CASE STUDIES IN MATERIALS ENGINEERING

Why Case Studies?

New learners of a subject seem to love examples, and always want more of them during their process of learning. Examples are great because they demonstrate how to solve problems: they offer guidance on processes with respect to styles of problems. A commonly held misconception is that people will learn by observing how to solve a particular type of problem through the practice of watching examples worked out by instructors. **In reality, examples are poor learning objects for higher order thinking skills development such as synthesis, integration, and creation; case studies are superior, and case studies are not examples**.

So, when is it best to learn through case studies? The answer lies in the differences between examples and case studies, as detailed in Table 1. Perhaps *the most critical difference between examples and case studies is the role assumed by the student*: in examples, learners are **followers** of thought and their role switches to **leaders** of thought in case studies. Thus, learners must access and operate at higher levels/orders of thinking during case studies, and in so doing can achieve learning that is more effective (i.e., deeper knowledge acquisition and development along with improved reasoning skills and engineering judgement). Open-ended cases are much harder to think through, but richer in learning!

Table 1. Comparison and Contrast of Examples and Case Studies

Characteristic	Example	Case Study
Procedural Knowledge	• Indicate • Demonstrate • Explain	• Decide • Perform • Justify
Prior Knowledge	• Recall	• Decide Relevance • Apply
Activity	• Watch • Follow thinking • Observe judgements	• Do • Participate in thinking, reasoning, and questioning • Develop and practice judgement

Examples of Educational Outcomes Intended for Case Studies

1. Practice observation without judgement (learn how to see evidence in a failure, or determine how to go about finding evidence).
2. Acquire processual skills to think as a problem analyst and solver – diverge (create choices) and converge (make choices).
3. Practice asking the ***right*** questions in the context of problem analysis and solving.
4. Apply problem analysis to identify actual problems.
5. Apply decision analysis to identify and evaluate possible decisions.
6. Apply problem/opportunity analysis, situation analysis.
7. Synthesize information (from various experiences and contexts) into appropriate and viable solutions (safety, ethics, technical, human factors, economics, etc.).

8. Apply logic to problem solving (induction, deduction, and the two forms of abduction).
9. Recognize logical fallacies and avoid them.
10. Construct logical and evidence-based arguments for conclusions.
11. Improve self-awareness of thought (metacognition), and self-assessment of abilities.

Examples of Common Lines of Questioning & Thinking in Open-Ended Case Studies

In the context of failure:

1. For a “failure”: what happened, and how? What didn’t happen?
2. How did events happen? What could have been done to prevent the events?
3. Assess for red herrings and silver bullets.
4. Can a bad solution be spotted before being implemented?
5. …

In the context of performance:

1. What does “performance” mean in this situation?
2. What specifications were in place?
    - What was the intended function of the component?
    - What were the constraints?
    - What was the objective?
    - What were the free variables?
3. Were the specifications appropriate?
    - Did the specifications support the implied or explicit definition of performance? If yes, how? If no, why not?
4. What material properties would be required to achieve the desired/specified level of performance?
5. Were the required properties present in the material?
6. Was the microstructure of the material appropriate to exhibit the material properties of the materials in the given application and service environment as per the performance specifications?
7. Was the processing of the material adequate to provide the intended microstructure?
8. …

In the context of design:

1. What is the design?
2. What is the use case?
3. Can you identify the objectives, function, constraints, and free variables?
4. What problem was being solved by this design?
5. Can a bad solution be spotted before being implemented?
6. …

Administration of Case Studies

Case studies **must not** be run like examples – the thinking patterns are not to be on display by the instructor, but facilitated and challenged to **allow the learners to directly explore problems**. Such is the life of a professional engineer. It turns out people are terrible at learning by example[1] if they do not have the fundamental knowledge to be able to assess their own learning, or the subject matter.

Case studies must be designed to enable learners to get informative and accurate feedback on their abilities so that they may become better at self-assessment; facilitators must clearly identify errors in logic, fact, or application of knowledge in order to run effective case studies and improve the level of ability in their learners.

Case studies in this context are a mini-project, where learners do not do all the work, but are focused to do the questioning, researching, reflection, and interpretation—the learners must think and guide their inquiry with slight corrections (learning!) along the way. When a knowledge gap is identified, they are also guided to information sources that can allow them to build their own knowledge to assist in the resolution of the case.

Types of Case Studies: Why We Will Work Towards Unfolding Cases

There are many types of case studies (see the accompanying chart: TYPES OF CASES). Real life is often closest to an **unfolding case study**, wherein ***the body of evidence is unknown prior to the start*** of the case study. The unfolding case study can be accelerated as compared to actually doing all the work via data and information being delivered on a piecemeal basis, as needed, or as requested. As the course develops the facilitators will **only** supply data when requested (i.e., the facilitator will not offer information to assist the learners in solving the problem until requested).

Learners must ultimately justify their requests for data by stating what specifically they are hoping to find or learn, how the requested data will be appropriate for developing information and meaning (and ways it might not be), and moreover how such data will allow further development of a judgement to reach a conclusion for the case. Consideration of costs to obtaining such data will also be required (e.g., characterization and other testing costs).

Learners gather in teams of 4-5 people to think their way through the problem in order to ask questions, and receive data (choose your own adventure style). No interpretation is provided—just data, and perhaps some interview comments.

[1] See paper by: Kruger and Dunning in *Journal of Personality and Social Psychology* 1999, v77 [6] 1121-1134