

**AC 2007-2287: DISTINGUISHING AMONG PROCESSES OF PROBLEM SOLVING, DESIGN, AND RESEARCH TO IMPROVE PROJECT PERFORMANCE**

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# **Distinguishing Among Processes of Problem Solving, Design, and Research to Improve Project Performance**

## **Abstract**

Professionals in all disciplines are continually engaged in problem solving, design, and research. Because steps in these processes appear similar, many faculty conceptualize a single, universal model for all three processes. However, for students who are just learning these processes, a universal model may not be the best way to build performance skills. This work was undertaken to help novices understand unique characteristics of each process and the circumstances under which each process is most effective and efficient. This paper examines two tools that were created to build this understanding: (i) a matrix analyzing the similarities and differences among the processes and (ii) a graphical presentation highlighting key skills that are hypothesized for each process. Effectiveness of the two tools was evaluated in a freshman design course where teams of five students work on a six-week design mini-project. Data collected included notes by the instructor, observations by peer coaches who observed an activity, and written feedback provided by student teams. In the activity, teams were asked to use the tools to distinguish between problem-solving and design activities that they had performed earlier in the semester. Next, the students were asked to classify a number of simple scenarios. Finally, feedback was solicited about the greatest strengths and areas of improvement for each of the tools as well as insights gained through this class activity. Findings were validated by separate focus groups with design faculty and with students enrolled in a capstone design course. Both students and faculty envisioned the two tools to be a natural extension of project work, prompting new insights about the role of problem solving, design, and research in engineering practice.

## **Introduction**

One of the most valued skills of an engineer is the ability to solve problems. However, the definition of “problem solving” varies widely depending on the context or community in which it is used. Many faculty tend to favor a definition that is all encompassing – where any task, no matter how large or small, with an unknown solution denotes a problem. For mature problem solvers, such a definition is powerful and meaningful<sup>1</sup>. While valuable insights can be derived from a universal model, there may be drawbacks to doing so from the standpoint of novice problem solvers. Universal models tend to focus on methods rather than intermediate results. For those in a learning role, it is often difficult to translate abstract steps of a universal methodology into concrete, relevant actions. There may also be unique, value-added learning skills associated with problem solving, design, and research that tend to be diluted in a universal model. Lack of attention to limiting learning skills, in turn, may hinder development of expertise in a process area. Understanding key differences between problem solving, design, and research allows one to select the process that best supports a desired outcome, gives clearer vision of one’s location when executing the process, and provides guidance for making transitions between processes. The objective of this paper is not to re-define problem solving. Instead, working definitions that explicitly distinguish between problem solving, design, and research are presented to students who are then asked how this framework could benefit their project work. In addition to the qualitative feedback, comprehension of the three definitions was measured by asking students to classify common engineering challenges as primarily problem solving, design, or research.

Students were also prompted to think about skills that limited their performance in problem solving, design, and research. This was initiated by asking students to process a Venn diagram prepared by the authors that highlighted learning skills likely to be associated with each process. Skills that are common to all three processes as well as those that intersect two of the processes were also hypothesized.

This paper first introduces working definitions for problem solving, design, and research along with observations how these processes are commonly taught. Next two tools are outlined: (i) a table analyzing the similarities and differences between the processes in terms of common attributes and (ii) a figure highlighting key process-specific skills from the viewpoint of the authors. The bulk of the paper is a case study where the tools were examined in a freshman design course as well as a capstone design course. At the end of the paper, we present insights and edits based on student and faculty feedback.

## **Background**

Definition of Processes: WordNet from Princeton University defines Problem Solving as “the area of cognitive psychology that studies the processes involved in solving problems, or, the thought process involved in solving a problem.”<sup>2</sup> One of the more popular definitions comes from Newell and Simon<sup>3</sup> which was summarized by Woods:

*“A situation where a person desires to resolve the gap between a goal state and an initial state. Some blockage in the gap prevents the person from immediately seeing a course of action. If there is no blockage, then the situation is an exercise, not a problem.”<sup>4</sup>*

Woods later refined this definition stating that:

*“Problem Solving is a process whereby a ‘best’ value determined for some objective or unknown, subject to a specific set of constraints and criteria. The problems that we focus on to solve are ones where there is no immediately apparent procedure, idea, or route to follow; if one has an idea of how to solve ‘the problem,’ then this problem is simply an exercise. What we call a problem is a real challenge; it is a situation where we really have to struggle to define it, figure out what it means, and resolve it.”<sup>5</sup>*

While these definitions offer valuable insights to veteran problem solvers, they lack detail necessary for a novice to improve their skills.

