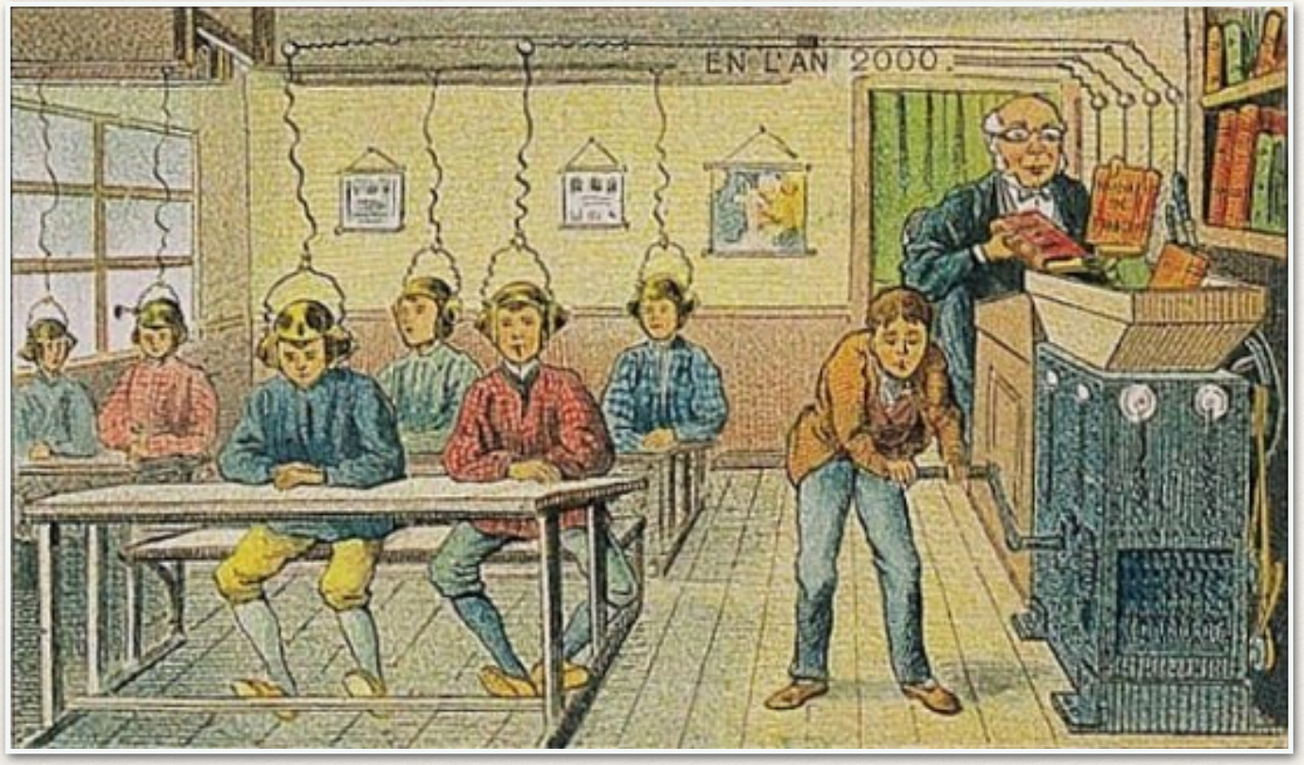


Authentic/Aligned ~~Exam~~ Prompts & Questions that Assess Problem Solving Ability ~~in Engineering~~

John A. Nychka
Chemical & Materials Engineering

Assess this: Educational Assessment Challenges and Practical Solutions Symposium, Aug. 6th 2015

