



2.5.3 Distinguishing between Problem Solving, Design, and Research

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Faculty, students, and professional practitioners are continually engaged in problem solving, design, and research. Steps in all three processes appear to be similar, generating confusion about which process is truly most effective and efficient for a particular need. This module analyzes similarities and differences between the three processes in eight different areas. The module identifies critical learning skills used by each process as well as learning skills that intersect multiple processes. Productivity in each process can be improved by recognizing and working on these skills. The module also examines common transition points between the three processes.

Need for Separation

Senior faculty members have considerable experience working in problem solving, design, and research (**1.2.4 Profile of a Quality Faculty Member**). As such, many tend to favor the use of a single, universal model for these three processes (Woods, 2000). While valuable insights can be derived from conceptualizing these under a universal model, there are many drawbacks to doing so for those learning these processes (**2.3.7 Learning Processes through the Use of Methodologies**). Universal models tend to focus on the means rather than the goal. For those in a learning role, it is difficult to translate the abstract steps of a universal methodology into specific, meaningful actions. Lastly, there are some unique, value-added learning skills for each process that tend to be discounted by a universal model. Lack of attention to these skills may hinder a learner's development of expertise in a process area (**2.3.3 Classification of Learning Skills**). Understanding key differences between problem solving, design, and research allows one to select the process that best supports a desired outcome; it gives a clearer vision of one's location during the execution phase of the process; and it provides guidance for making transitions between processes.

Definition of Processes

In an academic context, problem solving is often viewed narrowly in the context of single-answer homework problems. As such, typical homework assignments are more appropriately viewed as *transfer exercises* in the process of knowledge construction (**2.2.2 Elevating Knowledge from Level 1 to Level 3**). By contrast, true *problem solving* is much more open ended and is usually based around a situation, not a calculation (Woods, 2000). Problem solving seeks to resolve a discrepancy between one's expectations and the reality of one's situation. It usually has significant social and affective dimensions in addition to cognitive elements.

Design is used fairly consistently across multiple disciplines (Ullrich & Eppinger, 2004). Design commonly involves a third-party customer or user, and some hardware, software, or process that satisfies a need. Many

people confuse design with *fabrication*. While manufacturing is often a large component of design, design is as much planning, analysis, and documentation as it is 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 (Shavelson & Towne, 2002). The knowledge gap does not focus on personal knowledge, but rather the knowledge of a research community. Knowledge that is new to one person, but not to others, is better characterized as *project learning*. Undergraduate students who are writing a "research paper" or who are learning about off-the-shelf technologies for use in a design are really performing project learning. Research is the discovery and dissemination of knowledge that is not currently known by the community. Some communities refer to *research* as *Level 1 Research*, or research that produces knowledge that is new to a community; while *project learning* is referred to as *Level 2 Research*, that is, research that produces knowledge that is new to the individual.

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 necessary for the successful execution of a process. *Resources* can be used to amplify this knowledge base. *Common implementation steps* describe distinct stages in the execution of a process.

Table 1 **Characteristics of Problem Solving, Design, and Research**

| Characteristic | Problem Solving | Design | Research |
|------------------------------------|---|--|--|
| Purpose | 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 |
| Goal State | Agreement or validation that the situation is resolved | Hardware or process that satisfies the customer or user | Acceptance of new knowledge by peers |
| Starting Point | Undesirable or uncomfortable situation requiring change | Needs analysis, definition of specifications | Inconsistencies/ incompleteness of current community knowledge |
| End Product | Remedial action plan that can often be generalized | Tested artifact, tool, or process including supporting documentation | Theory, model, or answer to research question submitted for peer review |
| Time Scale | Days – weeks | Weeks – months | Months – years |
| Knowledge Base | Situational expertise | Product expertise | Discipline(s) expertise |
| Resources | Journals, newspapers, personal networking | Vendor information, patents, CAD/CAM, design of experiments | Archival literature, computer modeling, data analysis, theory |
| Common Implementation Steps | 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 | Discover a gap in Knowledge Literature search Research questions Develop method Perform study Peer review |

Table 1 can be used to determine whether problem solving, design, or research is best suited to a particular situation using the following method: Begin the process by reflecting on past activities associated with similar situations. Then decide whether the situation is most like problem solving, design, or research. It is helpful at this point to look at the prompts in each of the eight areas in Table 1; they serve as reminders of the ingredients necessary for the success of the selected process. Be aware that it is common to transition between processes, but by understanding which process you started from you will be better able to return to this point after you have completed a needed excursion into one of the other processes.

