Productive Failure: A Hidden Efficacy of Seemingly Unproductive Production

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Abstract

Contrary to the fairly established notion in the learning and cognitive sciences that un-scaffolded processes rarely lead to meaningful learning, this study reports a hidden efficacy of such processes and a method for extracting it. Compared to scaffolded, well-structured problem-solving groups, un-scaffolded, ill-structured problem-solving groups struggled with defining and solving the problems. Their discussions were chaotic and divergent, resulting in poor group performance. However, despite failing in their problem-solving efforts, these participants outperformed their counterparts in the well-structured condition on transfer measures, suggesting a latent productivity in the failure. The study's contrasting-case design provided participants in the un-scaffolded condition with an opportunity to contrast the ill-structured problems that they had solved in groups with the well-structured problems they solved individually afterwards. This contrast facilitated a spontaneous transfer, helping them perform significantly better on the individual ill-structured problem-solving tasks subsequently. Implications of productive failure for the development of adaptive expertise are discussed.

Introduction

Scaffolding learners so that they accomplish what they may not in the absence of the scaffold is both a profilic and prolific area of research in cognition and learning research (also see the 2004 special issue on scaffolding in volume 13(3) of The Journal of the Learning Sciences). In such research, "what can be accomplished" generally refers to an expert task that is often complex and ill-structured, and one that is beyond the existing skill set and abilities of the learner (Brown et al., 1989). A careful examination of this research surfaces a deeply-ingrained belief: learners need to be scaffolded while engaged in authentic, ill-structured tasks for, without such scaffolding, they may fail. This belief implies that there is little efficacy embedded in un-scaffolded, ill-structured problem-solving processes. While this belief is well-supported by empirical evidence, one must also wonder if another possibility can co-exist? Is it conceivable that by not scaffolding learners—leaving them to struggle and fail at tasks that are ill-structured and beyond their skills and abilities—may in fact be a productive exercise in failure? If this is a feasible possibility, the challenge for research would be to conceptualize ways of extracting the hidden efficacies in the un-scaffolded and seemingly unproductive production. In this paper, I invoke the adage "failure is a stepping stone to success" to make a case for *productive failure*. I support it with empirical evidence from a large-scale study of problem-solving groups in a computer-supported collaborative learning (CSCL) setting.

Generally speaking, research on scaffolding problem-solving processes focuses on what is gained from scaffolding but not on what is lost. In CSCL research, these scaffolds come in a variety of forms but typically operate within a problem-solving activity system (Leont'ev, 1978), e.g., scaffolding the object of the activity (e.g., Kapur & Kinzer, 2005); providing interactional support through reflection prompts (e.g., Lin et al., 1999), content support (e.g., Fischer & Mandl, 2005), question prompts (e.g., Ge & Land, 2003), argumentation tools (e.g., Cho & Jonassen, 2002); the division of labor (e.g., Schellens et al., 2004) etc. The argument for scaffolding is that it helps learners accomplish what they might not otherwise be able to in the absence of the scaffold – a Vygotskian (1978) zone of proximal development (ZPD) argument.

However, it is also reasonable to argue that in providing structure and support, scaffolds impose a certain amount of order on the problem and solution spaces, and in doing so, limit their exploration. Indeed, Reiser (2004) makes a timely argument that scaffolds should not only function to structure the task but also to problematize it. However, it seems that the proposed problematizing is itself structured, scripting conditions for learners to explore areas of the problem space that they may not otherwise. Nonetheless, Reiser's proposition presents a valuable contribution in the function of scaffolds (Pea, 2004), but it ironically also implies a resistance against simply allowing learners to explore, struggle, and even fail at tasks that are beyond their ZPD.

In fact, the tension between scaffolded and un-scaffolded processes can be situated in the larger tension between ordered and chaotic processes and systems. Sometimes it helps to step back and examine a phenomenon at a higher level of abstraction and through a pair of new eyes. Kauffman's work (1995) on the laws of self-organization and complexity provides such a view: as systems (biological, social, neural, etc.) comprising multiple interacting agents (genes, people, neurons, etc.) become increasingly complex over time, there comes a critical point where the system self-organizes and order emerges spontaneously from chaos. At this balance point (which Kauffman calls the *edge of chaos*) between deterministic order and chaos, the system is not only sufficiently efficient but also flexible and adaptive.

Assuming Kauffman's perspective, scaffolds impose order, thus scaffolded processes can be conceived as systems placed toward the ordered end of a continuum and un-scaffolded processes as systems placed toward the chaotic end of the continuum. Scaffolded processes, by design, create a lock-in that restricts a fuller exploration of the problem and solution spaces. This lock-in may be effective in helping learners accomplish the task *efficiently* in the shorter term. But, because this likely comes at the expense of building sufficient

cognitive complexity (in individuals as well as groups), this learning may not be sufficiently flexible and adaptive in the longer term especially when faced with novel challenges and problems.

