THE TEACHING AND LEARNING OF DESIGN

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Design is a profession of applications: products, services, procedures, processes, and structures. It is a field that measures its accomplishments by its creations. Traditionally, design training has focused on the skills and procedures necessary to create objects and services. These methods are taught in studio courses, where lectures and readings are minimized, and then, through projects and assignments, students create and instructors observe, critique, and assist.

Today, however, as designers are asked to address an extremely wide variety of issues, new kinds of knowledge and skills are required. Designers need to know more about the world: its history, politics, cultures, laws, and customs. They need to understand how life in many places has been forcibly imposed by colonizing forces, mostly from Europe and the United States, imposing their beliefs, religions, and customs. Because societal issues and relevant technologies and social structures are continually undergoing change, designers (and everyone) also need self-regulated and directed learning skills so that they can practice continual, life-long learning.

Moreover, the problems to be addressed invariably require multiple disciplines working collaboratively, so learning to navigate and ultimately understand the very different approaches and value systems of the variety of disciplines is a new kind of skill. Designers are used to working in teams with other designers. Those who are employed in companies are starting to learn how to work with engineering, marketing, sales, service, and the time and economic pressures of the company. As the range of projects expand, the list of collaborators includes many more disciplines as well as the citizens in the communities that are or will be affected and the political forces that support, oppose, or insist upon a major say in what is to be done and who control the budget and schedules.

These new skills require different forms of instruction. Some take on the more traditional methods of school systems with lectures, readings, and assignments. Some can build upon the project-centered instruction that is most appropriate for designers. Some may require new methods which, for example, blend formal and informal learning (van Merriënboer et al., 2009) or scaffold not only the acquisition of domain-relevant knowledge and skills (via first-order scaffolding) but also the acquisition of, amongst other things, self-regulative and self-directed skills (via second-order scaffolding) (Noroozi et al., 2018; van Merriënboer & Kirschner, 2018). And finally, for many of the topics and problems being faced, there are no standard procedures, no known answers, and, moreover, conflicting practices, perspectives, and goals from the various disciplines that must collaborate.

A word about why we recommend *project*-centered methods rather than the more common *product*- or problem-based method. Product- and Problem-based Learning and Project-centered Learning are forms of experiential learning. The difference is scope: Rather than just solving a problem or producing a product, project-centered instruction asks for the implemented, complete solution including the social, societal, economic, ethical, ecological aspects and so further of that solution. This is essential for designers because a design solution, no matter how clever and creative, will fail unless all the issues involved in implementation and actual usage in the broader context are addressed. If this is a commercial project, issues of cost, reliability, and for that matter, marketing, sales, and service must also be addressed. Moreover, more and more, issues about sustainability and environmental impact must also be addressed. Design is a system and emphasizing projects over products is critical to emphasize the necessity of considering designs as a (sometimes relatively small) part of the entire system. Today, designers often complain that their designs were "ruined" by other divisions of the project. No: if others had to modify the design, it meant that it failed to satisfy other critical requirements: The designers should have worked with all the other parties as a project (Kirschner, 2000).

Principles from the Learning Sciences

The learning sciences is, in itself, an interdisciplinary field that extends beyond psychology, in that it also accounts for, as well as contributes to computational, sociological, and anthropological approaches to the study of learning. Major contributing fields include cognitive science, computer science, educational psychology, anthropology, and applied linguistics. It is often regarded as a branch of cognitive science which pays particular attention to improving learning and education through the study, modification, and creation of new technologies and learning environments.

These disciplines have converged upon fundamental principles of human learning, understanding, and memory that apply to all learning situations. Each content area requires different ways to address the topics to be learned, but all are built upon the same basic laws of learning and memory. The critical ones can be quickly summarized.

Different Kinds of Knowledge

- Different kinds of knowledge: Explicit, implicit, declarative, procedural, episodic, Consciously-directed activity, subconscious (automated) activity.
- Skills at remembering: The use of tools for understanding (schemas, mental model, frameworks, mnemonics). When people understand, new knowledge can be accumulated rapidly, often without effort because there is an appropriate underlying framework that allows for subconscious assimilation.
- Skilled, subconscious learning requires considerable (directed) repetition. Full automation of skills can take years. Sheer repetition is not sufficient: there must be feedback, reflection, and modification. Coaches help, whether in athletics or drawing, arithmetic or management skills, and especially in the multiple different skills a designer needs to master.
- Learning works best through active construction on the part of the learner, guided by a teaching curriculum that carefully provides the right mix of problems and an appropriate supportive scaffolding.