Essential Skill Sets

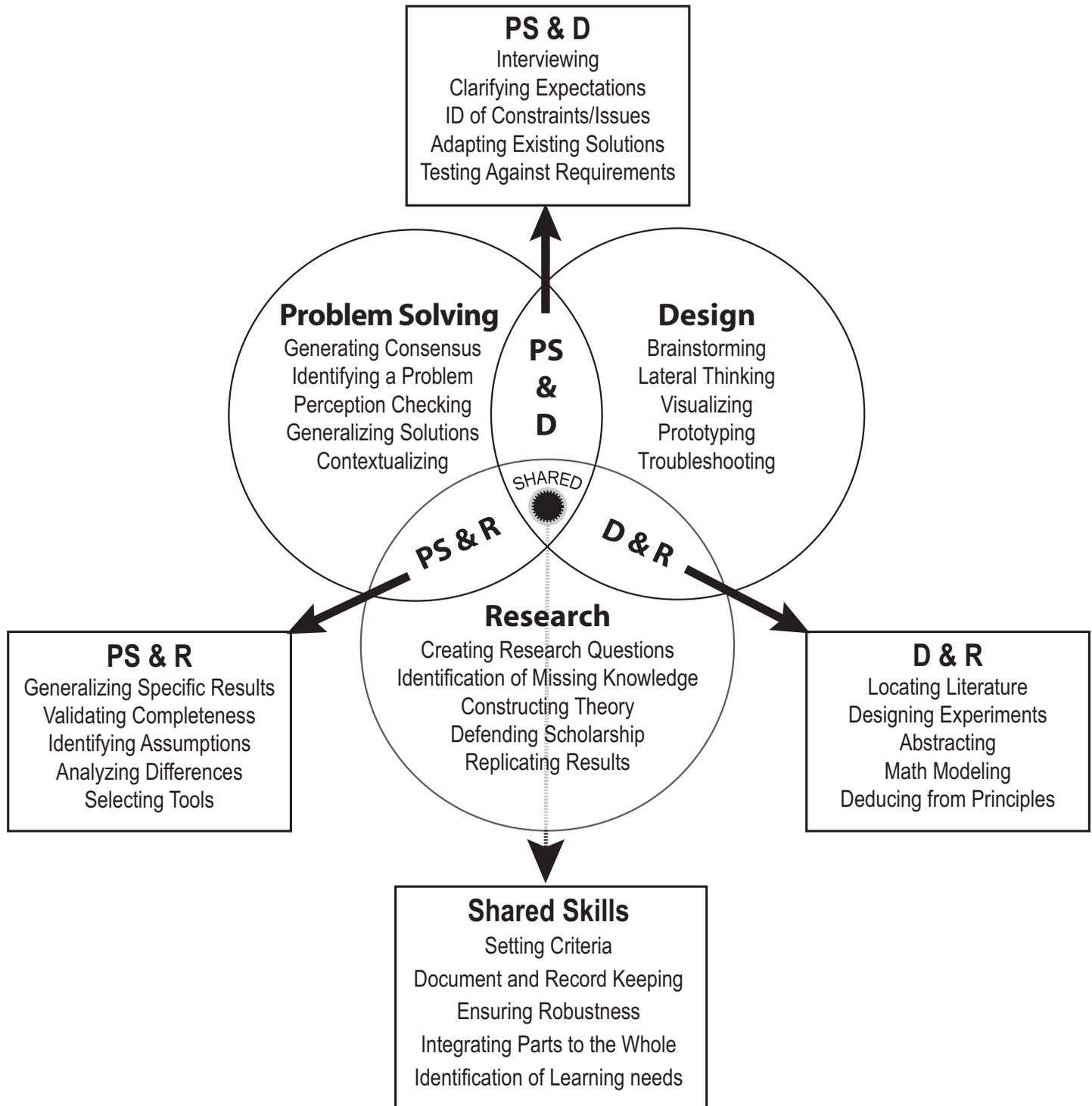
Multitudes of learning skills are outlined in other modules (2.3.4 *Cognitive Domain*, 2.3.5 *Social Domain*, 2.3.6 *Affective Domain*, and 2.2.1 *Bloom's Taxonomy—Expanding Its Meaning*). In creating Table 1 it appeared that a large source of the variation in problem solving, design, and research performance could be traced to a subset of these. Some of these skills are unique to particular processes and others are common to two or more processes. Figure 1 inventories these core skills and shows their relationship.