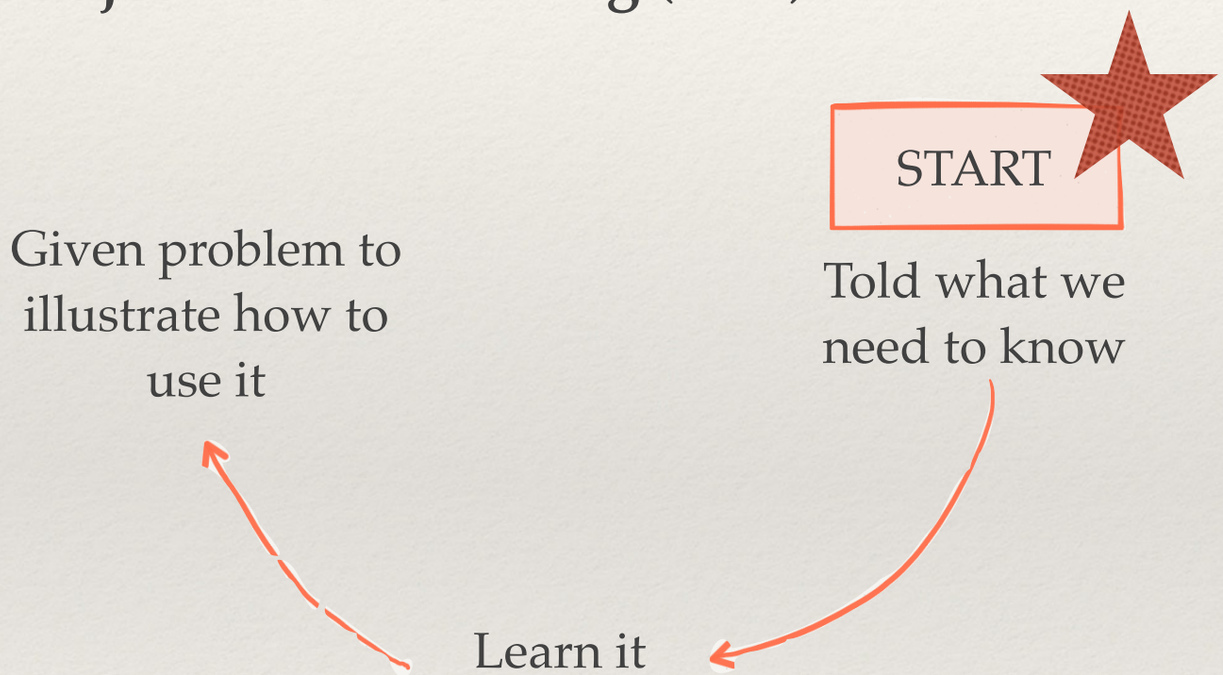
Open ended problems

- Real, true, authentic
- Messy
- Wicked
- Every solution seems to create more problems
- Question-based

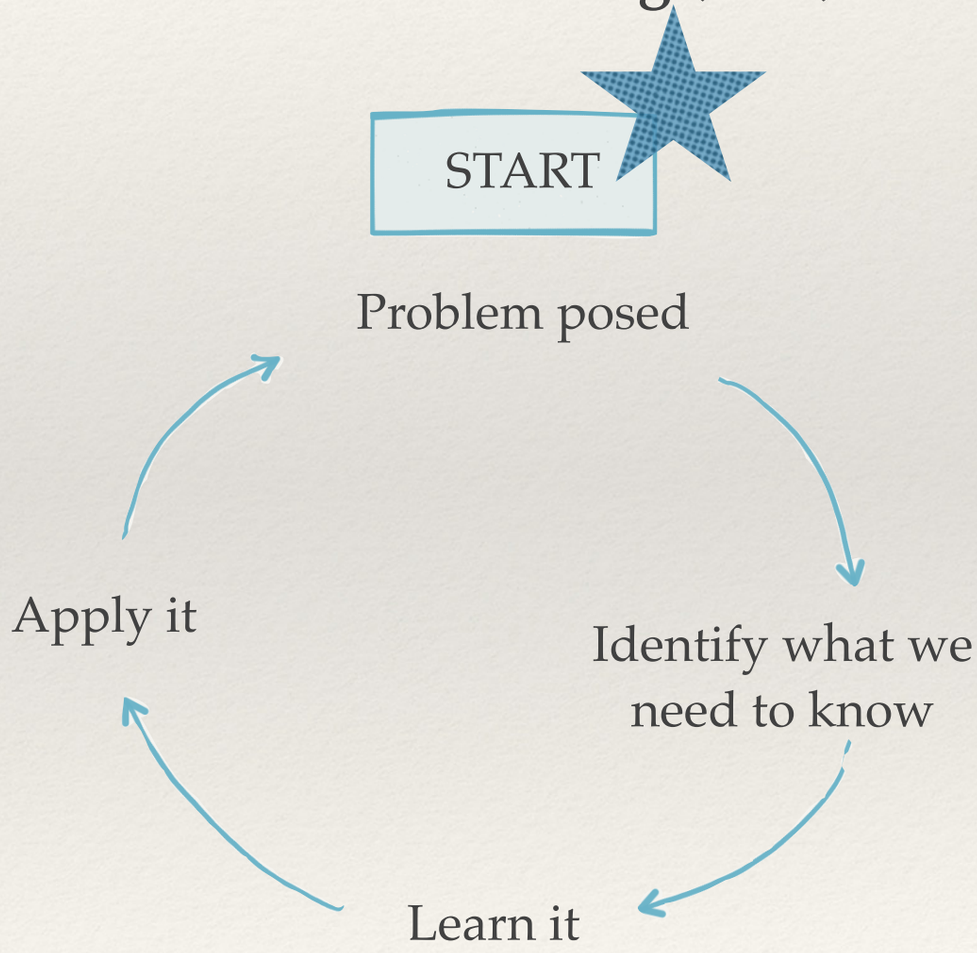
Problem Solving (PS) Methods

- Depend on the type of learning expected

Subject Based Learning (SBL)

