krathwohl, 1956)

*A taxonomy for learning, teaching, and assessing: A revision of Bloom’s taxonomy of educational objectives* (Anderson & Krathwohl, 2001).

*Evaluating the quality of learning: The SOLO taxonomy* (Biggs & Collis, 1982)

*Facets of understanding* (Wiggins & McTighe, 1998)

*Taxonomy of significant learning* (Fink, 2003)

*A taxonomic trek: From student learning to faculty scholarship* (Shulman, 2002)
<table>
<thead>
<tr>
<th>The Knowledge Dimension</th>
<th>The Cognitive Process Dimension</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Factual Knowledge</strong></td>
<td>Remember</td>
</tr>
<tr>
<td>- The basic elements that students must know to be acquainted with a discipline or solve problems in it.</td>
<td></td>
</tr>
<tr>
<td>a. Knowledge of terminology</td>
<td></td>
</tr>
<tr>
<td>b. Knowledge of specific details and elements</td>
<td></td>
</tr>
<tr>
<td><strong>Conceptual Knowledge</strong></td>
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<td>- The interrelationships among the basic elements within a larger structure that enable them to function together.</td>
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</tr>
<tr>
<td>c. Knowledge of theories, models, and structures</td>
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<tr>
<td><strong>Procedural Knowledge</strong></td>
<td>Remember</td>
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<tr>
<td>- How to do something; methods of inquiry, and criteria for using skills, algorithms, techniques, and methods.</td>
<td></td>
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<td>a. Knowledge of subject-specific skills and algorithms</td>
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<td>c. Knowledge of criteria for determining when to use appropriate procedures</td>
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<tr>
<td><strong>Metacognitive Knowledge</strong></td>
<td>Remember</td>
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<td>- Knowledge of cognition in general as well as awareness and knowledge of one's own cognition.</td>
<td></td>
</tr>
<tr>
<td>a. Strategic knowledge</td>
<td></td>
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<tr>
<td>b. Knowledge about cognitive tasks, including appropriate contextual and conditional knowledge</td>
<td></td>
</tr>
<tr>
<td>c. Self-knowledge</td>
<td></td>
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### 3.1 The Taxonomy Table

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<tr>
<td><strong>B.</strong> Conceptual Knowledge</td>
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<tr>
<td><strong>C.</strong> Procedural Knowledge</td>
<td></td>
</tr>
<tr>
<td><strong>D.</strong> Meta-Cognitive Knowledge</td>
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</table>

(Anderson & Krathwohl, 2001)
<table>
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<tr>
<th>Remember</th>
<th>Understand</th>
<th>Apply</th>
<th>Analyze</th>
<th>Evaluate</th>
<th>Create</th>
</tr>
</thead>
<tbody>
<tr>
<td>Retrieving relevant knowledge from long-term memory</td>
<td>Determining the meaning of instructional messages, including oral, written, and graphic communication.</td>
<td>Carrying out or using a procedure in a given situation</td>
<td>Breaking material into its constituent parts and detecting how the parts relate to one another and to an overall structure or purpose</td>
<td>Making judgments based on criteria and standards</td>
<td>Putting elements together to form a novel, coherent whole or make an original product</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Recall</th>
<th>Define</th>
<th>Relate</th>
<th>Review</th>
<th>Restate</th>
<th>Describe</th>
<th>Identify</th>
<th>Express</th>
<th>Employ</th>
<th>Translate</th>
<th>Demonstrate</th>
<th>Examine</th>
<th>Distinguish</th>
<th>Compare</th>
<th>Contrast</th>
<th>Deduce</th>
<th>Select</th>
<th>Defend</th>
<th>Interpret</th>
<th>Discriminate</th>
<th>Arrange</th>
<th>Combine</th>
<th>Construct</th>
<th>Propose</th>
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| **Factual Knowledge** – The basic elements that students must know to be acquainted with a discipline or solve problems in it.  
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| **Metacognitive Knowledge** – Knowledge of cognition in general as well as awareness and knowledge of one’s own cognition.  
  a. Strategic knowledge  
  b. Knowledge about cognitive tasks, including appropriate contextual and conditional knowledge  
  c. Self-knowledge |
When we truly understand, we
Can explain
Can interpret
Can apply
Have perspective
Can empathize
Have self-knowledge
## SIX FACETS OF UNDERSTANDING

