Iterations on a designerly science

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This set of chapters is written by courageous scholars willing to admit they are both designers and learning scientists at the same time. Through the challenge set by editors Svihla & Reeve, we have been invited (in the words of some of the authors) 'under the hood' of the learning sciences. Here we witness second-hand that the process of generating and testing learning science theory is much more 'designerly' than is readily reported in the final, published scientific papers. The invitation seems to suggest that the machinery of design is somehow incompatible with—or at least somewhat controversial in relation to—the machinery of science. This reflection aims to explore how the book chapters contribute to the science/design 'controversy,' as seen through the lens of the design studies literature. The paradox being that science generates knowledge using means that are not designerly in nature, but to design viable tools and interventions learning scientists must engage in designing as is practiced in the design disciplines.

The obvious choice of a starting point is the design studies recent classic 'Designerly ways of knowing' (2006) by Nigel Cross, where the historical controversies between design and science are unfolded. Cross argues that the science of design is the study of design, which leaves open the interpretation of the nature of design, and concludes that "the science of design refers to that body of work which attempts to improve our understanding of design through 'scientific' (i.e., systematic, reliable) methods of investigation. And let us be clear that a 'science of design' is not the same as a 'design science,'" which is "an explicitly organized, rational and wholly systematic approach to design" (p. 123). Cross argues that the science of design is the study of ‘designerly ways of knowing.’ He moves on to point out that there is some confusion or controversy over the nature of design research, but argues through the works of Bruce Archer (1981) that good research (and thus also good design research) is purposive, inquisitive, informed, methodological and communicable, and that these characteristics are normal features of good research in any discipline.

Because we may readily study designerly processes through scientific methods, one could be led to believe that the controversy between design and science is now resolved. So then where does this design/science apprehension come from, what’s the fuss? Believing that the establishment of a design research discipline proper resolves the issue, however, would be missing the key point of this book: a practiced designerly *process* may sometimes seem incompatible with a scientific investigation. Although designers and scientists both create knowledge, there may well be devils in the details of how they do so, hence the controversy. Designerly processes are characterized, for example, by iterations, collaborative participation and the ‘wickedness’ of the problems approached. A prime example of a still controversial aspect of a designerly scientific method is exactly this iterative nature of the design process, addressed in every chapter of this book.

To illustrate why an iterative process might be conceived of as controversial from a scientific methods standpoint, try for a second, to foreground your knowledge of statistics. How does ‘iterative statistical testing’ of some hypothesis sound? On the one hand, it could mean rigorous testing as in attempts at replication, which would be all fine and good. But on the other hand, it could also mean repeating tests again and again with slight variations in order to get the result you want. The latter would of course not be the best of scientific practices (see Simmons, Nelson & Simonsohn, 2011), in that repeated procedures are likely to bring about significant differences at some point—not because there is actually a difference to be found, but simply due to statistical conventions of a 5% significance level whereby 1 in 20 tests—by chance—will get you a significant difference where there actually is no difference. Reporting only on the final iteration ('final form') may thus not always seem like the best of scientific practices if the purpose is to test a theory. Or try instead to view the concept of iteration from the perspective of the philosophy of science scholar Karl Popper (1963); in the hypothetico-deductive method one should make bold conjectures, deduce hypotheses and then rigorously attempt to refute or falsify them. An iterative process may immunize the theory from refutation through embedding the falsifying observation into the theory. Such iterative (learning) processes are seen as problematic, in that they circumvent falsification in order to save the hypothesis, and thereby potentially limit scientific progress. Similar concerns are sometimes raised against AI models whereby a large number of iterative learning cycles on some dataset may tweak the model to mirror the dataset, but may not prove to be a valid model beyond. From such scientific perspectives, designerly iterations may give cause for concern!

One of the most defining characteristics of a designerly approach is that in creative design, the design problem and potential solutions 'co-evolve' through a series of iterations (Dorst & Cross, 2001; Maher, 1994; Kolodner & Willis, 1996). Through iterative co-evolution, not only do potential design solutions receive consideration in the context of the requirements that define the problem, but such requirements can also themselves be adapted in the light of novel solution attempts. Design problems (including the design of learning interventions and research designs) are not fixed problems to be solved along the lines of traditional problem solving models (e.g., Simon, 1969). Rather, through iterative processes, problem-solution pairings (or bridges) may be formed as a result of exploring and changing the nature of the problem and the solution. In real-world empirical investigations, co-evolution has been linked to creative activities such as analogizing and mental simulation in collaborative design teams (Wiltschnig, Christensen & Ball, 2013). Interestingly, scientific discovery has also been proposed as taking place through a dual search in two problem spaces: a hypothesis space and an experiment space that interact with each other (Klahr & Dunbar, 1988). The similarity of the scientific discovery as dual search model and the theory of co-evolution in design is striking, suggesting that the iterative co-evolution of problem and solution may not be specific to design.

The making of interventions and research designs are, however, creative endeavors or wicked problems in their own right, and need to be designed. As argued by Glynn (1985), “it is the epistemology of design that has inherited the task of developing the logic of creativity, hypothesis innovation or invention that has proved so elusive to the philosophers of science” (pp. 125-126). While it may be possible to argue in general terms from theory how a learning intervention or a research design should look in a particular research project, many of the devilish details cannot be deduced directly, and are only discovered through iterative trial and error as empirically-oriented scientists will be aware. Still (as put by one of the most creative and prolific professors in the learning sciences I know) given the format of scientific journals, we get to pretend that we deduced everything and knew all along when we write up the study.