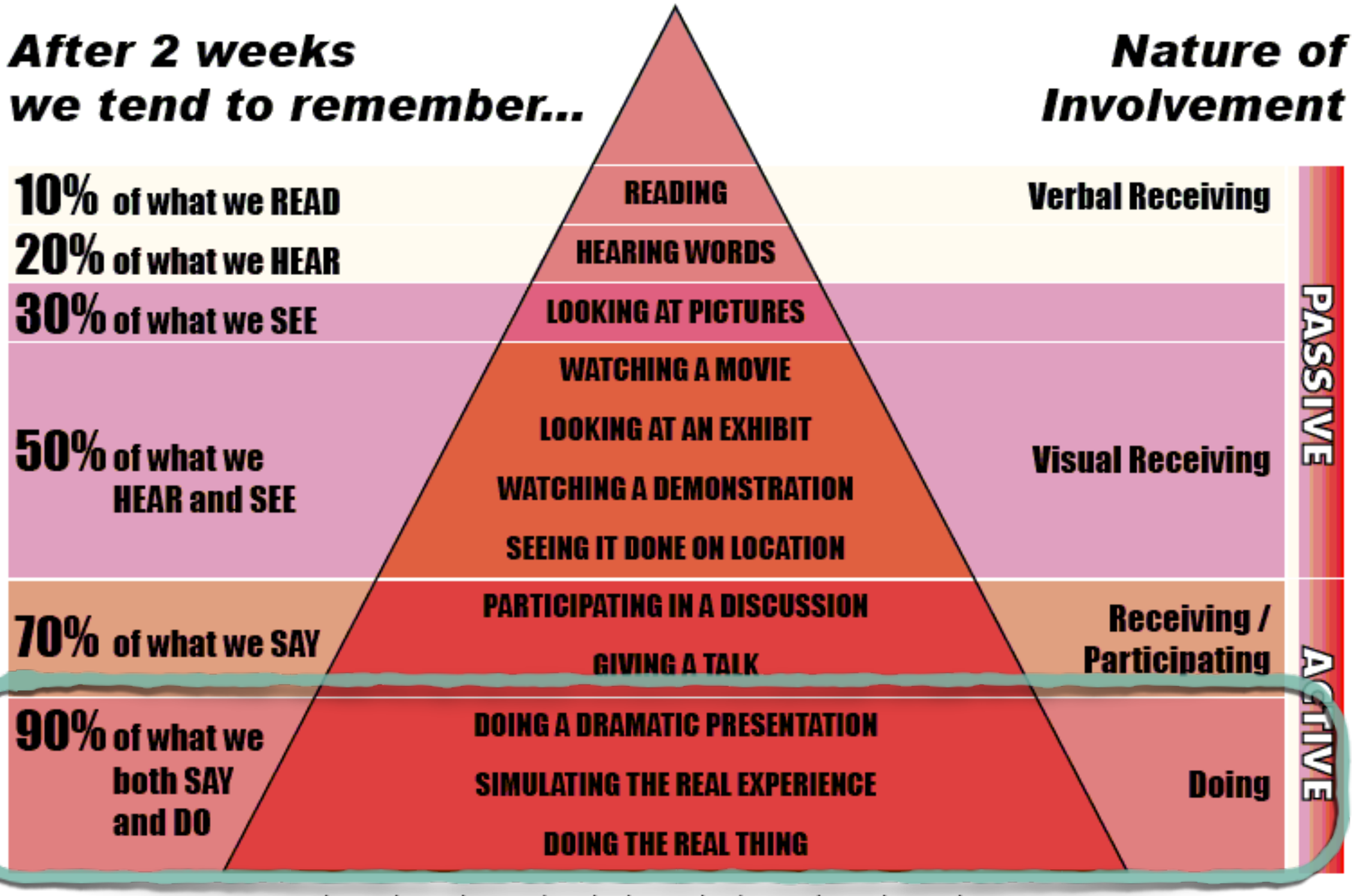


Problem Based Learning (PBL)



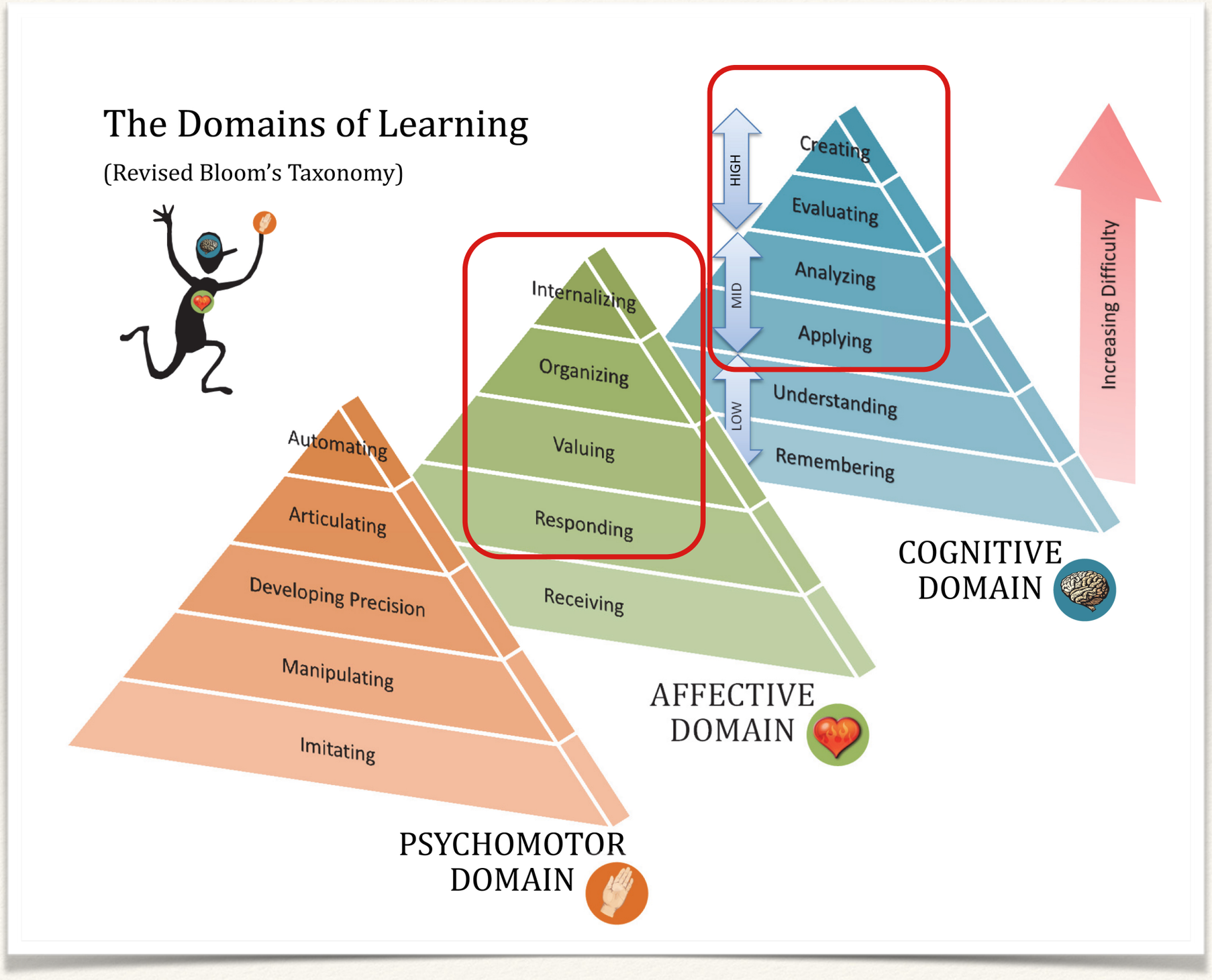
Schematics after Don Woods: http://chemeng.mcmaster.ca/sites/default/files/media/U36%20Problem-based%20Learning%2097.ppt