<table>
<thead>
<tr>
<th>Six Facets</th>
<th>Description</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Explanation</strong></td>
<td>To ensure students understand why an answer or approach is the right one. Students explain or justify their responses or justify their course of action.</td>
<td>Students develop an illustrated brochure to explain the principles and practices of a particular type of technology (i.e., transportation, construction, medical, information).</td>
</tr>
<tr>
<td><strong>Interpretation</strong></td>
<td>To ensure students avoid the pitfall of looking for the “right answer” and demand answers that are principled...students are able to encompass as many salient facts and points of view as possible.</td>
<td>Students develop a ‘biography’ of the development of a particular type of technology.</td>
</tr>
<tr>
<td><strong>Application</strong></td>
<td>To ensure students’ key performances are conscious and explicit reflection, self-assessment, and self-adjustment, with reasoning made evident. Authentic assessment requires a real or simulated audience, purpose, setting, and options for personalizing the work, realistic constraints, and “background noise.”</td>
<td>Students analyze a design of a product, taking it apart in order to determine how it works.</td>
</tr>
<tr>
<td><strong>Perspective</strong></td>
<td>To ensure students know the importance or significance of an idea and to grasp its importance or unimportance. Encourage students to step back and ask, “What of it?” “Of what value is this knowledge?” “How important is this idea?” “What does this idea enable us to do that is important?”</td>
<td>Students investigate about a technological artifact from the perspective of different regions and countries.</td>
</tr>
<tr>
<td><strong>Empathy</strong></td>
<td>To ensure students develop the ability to see the world from different viewpoints in order to understand the diversity of thought and feeling in the world.</td>
<td>Students imagine they are politicians debating the value of nuclear power. They write their thoughts and feelings explaining why they agree or disagree with the use of nuclear power.</td>
</tr>
<tr>
<td><strong>Self-Knowledge</strong></td>
<td>To ensure students are deeply aware of the boundaries of their own and others’ understanding; able to recognize their own prejudices and projections; has integrity – able and willing to act on what one understands</td>
<td>Students reflect on their own progress of understanding about one of the standards in Standards for Technological Literacy: Content for the Study of Technology. They evaluate the extent to which they have improved, what task or assignment was the most challenging and why, and which project or product of work they are most proud of and why.</td>
</tr>
</tbody>
</table>

### A TAXONOMY OF SIGNIFICANT LEARNING

1. **Foundational Knowledge**
   - "Understand and remember" learning
     - For example: facts, terms, formulae, concepts, principles, etc.

2. **Application**
   - Thinking: critical, creative, practical (problem-solving, decision-making)
   - Other skills
     - For example: communication, technology, foreign language
   - Managing complex projects

3. **Integration**
   - Making "connections" (i.e., finding similarities or interactions) . . .
     - Among: ideas, subjects, people

4. **Human Dimensions**
   - Learning about and changing one's SELF
   - Understanding and interacting with OTHERS

5. **Caring**
   - Identifying/changing one's feelings, interests, values

6. **Learning How to Learn**
   - Becoming a better student
   - Learning how to ask and answer questions
   - Becoming a self-directed learner
Stage 2. Determine Acceptable Evidence

Types of Assessment

Quiz and Test Items:
  Simple, content-focused test items

Academic Prompts:
  Open-ended questions or problems that require the student to think critically

Performance Tasks or Projects:
  Complex challenges that mirror the issues or problems faced by graduates, they are authentic
Stage 3. Plan Learning Experiences & Instruction

- What enabling knowledge (facts, concepts, and principles) and skills (procedures) will students need to perform effectively and achieve desired results?
- What activities will equip students with the needed knowledge and skills?
- What will need to be taught and coached, and how should it be taught, in light of performance goals?
- What materials and resources are best suited to accomplish these goals?
- Is the overall design coherent and effective?
Pedagogies of Engagement
At M.I.T., Large Lectures Are Going the Way of the Blackboard

The Massachusetts Institute of Technology has changed the way it offers some introductory courses. Prof. Gabriella Solda at a class on electricity and magnetism.

By SARA PERER
Published: January 12, 2009

CAMBRIDGE, Mass. — For as long as anyone can remember, introductory physics at the Massachusetts Institute of Technology was taught in a vast windowless amphitheater known by its number, 50.