In this paper, we choose to associate “problem solving” with smaller day-to-day challenges, recognizing that these “problems” are often parts of a much larger “Problem.” In an academic context, problem solving is often viewed as synonymous with homework assignments. However, the authors consider many homework assignments to be more “transfer exercises” or “analytic problem solving”<sup>6</sup> which involve calculations leading to one correct answer. “Creative problem solving”, in contrast, is much more open-ended and revolves around a situation—not a calculation<sup>1</sup>. Creative problem solving involves resolution of a discrepancy between one’s expectations and the reality of one’s situation. Where “analytic” problem solving tends to focus

on strictly cognitive issues<sup>7</sup>, “creative” problem solving includes significant social and affective dimensions. The authors definition of problem solving is synonymous with creative problem solving.

The term “design” is used fairly consistently across multiple disciplines<sup>8</sup>. Design commonly involves a third-party customer/user, and the innovative devising of a product or process, eg. hardware, software, or production system, that satisfies a need. Many people confuse design with fabrication. While manufacturing is often a large component of design, design involves as much planning and analysis as it does physical prototyping.

Research is often a major component in evaluating faculty performance. Research starts with a gap in current knowledge and seeks to fill this gap with theory and data that is accepted by a wider community<sup>9</sup>. The knowledge gap does not focus on personal knowledge, but rather the knowledge of a research community. Research therefore is the discovery and dissemination of empirical knowledge that is not currently known by a community of experts. Knowledge that is new to one person, but not to others, may be better characterized as “project learning”. An example of project learning is when students “research” the literature, and write a “research paper.”

Teaching the Processes: Introductory as well as advanced engineering texts<sup>6,10</sup> cover problem solving and design in separate sections. However, these sections are often interconnected and there is often loose use of terminology. When teaching creative problem solving special emphasis is usually given to problem definition. Sometimes the real problem is not as it first appears. Problem definition, brainstorming, data gathering, picking a best solution, implementation of the solution, and anticipating possible outcomes of implementing the solution are cited as the critical steps by Oakes et al.<sup>6</sup>. Wankat and Oreovicz<sup>10</sup> identify analysis, synthesis, generalization, simplification, creativity, and decision-making as central elements of problem solving.

Many authors present guides on teaching engineering design<sup>6,10,11</sup>. The steps in the design process are usually given to be some variation of problem definition, gathering information, generation of ideas/alternatives, modeling, feasibility analysis, evaluation, decide on one alternative, communication, and implementation/production. All authors emphasize that design should be taught so that students can experience the steps as a process. Atman et al.<sup>11</sup> conclude that there are several general characteristics of a successful design process: (1) the use of a prescribed methodology that allows for flexibility and opportunistic design, (2) the effective use of transitions among design steps; and (3) the development of good conceptual models, including effective scoping of the problem. Iteration is frequently mentioned as critical to design, and important to emphasize with novice engineers who may believe that linear thinking leading to one correct endpoint is a desirable course of action.

Methods of (basic) research are usually reserved for graduate study. When research principles are introduced to undergraduates, they are frequently presented in the context of “the scientific method”. For graduate students, the research process<sup>9,12</sup> may be explicitly taught, and/or implicitly mentored by the major professor.

## Comparison of Processes

Important similarities and differences between problem solving, design, and research emerge when they are compared as to their purpose, goal state, starting point, end product, time scale, knowledge base, resources required, and sequence of execution. These are summarized in Table 1. **Purpose** describes the intentions of the process, and why a process might be initiated. The **Goal State** is a desired end point and includes likely stakeholders. The **Starting Point** defines the necessary conditions that should exist before beginning a process, while the **End Product** describes what will be accomplished when the process is successfully completed. **Time Scales** refer to the duration and amount of effort one usually devotes to a particular process. **Knowledge Base** is the set of factual and conceptual understanding, experience, and skills required to operationalize a process. **Resources** can be used to leverage this knowledge base. **Implementation Steps** describe distinct stages in the execution of a process.