Cone of Learning (Edgar Dale)



Edgar Dale, *Audio-Visual Methods in Technology,* Holt, Rinehart and Winston.

Ability: what we want



How to Assess?

- Self (with training)
- Peers
- Facilitators
- Industrial Mentors

} Via Prompts & Questioning

Authenticity: what we try to create

- "In general, an authentic task is one which:
  - *is purposeful and engaging*
  - *models how people solve real problems in work and/or communities*
  - *puts knowledge to work*
  - *potentially demonstrates what students know and can do*
  - *supports multiple representations and solution strategies*
  - *offers opportunities for meaningful learning and higher order cognitive thinking*
  - *results in some product, presentation or outcome as a result of the deliberations of the group and/or individual."*

http://www.education.vic.gov.au/school/teachers/teachingresources/discipline/maths/assessment/pages/authtasks.aspx

Authenticity

- Problems should be real:
  - *Relevant (aligned)*
  - *Poorly defined*
  - *Conflicting or missing information*
  - *Multifaceted*
  - *No one can answer questions for you*
  - *There is no "right" answer*
- Forward looking:
  - *What will your learners face in their futures?*
  - *How can/will acquired knowledge be used?*

Problem solving skills I want my students to develop

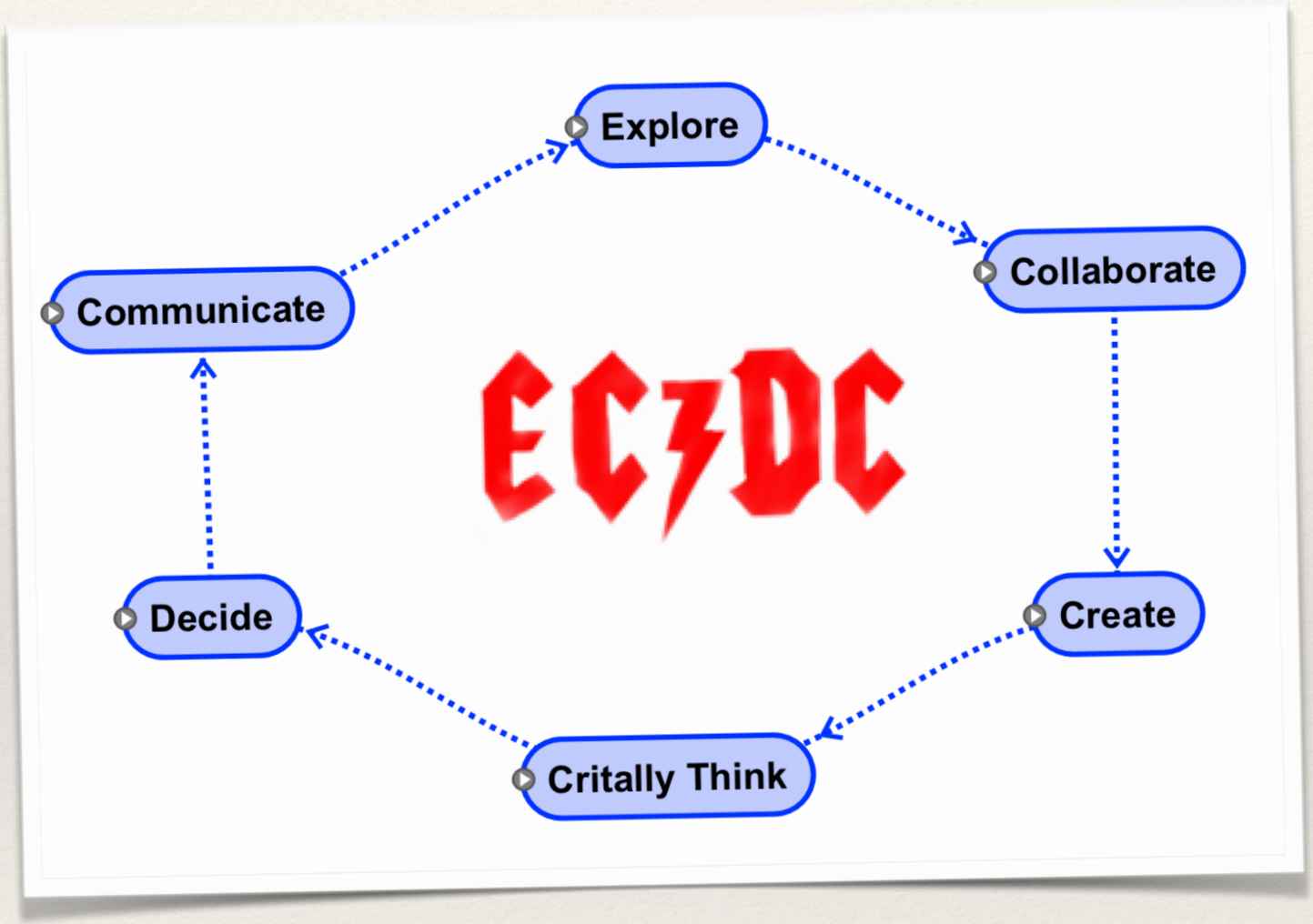
Exploration

Collaboration
Creativity
Critical Thinking

Decision
Making

Communication

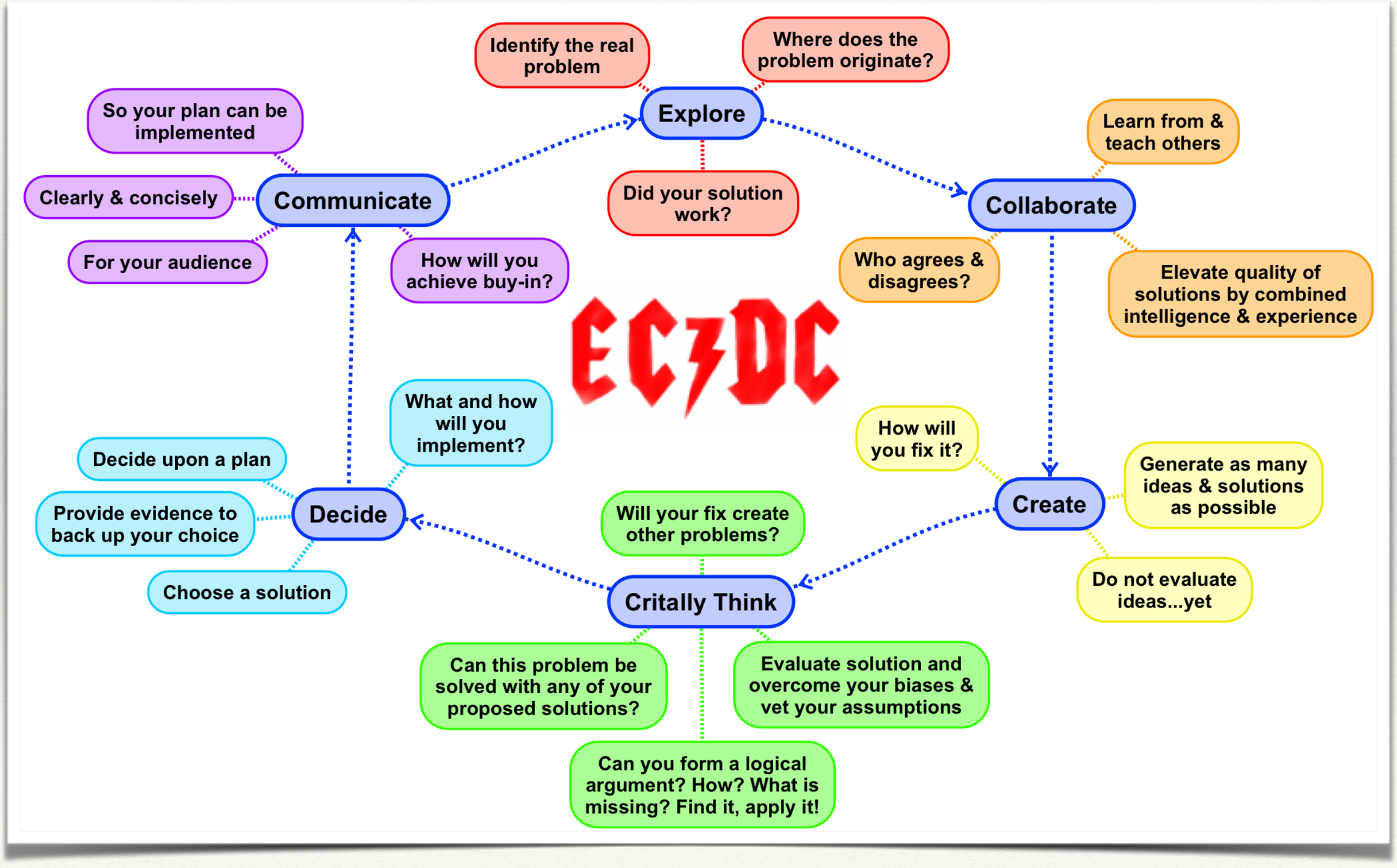
A Common PS Approach



- Identify the problem
- Explore possible solutions
- Evaluate solutions
- Decide and plan
- Implement