Farewell, Lecture?
Eric Mazur

Discussions of education are generally predicated on the assumption that we know what education is. I hope to convince you otherwise by recounting some of my own experiences. When I started teaching introductory physics to undergraduates at Harvard University, I never asked myself, how would I educate my students. I did what my teachers had done: I lectured. I thought that was how one learns. Look around anywhere in the world and you’ll find lecture halls filled with students and, at the front, an instructor. This approach to education has not changed since before the Renaissance and the birth of scientific inquiry. Early in my career, I realized the first hint that something was wrong with teaching in this manner, but I had ignored it. Sometimes it’s hard to face reality.

When I started teaching, I prepared lecture notes and then taught from them. Because my lectures deviated from the textbook, I provided students with copies of these lecture notes. The infuriating result was that on my end-of-semester evaluations—which were quite good otherwise—a number of students complained that I was “teaching straight from the lecture notes.” What was I supposed to do? Develop a set of lecture notes different from the textbook?

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Click here. Students continually discuss concepts among themselves and with the instructor during class. Discussions are spurred by multiple-choice conceptual questions that students answer using a clicker device. See supporting online text for examples of such “clicker questions.”

from the ones I handed out? I decided to ignore the students’ complaints. A few years later, I discovered that the students were right. My lecturing was ineffective, despite the high evaluations. Early on in the physics curriculum—in week 2 of a typical introductory physics course—the Laws of Newton are presented. Every student in such a course can recite Newton’s third law of motion, which states that the force of object A on object B is in an interaction between two objects is equal in magnitude to the force of B on A. It is sometimes known as “action is reaction.” One day, when the course had progressed to more complicated material, I decided to test my students’ understanding of this concept by doing traditional problems, but by asking them a set of basic conceptual questions (7, 2). One of the questions, for example, requires students to compare the forces that a heavy truck and a light car exert on one another when they collide. I expected that the students would have no trouble tackling such questions, but much to my surprise, hardly a minute after the test began, one student asked, “How should I answer these questions? According to what you taught me or according to the way I usually think about these things?” To my dismay, students had great difficulty with the conceptual questions. That was when it began to dawn on me that something was amiss.

In hindsight, the reason for my students’ poor performance is simple. The traditional approach to teaching reduces education to a transfer of information. Before the industrial revolution, when books were not yet mass commodities, the lecture method was the only way to transfer information from one generation to the next. However, education is so

Calls for evidence-based teaching practices
In the late 1990s, educational innovations in teaching freshman physics, specifically a method called interactive engagement, were delivering greater learning gains than the traditional lecture format. These innovations were not just on Professor John Belcher, teacher of freshman physics at MIT and one of the three principal investigators of the Technology-Enhanced Active Learning (TEAL) project. Rather, it was engaging the research between traditional teaching methods and how students actually learn. Despite great lectures, attendance at MIT’s freshman physics course dropped to 88% by the end of the term, with a 10% failure rate. Even though MIT freshmen had good math skills, they often had a tough time grasping the concepts of freshman physics. Traditional lectures, although excellent for many purposes, do not convey concepts well because of their passive nature.

In the TEAL project, Belcher teamed up with Co-Principal Investigators Peter Doumarshkin and David Lister to reform the teaching of freshman physics at MIT with a new mix of pedagogy, technology, and classroom design. They borrowed from innovations made at other universities, most notably from North Carolina State University’s Spade-up program, and added visualizations of electricity and magnetism to meet the needs of E&I. MIT’s second term feature,

http://web.mit.edu/edtech/casestudies/teal.html#video
The primary goal of the Student-Centered Activities for Large Enrollment Undergraduate Programs (SCALE-UP) Project is to establish a highly collaborative, hands-on, computer-rich, interactive learning environment for large-enrollment courses.

Educational research indicates that students should collaborate on interesting tasks and be deeply involved with the material they are studying. We promote active learning in a redesigned classroom of 100 students or more. (Of course, smaller classes can also benefit.) We believe the SCALE-UP Project has the potential to radically change the way large classes are taught in colleges and universities. The social interactions between students and with their teachers appears to be the "active ingredient" that make the approach work. As more and more instruction is handled virtually via technology, the relationship-building capability of brick and mortar institutions becomes even more important. The pedagogical methods and classroom management techniques we design and disseminate are general enough to be used in a wide variety of classes at many different types of colleges.