Table 1 can be used to classify whether problem solving, design, or research is best suited to a particular situation. Classification begins with reflection about past activities associated with similar situations. Classification continues by recognizing the situation as most like problem solving, design, or research. In doing so, prompts in each of the eight areas remind the user about necessary ingredients for the selected process to be successful. Users should be aware that it is common to transition between processes, but understanding which process you started from will help you return to this when a needed excursion into one of the other processes is completed.

## Essential Skill Sets

In creating Table 1 it appeared that a large source of the variation in problem solving, design, and research performance, could be traced to a subset of critical learning skills. Learning skills are used across many contexts that have grown out of life's experiences, and work jointly with specialized knowledge. They can be refined and improved through conscious effort. When looking at the core skills used in each of these processes, some are unique to particular processes while others are common to two or more processes. Figure 1 inventories these core skills and shows their relationship.

Figure 1 is limited to the five most critical skills in each portion of the Venn diagram. Skills in each list are ordered as they are typically applied. In teaching problem solving, design, and research processes to others, it is probably a good idea to explicitly identify and reflect on these skills within a disciplinary context. As a facilitator of learning, these are the skills you will want to intervene on to produce the greatest gains in performance.

Because problem solving is often situational and interpersonal, solutions may come in the form of a change in perception. Querying others, understanding context, and coming to a shared consensus are often as important as logical thinking in resolving a problem. To improve problem solving efficiency in future situations, it is important to generalize solutions.

The design process rewards creativity while identifying and exploring solution options. Equally important is visualizing hardware and software systems, detailing features that can be reliably manufactured, and troubleshooting until target specifications are met. Design integrates ideation, creation, and verification in purposeful iteration between prototypes.

Table 1: Tool 1 - Characteristics of Problem Solving, Design, and Research

<b>Characteristic</b>	<b>Problem Solving</b>	<b>Design</b>	<b>Research</b>
<b>Purpose</b>	Remove/reduce difference between current and desired situation	Develop a device or system to meet a specific need	Develop new knowledge for use in a community
<b>Goal State</b>	Agreement or validation that situation is resolved	Hardware or process that satisfies customer or user	Acceptance of new knowledge by peers
<b>Starting Point</b>	Undesirable or uncomfortable situation requiring change	Needs analysis, definition of specifications	Inconsistencies or incompleteness of current knowledge
<b>End Product</b>	Remedial action plan that can often be generalized	Tested artifact, tool, or process with supporting documentation	Theory, model, or answer to research question submitted for peer review
<b>Time Scale</b>	Days – weeks	Weeks - months	Months – years
<b>Knowledge Base</b>	Situational expertise	Product expertise	Discipline(s) expertise
<b>Resources</b>	Journals, newspapers, personal networking	Vendor information, patents, CAD/CAM, design of experiments	Archival literature, computer modeling, data analysis, theory
<b>Common Implementation Steps</b>	Identify a problem Engage/Motivate Define problem Explore ideas Plan solution Execute plan Validate	Recognize a need Needs analysis Target specs Concept design Detailed design Implementation Test/refinement	Awareness of knowledge gap Literature search Research Questions Develop Method Perform study Peer Review

While the other processes are looking for things that “are,” research is looking for things that “aren’t yet” and tries to construct them. Research involves creating new knowledge that may or may not be align with prevailing theories and data. Because of this, ensuring validity is a large component of research.