Un-scaffolded processes, on the other hand, may be less efficient in the shorter term for they allow learners to engage and explore the problem and solution spaces in a more exhaustive, open-ended albeit chaotic manner. When persisted with, such explorations may engender increasingly high levels of cognitive complexity over time. So, while they may not be as efficient in the shorter term, they may allow for learning that is potentially more flexible and adaptive in the longer term. The challenge, as argued earlier, is to extract this potentiality.

Schwartz & Bransford's (1998) contrasting-cases method may be leveraged to extract this potentiality of un-scaffolded processes. In their oft-cited article, "A Time for Telling," they showed that having students examine the similarities and differences among contrasting cases representing a target concept prepared them to derive greater benefit from a subsequent lecture or reading on that concept. By extending the contrasting cases method, one might conceive scaffolded processes as a contrast to un-scaffolded processes. Within an activity system, an ill-structured problem without the provision of scaffolds can serve as an un-scaffolded condition whereas a well-structured version of the same problem can serve as the scaffolded condition (see Jonassen (2000) for the difference between well- and ill-structured problems). This conception of scaffolding via structuring is central to scaffolding theory as captured in Wood et al.'s (1976) articulation of scaffolding as a "reduction in degrees of freedom" in a problem (also see Reiser, 2004; Pea, 2004).

Thus, it would be reasonable to argue that contrasting ill-followed by well-structured problems might help learners separate the relevant from the irrelevant components of an ill-structured problem. In turn, this may help them become better solvers of both well- and ill-structured problems; the latter being the ultimate goal. This way, the contrasting mechanism can be seen as a scaffolding mechanism. However, this scaffolding mechanism operates at a higher level *across* activity systems, as opposed to operating *within* them, thereby setting up conditions for testing the hypothesis of productive failure. If this conception of the contrasting-case mechanism holds up to an empirical examination, then it is hard not to argue, albeit tongue-in-cheek, that just as there is "a time for telling," there is also "a time for failure"—productive failure.

Purpose

The purpose of this study was to test the hypothesis of productive failure: whether or not there is a hidden efficacy in un-scaffolded, ill-structured problem-solving processes and if it can be extracted using a contrasting-case mechanism.

Method

Participants. Participants were $N = 309$, 11th-grade science students (197 male, 112 female) from 7 co-educational, English-speaking high schools in the National Capital Region of India.

Research Design. A randomized experimental design was used. Within each school, participants were first randomly grouped into triads, resulting in $n = 103$ groups. These groups were then randomly assigned to an un-scaffolded (50 groups) or a scaffolded problem condition (53 groups). Groups in the un-scaffolded problem condition were asked to solve two ill-structured problems without the provision of any scaffolds. Groups in the scaffolded problem condition were given the same problems but in a more structured format (Wood et al., 1976). All problems dealt with car-accident scenarios requiring students to apply concepts in Newtonian kinematics and were content validated by physics teachers.

Before group work, all participants individually took a 25-item multiple-choice pre-test on concepts in Newtonian kinematics (*Cronbach's alpha* = .74). The study was carried out in the schools' computer laboratories, where group members communicated with each other only through synchronous, text-only chat. The chat application automatically archived the transcript of their discussion and group solutions. Groups were given 1.5 hours per group problem; each group solved two ill- or well-structured problems (their order counter-balanced) as appropriate to their assigned condition. No other help or support was provided. After group work, all participants individually solved well-structured problems (post-test 1), creating a contrast for participants from the un-scaffolded, ill-structured problem-solving groups. This is because participants in these groups solved ill-structured problems first, and then contrasted that with solving well-structured problems individually. Finally, the scaffolding was removed and all participants individually solved ill-structured problems (post-test 2). Both post-tests dealt with two car accident scenarios each, and were content validated as well. The scaffolded (well-structured) problems in post-test 1 were similar to the group problems. The un-scaffolded (ill-structured) problems in post-test 2 required participants to apply more advanced concepts in Newtonian mechanics.

Note that this design also provided a comparison against a typical scaffolding sequence, i.e., *fading* away from a scaffolded condition (Pea, 2004). Participants from the well-structured groups (hereinafter referred to as WS groups) experienced such fading as they remained in a scaffolded condition right through post-test 1, and only then was the scaffold removed in post-test 2. However, participants from ill-structured groups (hereinafter referred to as IS groups) went from an un-scaffolded to a scaffolded condition, and then back to an un-scaffolded condition.

*Data Coding. Quantitative Content Analysis (QCA) (*Chi, 1997) *was used to s*egment and code interactions. The unit of analysis was semantically defined as the function(s) that an intentional utterance served in the problem-solving process. Thus, every utterance was segmented into one or more interaction unit(s), and coded into categories adapted from the Functional Category System (FCS)—an interaction coding scheme developed by Poole and Holmes (1995). Accordingly, each interaction unit was coded into one of seven categories:

1. PA: Problem Analysis (e.g., "*I think the man was driving too fast*"),

2. PC: Problem Critique (e.g., "*how can you be sure that the man was driving fast*"),
3. OO: Orientation (e.g., "*lets take turns giving our opinions*"),
4. CD: Criteria Development (e.g., "*we need to find the initial speed of the car*"),
5. SD: Solution Development (e.g., "*use the 2nd equation of motion*"),
6. SE: Solution Evaluation (e.g., "*yes, but how do we get acceleration*"), or
7. NT: Non-Task (e.g., "*lets take a break!*").