Open ended problem solving: Prompts & Questions

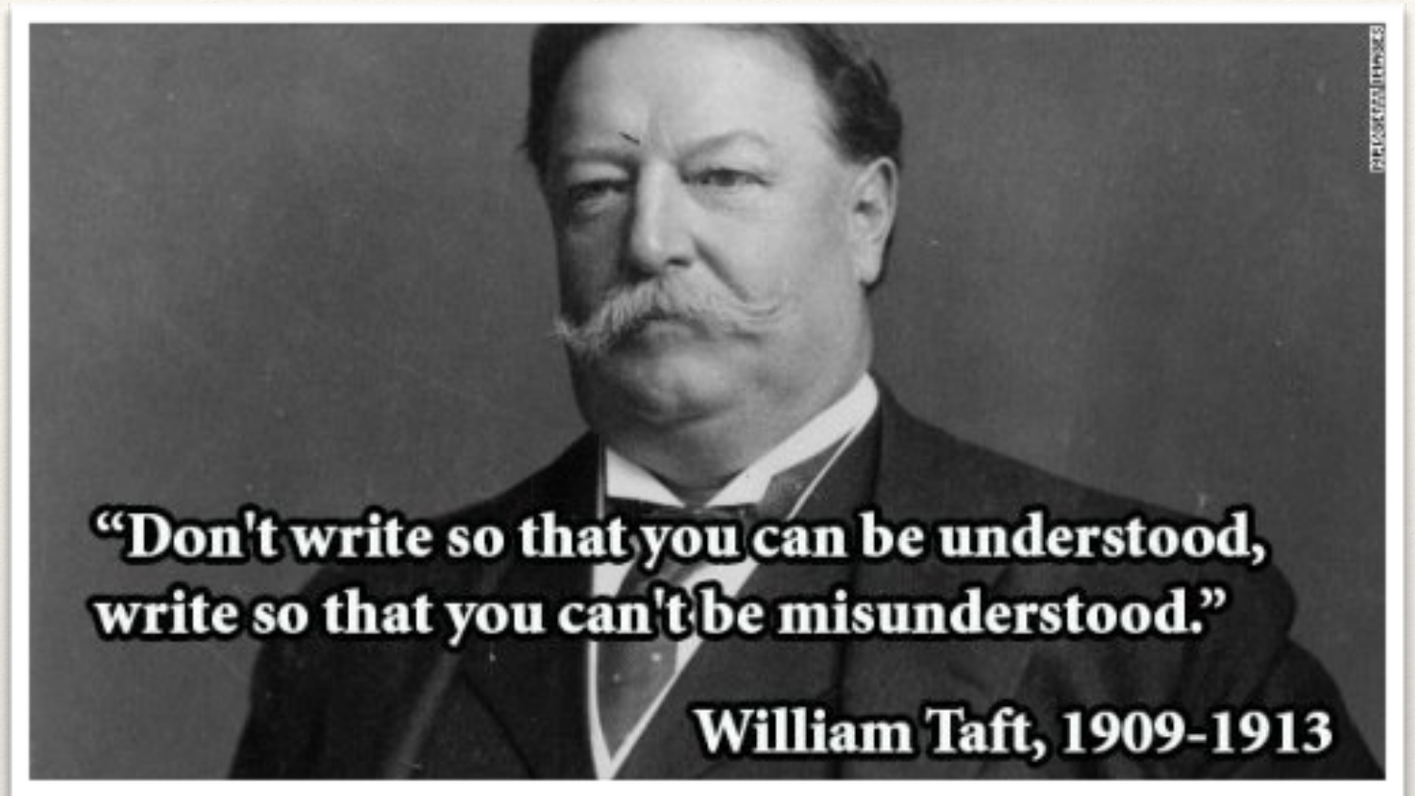
(Useful in: design, research, art)



Alignment

- What are your educational objectives?
- Did you communicate your objectives clearly so students understood them?
- Did you teach what you said you would?
- Are you assessing what you said you would?
- Prove it! Map it! Have someone else review it!

Overcoming Misalignment



- Collaborate
- Reflect, Review, Revise, Refine
- Ask for feedback, appreciate it, understand it, and be prepared to act on it!

Example Integrated Course Map

Integrated Course Map, Mat E 465

PHASE	OUTCOME (WHY DO IT?)	HIGH LEVEL DELIVERABLES	DEMONSTRATION OF KNOWLEDGE (HOW TO DO IT?)	METHODS (WHAT TO DO?)	DEGREE OF COMPLEXITY & COMPLICATIONS	DEGREE OF ITERATION	DEGREE OF UNCERTAINTY
I	**Identify the Problem**	**Concept** ✓ Complex system map ✓ Problem statement ✓ Design Specification Matrix ✓ Gap analysis	• Exploration • Interrogation • Systems thinking • Critical thinking • Analysis • Evaluation • Collaboration • Communication	• Fact finding questions (FFQ); The Phoenix Checklist • Identify resources & start researching • Identify stakeholders • Construct complex system map • Gap analysis: what will you and your team need to learn & teach yourselves and each other? • Bias identification: how to recognize cognitive bias • Ashby method (define: goals, objectives, function, constraints, free variables) • Challenge assumptions, Socratic questioning • Define success: what are the elements of success? Scope?	• Complexity may not yet be fully realized: search for all variables and elements of the system • Complications need to be identified and assessed; might not see them all yet	Highly iterative	Highly uncertain; you might feel overwhelmed at how much you do not know…yet
II	**Formulate Solutions**	**Embodiment** ✓ Potential solutions & ideas ✓ Design Specification Matrix (updated) ✓ Complex system map (updated)	• Exploration • Creativity & ideation • Iteration • Integration & synthesis • Systems thinking • Critical thinking • Evaluation • Collaboration • Communication	• Heuristic processes • SCAMPER • Duncker diagrams • Thinking traps, Bias lists, Socratic questioning • Research; QFD's • Divergent thinking • Ishikawa diagrams • Challenge first ideas • Refine complex systems map (narrow scope?); nodal analysis	• Complexity continues to be revealed • Identify complications to resolve: where should you be spending time?	Highly iterative; goal is to iterate as much as possible to generate ideas	Very uncertain, but beginning to be identified, and perhaps even managed
III	**Develop Models & Prototypes**	**Details** ✓ A few chosen solutions for testing & evaluation in design specification matrix ✓ Decide final approach ✓ Reasoning for choices (justification) ✓ Updated complex system map	• Exploration • Investigation • Analysis • Evaluation • Integration & synthesis • Critical thinking • Systems thinking • Decision making • Collaboration • Communication	• Heuristic processes • Rate, rank, prioritize (Ashby method; CES) • Research; Decision making methods • Reframe, simplify, generalize, educated guess, find errors • Determine biases; Criticism and feedback; Socratic questioning • Satisficing; Expert vs. novice thinking • Model & test, analyze, revise, refine • Matrix (K-T), weighting, TRIZ methods • FMEA: identify, assessment, corrective actions	• Complexity: likely more stable, but with some extra elements appearing the deeper you dig • Complications are beginning to be resolved in more detail	Minimal iterations: iterations should be small in order to satisfice (e.g., slight changes in dimensions)	Uncertainties are mostly known and being addressed through research and testing to determine management solutions
IV	**Present & Implement**	**Design Specifications** ✓ Final design solution ✓ Detailed specifications (with design compliance matrix) ✓ Evidence based arguments	• Critical thinking • Decision making • Justification • Reasoning • Systems thinking • Collaboration • Communication	• Construct evidence based arguments • Decide upon & specify: material, process, microstructure, final design • Cost model: FFQ, ROR, equations • Data, graphs, schematics, drawings, infographics, PFD • Unanswered questions: what needs to be done, and how will decisions be made?	• Complexity remains, but is understood & mapped • Complications which are central to study have been revealed & resolved/managed	Ideally not iterative	Uncertainties are well identified & managed (or reduced)