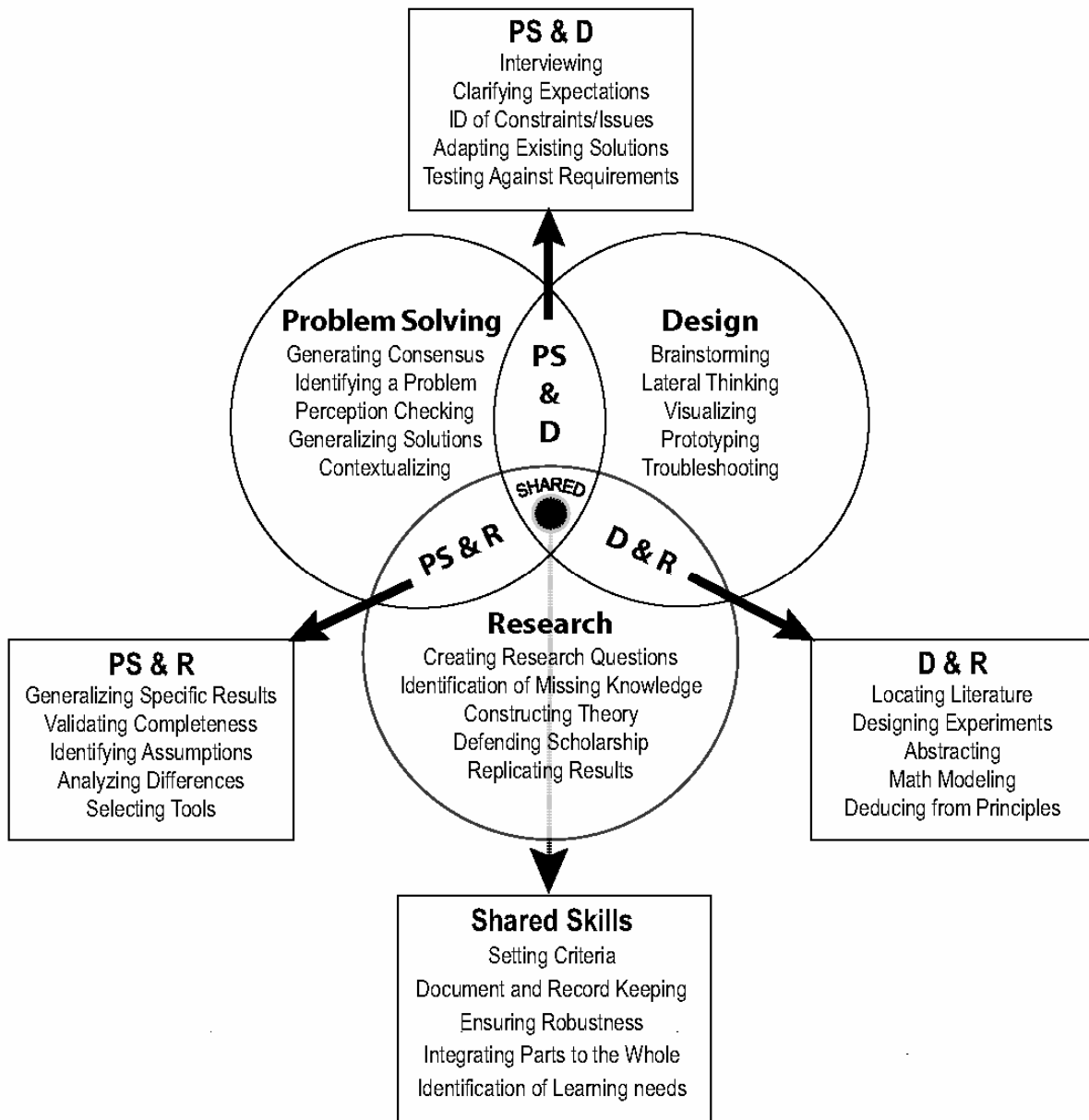


Figure 1: Tool 2 - Learning skills associated with problem solving, design, and research

For both problem solving and design there is usually an interpersonal information gathering. Similarly, the ability to find information and use it to create/answer something is a relevant to both design and research. Since problem solving happens on a short time scale, formal experiments and modeling are usually not appropriate. Different time scales between problem

solving and research initially made it hard to identify common skills. Most of the skills in Figure 1 are at Bloom's Level 3 and higher, however a large number of the skills that intersect problem solving and research are at lower levels in Bloom's taxonomy.

### **Case Study: Feedback from Freshman**

In a freshman introductory engineering design course, the topics of problem solving and engineering design were introduced separately using activities. The students had previously attained practical experience applying each process before the guided activity in this case study. The following timeline describes critical events leading up to the guided activity described herein:

- Week 1: Students introduced to the concept of learning skills when comparing the different activities performed by repairmen, engineers, supervisors, dishwashers, etc.
- Week 5: (After the first round of tests occurred in all of their classes) Students introduced to problem solving in the context of study skills and time management as toolbox elements for the problem of lower than expected test scores.
- Week 6: Design process is introduced.
- Weeks 7 - 14: Students were guided through a step-by-step process of engineering design. Each team of 5 students focuses on a unique problem.
- Week 12: Students were asked to identify a problem that their team would have to overcome in order to move forward on their design project. After reaching consensus on the problem priority and definition, they were asked to use the process given in Table 1 to solve the identified problem.
- Week 13: The activity described below occurred.