Different Forms of Knowledge

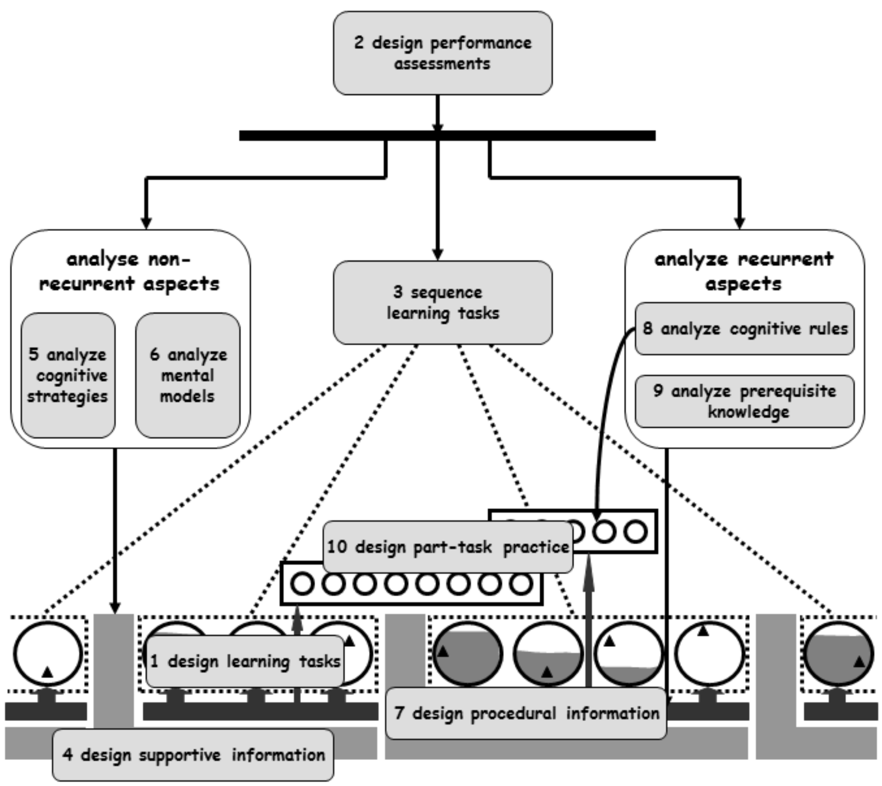
- Explicit (Declarative). Knowing that: factual statements such as 8+6=14; the name of my university is …).
- Procedural. Knowing how: such as the routine for doing long division with paper and pencil)
- Skills. Activities so well learned that they are done subconsciously, often without conscious awareness such as riding a bicycle, catching a ball
- Implicit (sometimes referred to as tacit) knowledge and Explicit knowledge. We are aware of our explicit knowledge and can easily present and explain it to others. Implicit knowledge includes skills and procedural knowledge that is so-well learned, that it is performed subconsciously, often without awareness. It is difficult to describe or explain implicit knowledge, which is why experts are often poor instructors.
- Fluid intelligence. The basic processes of reasoning and other mental activities that only minimally depend on prior learning (i.e., formal, and informal education) and acculturation. In this way they can be considered similar to biologically primary knowledge and skills. Tasks measuring fluid reasoning require the ability to solve abstract reasoning problems such as figure classifications, figural analyses, number and letter series, matrices, and paired associates.
- Crystallized intelligence. Learned procedures and knowledge based upon formal or informal learning, experience, and acculturation. In this way they can be considered similar to biologically secondary knowledge and skills. Tasks that measure crystallized intelligence are, for example, vocabulary, general information, abstract word analogies, and mechanics of language.

The Ten Steps to Complex Learning

The *Ten Steps to Complex Learning* (Kirschner & van Merriënboer, 2009; van Merriënboer & Kirschner, 2018) is a practical and modified version of the four-component instructional design (4C-ID) model originally posited by van Merriënboer (1997). It will typically be used for developing substantial learning or training programs ranging in length from several weeks to several years or that entail a substantial part of a curriculum for the development of competencies or complex skills. Its basic assumption is that blueprints for complex learning can always be described by four basic components: learning tasks, supportive information, procedural information, and part-task practice.