Prompts & Questions: Tips

- Clearly align tasks with learning outcomes
- Gain knowledge and practice/training in facilitation
- Socratic questioning works well - teach learners how to do this themselves
- Avoid "Yes or No" or "True or False" questions; ask open-ended questions
- Ask until there are no more answers
- Implement self and team behavioural checklists

Lists of prompts for reference

The Phoenix Checklist (CIA)

ECCC/DC Prompts (CH E & MAT E 465, "*Tools & Tactics of Design*") used in behavioural checklists (aligned with CEAB Graduate Attributes)

The Phoenix Checklist (as developed by the CIA)

The Problem

- Why is it necessary to solve the problem?
- What benefits will you gain by solving the problem?
- What is the unknown?
- What is it you don't yet understand?
- What is the information you have? What isn't the problem?
- Is the information sufficient? Or is it insufficient? Or redundant? Or contradictory?
- Should you draw a diagram of the problem? A figure? Where are the boundaries of the problem?
- Can you separate the various parts of the problem? Can you write them down? What are
- the relationships of the parts of the problem?
- What are the constants (things that can't be changed) of the problem?
- Have you seen this problem before?
- Have you seen this problem in a slightly different form? Do you know a related problem?
- Try to think of a familiar problem having the same or a similar unknown.
- Suppose you find a problem related to yours that has already been solved. Can you use it? Can you use its method?
- Can you restate your problem? How many different ways can you restate it? More general? More specific? Can the rules be changed?
- What are the best, worst, and most probable cases you can imagine?

The Plan

- Can you solve the whole problem? Part of the problem?
- What would you like the resolution to be? Can you picture it? How much of the unknown can you determine?
- Can you derive something useful from the information you have?
- Have you used all the information?
- Have you taken into account all essential notions in the problem?
- Can you separate the steps in the problem-solving process? Can you determine the
- correctness of each step?
- What creative-thinking techniques can you use to generate ideas? How many different
- techniques?
- Can you see the result? How many different kinds of results can you see?
- How many different ways have you tried to solve the problem? What have others done?
- Can you intuit the solution? Can you check the result?
- What should be done? How should it be done? Where should it be done?
- When should it be done?
- Who should do it?
- What do you need to do at this time?
- Who will be responsible for what?
- Can you use this problem to solve some other problem?
- What is the unique set of qualities that makes this problem what it is and none other?
- What milestones can best mark your progress? How will you know when you are successful?

Process for self and team administration of behavioural checklists

For each behaviour and feeling rate yourself and your team members. In addition, try to:

a. Think of an example that is specific to you or members in your team.
b. Indicate what (if anything) you or members in your team did to deal with the behaviour or feeling.
c. Provide recommendations for improving the situation even more, if possible.

Rating: 1 = Never 2 = Rarely 3 = Sometimes 4 = Frequently 5 = Always N = Does Not Apply

This document was adapted and modified by J.A. Nychka from the Behavioral Checklist for Phase 1 on page 71 of Tools and Tactics of Design by P.G. Dominick, J.T. Demel, W.M. Lawbaugh, R.J. Freuler, G.L. Kinzel, and E. Fromm and the Team Assessment Rubrics for the CHE 435/465 and Mat E 465 courses, 2015.

Exploration

1. Asked questions and sought answers to identify the problem as a perceived or real problem.
2. Recognized and reflected about current stage of growth applicable to this stage of design (Perry's Schema)
3. Tried to identify cognitive biases within self (30 Second Design Psychology)
4. Referenced and used the Phoenix Checklist and Socratic Questioning tools to aid in exploration of the problem.
5. Participated with team to use different tools to map out the problem (complex systems map, QFD, FFQ, Duncker diagrams)
6. Thought about potential stakeholders of the problem and shared thoughts with team and sponsor.
7. Avoided assessing potential solutions and ideas too rapidly before exploring their details and performing analyses.
8. Participated with team to use different analysis and testing tools to develop knowledge and information base.
9. Performed a strengths and weaknesses inventory on team members' skills and abilities.
10. Performed a gap analysis of team's skills and abilities with respect to anticipated needs for the problem.