Step 1 - Process analysis and application: Each team was provided a handout depicting Tool 1 (Table 1) and Tool 2 (Figure 1). Each team was asked to

- (a) Describe two similarities between the processes of problem solving and design.
- (b) Describe two differences between the processes of problem solving and design
- (c) Recall that during the previous class, they were asked to solve a problem that their team was having within their design process. For the case study, they were asked to analyze what things seemed different during the problem solving experience that hadn't been occurring during the design experience.

Observations taken by facilitators while teams work independently on this step included the following:

- Some teams were comparing the process/methodology, while others were looking more at the motivation for using each process.
- Lots of discussion among teams trying to come to agreement about what the definition of each process was.
- Most teams quickly figured out that there is likely to be overlap in the processes and transitions between them.
- Discussion on "Which comes first? Does one lead to another?"



- Most teams had a clearer image of what “design” was, and less of what problem solving was. (This may be due to the context of the course; design was covered over more weeks and in greater depth than was problem solving.)
- Why choose problem solving or design? Timescale and scope. Also, the start point of the project may dictate one or the other

Teams were then asked to report their findings to the group. The following is a transcription of verbal and written responses.

- (a) Describe two similarities between the processes of problem solving and design
  - Both use teamwork and knowledge
  - Testing against requirements/standards
  - Both are recognizing an issue or problem
  - There is a central idea that’s being tackled
  - Visualizing helps with perception checking
  - Both likely to utilize modification of existing solutions
  - Clarifying expectations and interviewing
  - Both are trying to improve something
  - Problem solving gives initial ideas for design
- (b) Describe two differences between the processes of problem solving and design
  - Problem solving more likely to have solution, design likely to have product
  - Timescale different between two (several teams identified)
  - Design → Conceptual, and Problem solving → Contextual
  - Purposes are different (closing gap versus developing a product)
  - Problem solving → Qualitative, and Design → Quantitative
  - Design more likely to build prototype to troubleshoot than problem solving
- (c) Explain what things seemed different during the problem solving experience the previous class that hadn’t been occurring during the design process over the several preceding classes
  - Design process was more broad, problem solving more specific (we note that this response may have been in part contextual because they were asked to solve a specific problem they had encountered in their design process)
  - Problem solving leads to greater focus and better problem definition
  - Problem solving → gather information, Design → given information
  - Problem solving process will improve the design process
  - After problem solving, realized design will need consumer review
  - Design process composed of lots of problem solving processes
  - Problem solving likely to happen most in the detailed design and troubleshooting phases
  - Problem solving has obvious endpoints, while design is more iterative

Step 2 – Classification: Teams were asked to classify the following list of scenarios (after Oakes et al.<sup>6</sup>) as being suitable for either Problem Solving (PS) or Design (D).

- (a) A company has hired you to develop a new kind of amusement park ride. PS or D?  
Why? Response: Unanimously Design
- (b) An explosion has occurred in your building. Your classroom has sustained damage and is in immediate danger of collapsing on you and your classmates. You and your professor quickly determine that all exits but one are completely blocked, and that one is partially blocked. How do you get yourself and your classmates (as well as your prof!) to safety? PS or D? Why?  
Response: Unanimously Problem Solving
- (c) You are standing in a long line of snarled traffic that hasn't moved at all in twenty minutes. You're idly drumming your fingers on the steering wheel, when you accidentally drum on the horn twice. The driver in the pickup in front of you gets out of his truck, scowling, and walks menacingly toward you. What do you do? PS or D? Why? Response: Unanimously Problem Solving
- (d) You work for a tire manufacturing company, and your boss asks you to calculate how much of a tire wears off in one rotation. How do you do this? PD or D? Why?  
Response: 3 Teams Problem Solving, 2 Teams Design; depends on how you approach the problem – you could make a rough calculation, or design a device to measure wear.

Step 3 – Relevance in Project Work: Students shared the following insights about classifying different situations as problem solving or design.