The development of the projects reported in this volume may be viewed as creative attempts at reaching a problem-solution pairing through co-evolution iterations. For example, in the chapter by Smith, the original concept in BGuILE changed radically through the iterative development of software for high school biology classrooms. Through a series of iterations, user input and serendipitous remarks by colleagues fundamentally changed a piece of software entitled ‘Animal Landlord’ from an initial lion hunting simulation utilizing an aerial view of the Serengeti, through combining the watching of an actual video clip with a later simulated model, to finally abandoning the original simulation to instead rely on multiple case videos.

Several of the chapters tackle head on how their initial abstract and research-based design principles evolved over time through iterations with attempted solutions (e.g., Steiff & Ryan; O'Neill; Goldman & Jiménez).

Between the lines, one may detect in some of the chapters a certain longing for the sufficiency of analysis: if only analyzing and deducing from theory in itself would bring about a design, that would make the designerly research efforts seem much more like how you write up 'proper' research and less like creative design. As the concept of the co-evolution of problem space and solution space informs us, there *is* a certain gap to be creatively filled: All the analysis in the world of the research problem space will not be deducible to a mere singular designed solution—the researchers need to take a designerly leap-of-faith in bridging the two. The vocabulary on that leap differs between chapters, but the creative non-deductive leap-of-faith seems clear: opportunism, educated guesses or design serendipity (Smith), trial and error (Stieff & Ryan), brainstorming (Goldman & Jiménez; Danish, Enyedy, Saleh, & Lee) and tweaking (Pierroux & Steier) are some of the terms used. In the words of Goldman & Jiménez we need to somehow *translate* the research findings or design principles into design solutions through a series of steps. In that translation process it may be worth considering whether the design principles can serve as what Darke (1979) dubbed 'primary generators' where an understanding of the problem is gained by testing conjectured solutions. 'Principles' should thus not be mistaken for immutable problem boundaries as in the 'classic' problem solving sense, but rather seen as generative for solution conjectures in an iterative process.

The need for problem framing is discussed in some of the chapters with a theoretical orientation towards cultural historical activity theory (CHAT). If theories could be placed on a continuum of how many variables they attempt to incorporate, CHAT would probably be placed at the more ‘complex’ end. The chapter by Teeters, Jurow & Shea, for example, approached a particular high-level design challenge of developing methods for doing equity-oriented research (i.e., research & design efforts that facilitate members of marginalized communities in gaining greater access to and control over resources to shape their own lives). A certain amount of theoretical re-conceptualization, or self-imposed theoretical simplification may help avoid getting lost in the quagmire of possibilities set by such problems, as when Danish et al. report how an ever-expanding sequence of CHAT triangles were re-conceptualized more simply into how the activity of play transformed into the activity of scientific modeling. In other chapters, we also find direct examples of how solution conjectures lead to reformulation of the problem space. O’Neill describes the development of the Collaborative Notebook, highlighting how certain key assumptions and central design decisions led to the implementation of a user interface that disallowed normal user behavior and alienated their original target audience. The design failure is mainly attributed to the lack of a proper needs assessment of the target audience. Nonetheless, while not useful for their original target audience (K12 teachers), the novel design did manage to find other more suitable audiences in other contexts (problem-based learning at medical schools, and literary support among African-American students). O’Neill describes these later attempts at finding new audiences for their software as a trap of ‘desperation for success’ that should instead have been met with the acceptance of failure, and attempts to report this design failure. However, when seen from the perspective of co-evolution of problem and solution, the teams’ actions to re-contextualize the software appears to be a perfectly valid attempt at finding a learning problem fitting their novel solution. Indeed, the software did appear to match other contexts much better than the original target audience, and it is only by maintaining that the software was designed to solve a single fixed problem that it could be seen as a failure. This is not to say that scholars should not *also* report design failures as encouraged by O'Neill (after all, the *desk-drawer problem* of never-reported null-results needs to be taken seriously in science), but rather to say that there may be a multitude of creativity in opening up the *problem* space, and re-thinking what exactly the software may have to offer in other problem contexts. That path should not be seen as a guilt-ridden path of desperation! The creative potential in finding new functions to pre-existing forms (aka the form-before-function approach to design) is well documented in both laboratory studies (Finke, Ward & Smith, 1991), as well as in real-world design situations (Ball & Christensen, 2009). My most frequently used warm-up exercise for brainstorming sessions illustrates the potential: 'The manager of a Ping-Pong ball factory has accidentally over-inflated his latest shipment, rendering the balls unusable for regular table tennis. What might be all the ways you can use 10.000 over-inflated Ping-Pong balls?' Most groups will have no problem producing 15 novel ideas in a mere 3-minute session. What creative waste if we were to only think of the over-inflation as a manufacturing failure. Fortunately, creative desperation proved the mother of invention also for O'Neill as the design found new audiences. Similar stories can be found throughout this volume: Pierroux & Steier reports on the development of VisiTracker—a tablet based research tool and online portal for museum curators that proved highly useful in a multitude of other contexts as well, which challenged the research team in the borderlands between research and entrepreneurship. Further, problem re-definition is not limited to contextual shifting, as evidenced in Ko, Goldman, Radinsky, James, Hall, Popp, Bolz & George. The development of READI proved to be a process where a key artifact—evidence and interpretation charts—co-evolved with the team's conceptual understanding, diverging from an initial universal model through numerous iterations to a domain specific one, where the literature team, the history team and the science team utilized the charts in different ways.

Hopefully, these case stories will help the rest of us realize that when doing designerly research, creative leaps and co-evolutionary iterations are necessary both on the path from theory to design, and as crucial parts of the learning sciences.

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