Collaboration

1. Consistently involved all others in discussions and decisions by soliciting their input.
2. Encouraged contrary opinions.
3. Allowed time for debate and discussion.
4. Understood thorough understanding of the technical issues to the project and your role.
5. Worked toward making work assignments fair and equitable; responded to change.
6. Behaved in a professional manner (timely, appropriate dress).
7. Handled minor conflicts well.
8. Acknowledged others' contributions and ideas respectfully.
9. Recognized and responded to others' feelings and concerns.
10. Was friendly toward others and sought to build rapport.
11. Demonstrated patience with others.
12. Familiar with Tuckman's team development model, and encouraged self and others to work on transforming to next stages.
13. Helped to clarify confusion and conflict over roles and responsibilities.
14. Supported others when they needed help or were pressed for time.
15. Recognized and respected individual differences in interpersonal style.
16. Discussed with others how to capitalize on style differences and similarities within the team.
17. Encouraged accountability among team members and discouraged social loafing.

Creativity

1. Focused on idea generation as an outcome.
2. Did not rush to conclusions regarding other's ideas.
3. Actively set aside time to think creatively.
4. Encouraged unusual and creative ideas.
5. Built on other's ideas and suggestions.
6. Used brainstorming or other idea-generation techniques to solve unexpected problems.
7. Used a formalized tool to practice disciplined creative thinking (e.g., SCAMPER, lateral thinking, Duncker).

Critical Thinking

1. Challenged first assumptions of self and others (team and sponsor).
2. Questioned resources and applied principles of the CRAAP test.
3. Practiced principles of Structured Critical Reasoning (SCR)
4. Aware of, and in the habit of looking for the top 11 logical fallacies.
5. Thought critically to understand tasks of reporting and demonstration of knowledge.
6. Thought with a forward thinking attitude about required evidence for arguments.
9. Evaluated and challenged analysis and test results for precision, accuracy, errors, true meaning, and aspects beyond technical implications.
10. Practiced contrary thinking to assess test plans and analyses for errors in logic, or inappropriate use of fundamentals.
11. Employed design of experiments principles for test and analysis planning.

Decision Making

1. Recognized constraints and limitations impacting the problem.
2. Worked to define functional requirements in specific terms.
3. Looked for biases and assumptions in order to clarify or redefine the problem.
4. Did not rush to conclusions regarding solutions.
5. Used objective facts and specific research to help define the problem.
6. Identified several alternatives before selecting a solution.
7. Objectively evaluated alternatives in relation to criteria derived from functional requirements and constraints.
8. Clearly defined the decision making process for challenging decisions.
9. Used objective facts and specific research to help determine paths forward.
10. Used a formalized tool (e.g., 6 simple Q's, Pugh's Matrix, K-T, etc.) to assist in decision making.
11. Established clear criteria for evaluating design performance.
12. Effectively used design reviews to identify ways of improving the design.
13. Carefully interpreted results from analyses and tests.
14. Was willing to change the design or make modifications based on results from analyses.
15. Planned and conducted design analyses in a systematic manner.
16. Used objective facts and specific research to help determine paths forward.
17. Actively made changes to process in response to information generated.
18. Attempted to anticipate potential problems in advance.
19. Developed and used a checklist to help ensure the readiness of the design.
20. Sought input from others outside the team in order to enhance overall decision quality.
21. Remained calm in the face of unexpected results or problems.

Communication

1. Consistently asked probing and open-ended questions to clarify issues and increase understanding.
2. Practiced active listening techniques.
3. Restated and paraphrased what others had said.
4. Gave full attention to others when they were speaking.
5. Helped to create the written problem statement so that it was well organized with clear main point(s) and supporting information.
6. Ensured that grammar, punctuation, and spelling of written documents were correct.
7. Gathered information and research from multiple and relevant sources.
8. Clearly articulated how the proposed solution(s) meets design requirements.
9. Appropriately documented references and resources used.
10. Used graphics and diagrams to effectively illustrate points and ideas.
11. Practiced active listening techniques.
12. Restated and paraphrased what others had said.
13. Provided feedback in a constructive and nonthreatening manner.
14. Clearly documented and articulated performance results from tests and analyses performed.
15. Appropriately documented references and resources used.
16. Developed well-written progress reports.
17. Devoted time for multiple stages of editing and proofreading.
18. Presented arguments with appropriate evidence to justify conclusions and decisions.
19. Developed presentations to include “big picture” overview for a wide audience.

Project Management

1. Actively participated in creation of the team's working agreement.
2. Helped the team clarify achievable goals and objectives that address project needs.
3. Clearly conveyed performance expectations and standards.
4. Helped the team to clarify individual roles and responsibilities.
5. Demonstrated appropriate flexibility with regard to meeting times and places.
6. Thoroughly identified all tasks and activities that had to be completed.
7. Clearly demonstrated awareness of the work of others, and saw their role.
8. Obtained meaningful results with a minimum of wasted effort.
9. Established realistic deadlines and time estimates.
10. Began documenting team progress and action steps.
11. Made effective progress toward individual and team milestones each week.
12. Consistently met individual and team deadlines each week.
13. Kept detailed records which others could easily follow.
14. Used a Gantt chart or other planning tool to track progress.
15. Modified tasks and timelines as new information was obtained.
16. Helped identify the right mix of skills and abilities needed to complete work.
17. Determined needs and resources for analyses and testing.
18. Helped team establish and use high-performance standards.
19. Regularly reviewed team and individual performance throughout the project.
20. Documented team progress and action steps.