- Better define goals and be aware of time constraints
- Determines how you approach a problem
- Gain perspective on a situation
- More insights about design
- Clarity of process
- Becomes an outline for how to do a task
- If not distinguished, your focus is limited to a narrow perspective
- If not distinguished, then not challenged to visualize in right context

Step 4 – Tool Assessment: Teams identified the following strengths and improvements for Tool 1 (table) and Tool 2 (figure).

Strengths-

- Easy to see/compare while side-by-side
- Tool 1 is very useful
- Categories in Tool 1 are well thought out

Improvements-

- Tool 2 does not define characteristics
- Tool 2 too subjective – need example or picture
- Tool 2 diagram is confusing
- Tool 2 language is not understood. Sounds contrived at times
- (Only 8 of 25 students knew that Tool 2 was talking about learning skills)

Insights-

- There's a lot of problem solving when doing design

- Understanding differences helps with time management
- Problem solving is identifying concepts, design is implementing concepts
- There is a difference between the two
- Tool is a lot more efficient than reading a book/chapter on the subject.

**Summary:** On the basis of the case study, the authors made the following conclusions about the student responses:

1. Students learned distinctions between problem solving and design from the tools (using Tool 1 primarily). They were able to create common meaning of the terms and use them appropriately.
2. Students used the tools to effectively classify scenarios as better addressed with problem solving or design (using Tool 1 primarily).
3. Students describe the tools as useful for distinguishing the processes, likely to improve time management. They were able to cite several situations where a “design” process was used when a “problem solving” would have been more effective, and visa-versa. They also found the tool much easier to use than the textbook format. The row labels gave them a simple structure to compare the processes.
4. Although students had been introduced to learning skills early in the semester, they were not explicitly told that Tool 2 was inventorying learning skills. Only 8 of 25 students recognized that the “words” in Tool 2 were learning skills. Comments from 17 students the about Tool 2 were that the terminology appeared contrived and abstract to them. Among the 8 students who did identify Tool 2 as learning skills, they still found the information in Tool 1 easier to apply, and were not exactly sure how to use Tool 2.

### **Case Study: Feedback from Faculty**

The two tools were presented to a faculty group interested in engineering education to get their feedback on the completeness/accuracy of the tools, and thoughts on using them. They felt the format of Tool 1 (table) allows much easy comparing/contrasting that written descriptions, and the categories made it simple to mentally separate the processes. There was discussion about wording, and the updates were implemented in Table 1. For using Tool 1, most agreed that it should not be the first introduction of the processes to students. Rather it would work best as a way to help users clarify the differences between seemingly similar processes after a more formal introduction.

Faculty quickly noted that Tool 2 (figure) inventoried skills. They found the diagram easy to follow, and limiting the number of skills in each bubble to five was about right. Use of Tool 2 was less obvious. Students learning these processes would have a hard time utilizing the information. As a facilitator of those learning a process, you want to intervene on deficient skills, not knowledge. Tool 2 would best be used to help plan constructive interventions in activities where students are engaged in one of more of these processes. It was also identified that in the classroom, problem solving and design are likely to receive primary attention, while research is more likely to be in a graduate-level seminar.

## **Revision of Tool 1**

The need to distinguish between these problem solving, design, and research came from confusion observed by the authors in many student projects. One area that was not covered in Tool 1 was different levels of research. While the scholarly definition of research requires the development of new knowledge within a community, students will often use the term “research” to describe the process of gathering background information. This knowledge may be new for the student, but is usually drawing from existing community knowledge, not adding to the community knowledge. We chose to add the process of “project learning” to Tool 1. “Research” and “Project Learning” are synonymous with “Primary Research” and “Secondary Research.”

## **Case Study: Feedback from Capstone Students**

This second iteration of Tool 1 was presented in a senior capstone course. Students were given an activity where typical situations that arise in senior projects were provided and then asked to use the tool to identify whether these called for problem solving, design, project learning, or research. The questions and responses are given below:

You’ve just returned from your second client interview where you presented your top three alternatives. The client says that you are solving the wrong problem, and shows you a picture of the piece they were hoping you would construct.

Response: Unanimously Problem Solving

In a magazine you saw some slick ideas for user interface that you would like to use on your capstone project. The article was not able to tell you much about how it works because it was “proprietary information.” How do you implement this on your project?