Class time is spent primarily on "exploration" and "construction." Essentially these are hands-on activities, simulations, or interesting questions and problems. There are also some lecture-driven labs where students have to write detailed reports. (This example is more complicated than most, but shows what the best students are capable of doing.) Students sit in three groups of three students at a 7-foot diameter round table. Instructors circulate and work with teams and individuals, engaging them in Socratic-like dialogues. Each table has at least three networked laptops. The setting is very much like a banquet hall, with lively interactions among all times. Many other colleges and universities are adopting/adapting the SCALE-UP room design and pedagogy. Engineering schools are especially pleased with the "source objectives," which fit in well with the requirements for ABET accreditation.

Materials developed for the course were incorporated into what became the leading introductory physics textbook, used by more than 1/3 of all science, math, and engineering students in the country.

Impact

Rigorous evaluators of learning have been conducted in parallel with the curriculum development effort. Besides hundreds of hours of classroom video and audio recordings, we also have conducted numerous interviews and focus groups, conducted many conceptual learning assessments (using nationally-recognized instruments in a pre/post test protocol), and collected portfolios of student work. We have data comparing nearly 8,000 traditional and SCALE-UP students. Our findings can be summarized as the following:

- Ability to solve problems improved
- Conceptual understanding increased
- Attitudes are improved
- Failure rates are drastically reduced, especially for women and minorities
- "At risk" students do better in later engineering statics classes

Details

A paper describing the approach and its underpinnings is available. A shorter description is posted on the PER website, or you can view an article describing the project from the proceedings of the Sigma Xi Forum on Reforming Undergraduate Education. The Raleigh News & Observer newspaper also has a description of the project. The very successful pilot project was described in the first issue of the Physics Education Research Supplement to Am. J. of Physics. See our publication page for more information.

More than 50 colleges and universities across the US have adopted the SCALE-UP approach to their own institutions. In all cases, the basic ideas remain the same; get the students working together to learn something interesting. That frees the instructor to roam about the room, asking questions and starting up debates. Classes in physics, chemistry, math, engineering, and even literature have been taught this way. If you want more information, please contact Dr. Robert Beichner.

http://www.ncsu.edu/PER/scaleup.html
Challenged-Based Learning

- Problem-based learning
- Case-based learning
- Project-based learning
- Learning by design
- Inquiry learning
- Anchored instruction

John Bransford, Nancy Vye and Helen Bateman. Creating High-Quality Learning Environments: Guidelines from Research on How People Learn
STAR.LEGACY

The Challenge

Go Public

Generate Ideas

Test your mettle

Multiple Perspectives

Research & Revise

https://repo.vanth.org/portal/public-content/star-legacy-cycle/star-legacy-cycle
Cooperative Learning
• Positive Interdependence
• Individual and Group Accountability
• Face-to-Face Promotive Interaction
• Teamwork Skills
• Group Processing
Cooperative Learning Research Support

• Over 300 Experimental Studies
• First study conducted in 1924
• High Generalizability
• Multiple Outcomes

Outcomes

1. Achievement and retention
2. Critical thinking and higher-level reasoning
3. Differentiated views of others
4. Accurate understanding of others' perspectives
5. Liking for classmates and teacher
6. Liking for subject areas
7. Teamwork skills
Faculty interest in higher levels of inquiry in engineering education

- **Level 0** Teacher
  - Teach as taught

- **Level 1** Effective Teacher
  - Teach using accepted teaching theories and practices

- **Level 2** Scholarly Teacher
  - Assesses performance and makes improvements

- **Level 3** Scholar of Teaching and Learning
  - Engages in educational experimentation, shares results

- **Level 4** Engineering Education Researcher
  - Conducts educational research, publishes archival papers

Session Summary
(Minute Paper)

Reflect on the session:

1. Most interesting, valuable, useful thing you learned.
2. One thing you’d be willing to try
3. Questions/Comments
4. Pace: Too slow 1 . . . . 5 Too fast
5. Relevance: Little 1 . . . 5 Lots
6. Instructional Format: Ugh 1 . . . 5 Ah
Q4 – Pace: Too slow 1 . . . 5 Too fast (2.7)
Q5 – Relevance: Little 1 . . . 5 Lots (4.3)
Q6 – Format: Ugh 1 . . . 5 Ah (4.1)