Figure 1 is restricted to the five most critical skills in each portion of the Venn diagram. Skills in each list are presented in the order in which 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 (3.2.7 *Constructive Intervention* and 3.2.8 *Constructive Intervention Techniques*).

Because problem solving is often situational and interpersonal, solutions 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 the germination of ideas with creation and verification in the purposeful iteration between prototypes.

Figure 1

Learning Skills Associated with Problem Solving, Design, and Research

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

Both problem solving and design usually involve a stage of interpersonal information gathering. Similarly, both design and research require the ability to find information and use it to create something or answer a question. Since problem solving happens on a short time scale, formal experiments and modeling are usually not appropriate. The 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 above, however many of the skills that intersect problem solving and research are at lower levels in Bloom's taxonomy.

Linkages Between Processes

There will be times when one needs to transition mid-way through a process to complete a supporting process before proceeding with the original process. These transitions tend to cause major confusion when one is using a universal model. Table 2 summarizes steps associated with problem solving, design, and research and illustrates common jump-off points to the other two processes. Most of these have a two-way arrow, indicating that if you jump-off from the original process you will return back to it once you have completed the secondary process. However, in the case of design, there can be several one-way jump-off points.

Problem solving usually involves a shorter timescale than the other processes. For this reason, it is rare that a problem-solving process would spawn a research process. It is not unlikely for difficult problems to transition to design once a need has been clearly established.

It is common in the design process to identify areas that are currently unexplored while looking for potential options. Because the research process is often much longer than a design cycle, there is often not sufficient time to create and use these ideas in the current iteration. The original process continues, and if resources are available, the research questions can be explored in parallel. In implementing a design, many transitions to problem solving can be anticipated.

The research process can be long and complicated. Even if there are only one or two primary researchers, often there will be large groups of support people working on the project. Problem solving becomes a critical skill unto itself when performing research as there are countless problems to be solved when constructing and validating knowledge. It is common to transition to design when looking at methods for answering research questions. In almost every case, the research process will continue once the other processes have been completed.

Being aware of the differences in these processes is the first step in alleviating confusion. It also helps to understand that transitions are likely to happen, and to know where in a methodology to look for them. It is good to step back from time to time to identify what process is underway, and to note where that fits in the primary process. Looking at current in-use skills, and the tool in Table 1 will be helpful in identification of processes.

Table 2

Common Transitions Between Processes

| |
|---|
| <p>Problem Solving—PS Engage/Motivate Define problem Explore ideas Plan solution ↔ D Execute plan Validate</p> |
| <p>Design—D Needs analysis → R Target specs Concept design → R Detailed design ↔ PS Implementation Test/refinement ↔ PS</p> |
| <p>Research—R Knowledge gap ↔ PS Literature search Research questions ↔ PS Develop method ↔ D Perform study ↔ PS Peer review</p> |

Concluding Thoughts

Problem solving, design, and research can be made more powerful by understanding the natural strengths of each process and matching the correct process to the desired outcome, whether it be the removal of a gap between a current and future situation, a device or method to meet a specific need, or expanding the boundaries of what is currently known. The learning skills mapped in this module provide a vehicle for promoting constructive intervention and reflective practice in each process. These skills have no upper bound and can improve personal performance in problem solving design, or research, no matter what one's current level of experience.

References

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