Response: Unanimously Project Learning

Your team has decided on the make/model for the primary components in the design. Three vendors have been identified. One is least expensive, one offers better packaging/interface between the components, and one is local and offers better support. How will you choose?

Response: Unanimously Problem Solving

Your team has selected a component, but your mentor believes it is inappropriately sized for the application. How do you resolve this?

Response: Unanimously Problem Solving

One of your team members is consistently “too busy” to take on team tasks. Other team members are expressing frustration between each other. What do you do?

Response: Unanimously Problem Solving

Your design review is 2-days away, and the team is still finalizing solution ideas. However, Lemon Demon will be performing live tomorrow night and \*everyone\* is going to be there. How do you have your cake and eat it too?

Response: Unanimously Problem Solving

Table 2: Revision of Tool 1

<b>Characteristic</b>	<b>Problem Solving</b>	<b>Design</b>	<b>Project Learning</b>	<b>Research</b>
<b>Purpose</b>	Remove/reduce difference between current and desired situation	Develop a device or system to meet a specific need	Uncover existing knowledge and tools to use on current task	Develop new knowledge for use in a community
<b>Goal State</b>	Agreement or validation that situation is resolved	Hardware or process that satisfies customer or user	Understanding of topic enough to apply on project	Acceptance of new knowledge by peers
<b>Starting Point</b>	Undesirable or uncomfortable situation requiring change	Needs analysis, definition of specifications	Awareness that current knowledge of topic is insufficient	Inconsistencies/ incompleteness of current community knowledge
<b>End Product</b>	Remedial action plan that can often be generalized	Tested artifact, tool, or process with supporting documentation	Added value by implementing what is learned	Theory, model, or answer to research question submitted for peer review
<b>Time Scale</b>	Days – weeks	Weeks - months	Days – weeks	Months – years
<b>Knowledge Base</b>	Situational expertise	Product expertise	Experience in discipline(s)	Discipline(s) expertise
<b>Resources</b>	Journals, newspapers, personal networking	Vendor information, patents, CAD/CAM, design of experiments	Product literature, textbooks, web pages, tutorials, consultation	Archival literature, computer modeling, data analysis, theory
<b>Common Implementation Steps</b>	Identify a problem Engage/Motivate Define problem Explore ideas Plan solution Execute plan Validate	Recognize Need Needs analysis Target specs Concept design Detailed design Implementation Test/refinement	Identify missing knowledge General search Definitions/terms Specific search Critical thinking Transfer exercises Generalize	Aware of gap in knowledge Literature search Research Questions Develop Method Perform study Peer Review

Teams were asked to provide feedback on the revised Tool 1 which was recorded and compiled as follows:

**Strengths:**

- Tool helps create a shared language for discussing project tasks.
- Will be useful as a quick reference for team discussion.
- The tool promotes awareness of the different timescales for different processes.
- Helps keep track of what you need to start a process and how to proceed.

**Suggested improvements:**

- Use key words bolded in the text of the table for quicker identification.
- Supply accompanying text on how to use the tool for intermediate situations.
- May consider making electronic version of the tool that links with a second tier of information about a given area for each process.

**Relevance to capstone teams:**

- Can help avoid using the term “research” as synonym for “project learning.”
- Should help team members agree on the right process for the task at hand.
- Provides a resource to inventory what is necessary to start a process.
- Helps generate consensus in team about when a process has been completed to an acceptable level.

**Conclusions**

The following conclusions can be drawn about the two tools from the case studies.

- After students in the case studies reviewed and used the tools, they were able to articulate distinctions between problem solving and design, found the distinctions compelling, and could competently classify scenarios as better served by one process or the other.
- An inherent premise of the findings is that it is important for students to have already worked through guided experiences using each process before they work with the tools. We have not tested either of the tools with students who haven't had a formal introduction to both processes.
- Based upon the performance of the freshman students, Tool 2 (figure) is confusing for novice students. It is better used by faculty and upper-class students who are facilitating the learning of these processes. Awareness of the learning skills which are best-suited to a process will assist facilitators identify deficient skills when making real time interventions and redirects when students are struggling.
- Adding ‘project learning’ to Tool 1 is a more appropriate label for the type of research found in undergraduate projects.

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