The *Ten Steps*/4C-ID is a holistic design approach based upon authentic whole learning task[2]. This is the opposite of atomistic design where complex contents and tasks are usually reduced to their simplest or smallest elements. Such a holistic design approach deals with complexity without losing sight of the separate elements and the interconnections between them. In this holistic approach, each learning task confronts the learner with all or almost all of the constituent skills needed to perform the task, including the knowledge and attitudes associated with them. This approach solves three common educational problems, namely, compartmentalization (i.e., separation of a whole into distinct parts or categories), fragmentation (i.e., breaking something down into small, incomplete, or isolated parts which cannot magically be integrated when needed), and the transfer paradox (i.e., where methods that work best for reaching isolated, specific objectives are not best for reaching integrated objectives and transfer of learning.

The process has ten steps organized into the four basic components as shown in the following figure and the two tables:



Learning Tasks	Supportive Information	Procedural Information	Part-Task Practice
1. Design the Learning Tasks 2. Sequence Task Classes 3. Set performance Objectives	4. Design the Supportive Information 5. Analyze Cognitive strategies 6. Analyze Mental Models	7. Design the Procedural Information 8. Analyze cognitive Rules 9. Analyze Prerequisite Knowledge	10. Design Part-Task Practice
Authentic, whole-task experiences based on real tasks that integrate the necessary skills, knowledge, and attitudes organized in easy to difficult stages, with each stage having diminished learner support. A series of learning tasks serves as the backbone of an educational program.	Helps learners to perform non-routine aspects (problem solving, reasoning, decision making) of learning tasks. It is presented to them before they start working on learning tasks and/or made available to them while they are working on these tasks.	Tells learners how to perform routine aspects of learning tasks (how-to instructions). It is best presented to them just-in-time, precisely when they need it during their work on learning tasks.	Here students learn to perform routine activities in order to develop a high level of automaticity Part-task practice requires huge amounts of repetition and should only start after the routine has been introduced within a whole, meaningful learning task.

It is important to understand exactly what each of the ten steps entails[3].

Step	Description
1. Design Learning Tasks	Design authentic whole-task problems which require performing all relevant constituent skills in a coordinated fashion. These tasks should show high variability of practice. Begin by providing high support and guidance and slowly decrease this to zero (these steps provide what learning science calls "scaffolding").
2. Design Performance Assessments	Set performance objectives for all constituent skills involved in whole-task performance and represent their interrelationships in a skill hierarchy.
3. Sequence Learning Tasks	Organize learning tasks in simple-to-complex task classes in order to develop a global outline of the training program. Each task class describes a category of more or less equally complex tasks that learners will work on during the training.
4. Design Supportive Information	Present supportive information at the beginning of each task class. It should specify the relevant cognitive strategies and mental models (i.e., conceptual, causal, and structural) that will be needed.
5. Analyze Cognitive Strategies	Analyze the cognitive strategies that guide experts' task performance or problem solving behavior and specify heuristics and useful rules-of-thumb.
6. Analyze Mental Models	Analyze the mental models that experts use to reason about their tasks. This results typically take the form of conceptual models (that present a simplified overview of the profess), structural models (that show the organizational structure) and causal models (that show the underlying mechanisms).
7. Design Procedural Information	Design procedural information for each learning task in the form of Just-In-Time information displays, specifying how to perform the recurrent aspects practiced for this task. Give complete information at first, and then fade.

8. Analyze Cognitive Rules	Analyze expert task performance to identify cognitive rules or procedures that algorithmically describe correct performance of recurrent constituent skills. Perform a procedural analysis (e.g., information processing analysis) for recurrent skills that show a temporal order of steps. Perform a rule-based analysis for recurrent skills that show no temporal order of steps.
9. Analyze Prerequisite Knowledge	Further analyze the results of the procedural or rule-based analysis from Step 8 and specify for each cognitive rule the knowledge that enables the correct performance of this rule, or for each procedural step or decision the knowledge that enables performing the step or making the decision.
10. Design Part-task Practice	Design part-task practice for recurrent constituent skills that need a very high level of automaticity after the training, and for which learning tasks cannot provide enough practice to reach this. Use divergent examples in a distributed, not massed, training schedule.

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End Notes

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[2] The term learning task is used here generically to include case studies, projects, problems, and so forth. They are authentic whole-task experiences based on real-life tasks that aim at the integration of skills, knowledge, and attitudes. The whole set of learning tasks exhibits a high variability, is organized in easy-to-difficult task classes and has diminishing learner support throughout each task class.

[3] Taken from Appendix 1 of van Merriënboer and Kirschner (2018).