Two trained doctoral students independently coded the interactions with an inter-rater reliability (*Krippendorff's alpha*) of .84. The researcher and a physics teacher independently rated the quality of all group solutions as well as the individual post-test performances of all participants. Raters were blind to the treatment conditions. *Krippendorff's alphas* of .86, .92, and .88 were achieved for rating group solutions, well-structured problems post-test 1, and ill-structured problems post-test 2 respectively.

Data Analysis. Due to space constraints, data analysis procedures are described together with the results in the following section. It is important to note that in all the results reported in this paper—at the group and the individual levels—the effects of confounding factors (e.g., school, gender, counter-balanced problem order, etc.) and covariates (e.g., individual pre-test score, group prior knowledge as measured by mean pre-test score, etc.) were controlled for.

Group-Level Analysis

Functional Content. A MANOVA (with proportion of interactional activity in the 7 functional categories as the dependent variables) revealed that IS groups had significantly greater proportion of problem analysis ($F = 18.20$, $p < .001$, partial $\eta^2 = .16$, power = .99), problem critique ($F = 11.91$, $p = .001$, partial $\eta^2 = .11$, power = .93), and criteria development activity ($F = 4.09$, $p = .046$, partial $\eta^2 = .04$, power = .52). In contrast, WS groups had significantly greater proportion of solution development ($F = 7.23$, $p = .008$, partial $\eta^2 = .07$, power = .76) and solution evaluation activity ($F = 10.66$, $p = .002$, partial $\eta^2 = .10$, power = .90). As a rule of thumb, partial $\eta^2 = .01$ is considered a small, .06 medium, and .14 a large effect size (Cohen, 1977).

Sequential Patterns in Group Discussion. Lag-sequential analysis (LSA) revealed how certain types of interactions followed others more often than what one would expect by chance (Wampold, 1992). The software program Multiple Episode Protocol Analysis (MEPA) developed by Gijsbert Erkens was used for carrying out the LSA (see http://edugate.fss.uu.nl/mepa/index.htm).

LSA revealed significant differences between the discussions of WS vs. IS groups. With regard to how groups sustained different types of interactional activity, IS groups were at least twice as likely to sustain PC, SE, and NT type of interactions. In contrast, WS groups were at least twice as likely to sustain PA, CD, and SD type of interactions. With regard to transitions, SD-SE transition was the only significant transition that WS groups were at least twice as likely to exhibit. In contrast, the discussions of IS groups were at least twice as likely to exhibit many significant transitions (PA-PC, PA-CD, CD-SD) as well as feedback loops (SE-PA, SE-PC).

Convergence & Group Performance. Convergence is a measure of how group members interact and develop a shared understanding of the problem, select a strategy, develop a solution, and manage the process (Fischer & Mandl, 2005). As such, convergence in group discussion was modeled as an emergent property of the interactions between group members, using methods developed by Kapur et al. (2005). An ANOVA showed that WS groups exhibited, on average, greater convergence in their group discussions than IS groups ($F = 10.01$, $p = .002$, partial $\eta^2 = .09$, power = .88). Linear regression showed that convergence, in turn, was a significant predictor of group performance, as evidenced by the quality of group solutions ($t = 12.253$, $p < .001$). As a result, WS groups produced, on average, solutions of a higher quality than IS groups ($F = 7.20$, $p = .009$, partial $\eta^2 = .07$, power = .76).

Discussion of Group-Level Results

Differences between groups on the various process and outcome measures can easily be explained in terms of the affordances of well- vs. ill-structured problems. Because ill-structured problems do not provide a clear problem definition, IS groups spent proportionally greater amounts of interactional activity on problem analysis, problem critique, and criteria for developing a solution. LSA further revealed that this lack of clarity in problem definition also resulted in sustained critiquing of problem analysis attempts. The larger solution space afforded by ill-structured problems resulted in sustained evaluation of attempts at solution development, which, in turn, fed back into problem analysis and critique. Thus, the discussions of IS groups were, on average, more complex and chaotic, and exhibited greater numbers and variety of transitions and feedback loops. Because of this, IS groups found it difficult to converge on the causes of the problem, set appropriate criteria for a solution, and develop a solution. This lack of convergence in group discussion drove down group performance. WS groups, on the other hand, solved problems that offered more defined problem and solution spaces. Thus, their discussions were, on average, more coherent, less complex, and less likely to exhibit complex transitions or feedback loops. As a result, these groups found it relatively easier to converge on the causes of the problem, set appropriate criteria, and develop a solution, which, in turn, resulted in higher group performance. Thus, on many counts, IS groups *failed* compared to WS groups.

Group-to-Individual Transfer: Hierarchical Linear Modeling (HLM)

Given the nested structure of the data with students nested within groups within experimental condition, HLM was carried out. Two hierarchical models were gradually built

(space constraints restrict a fuller description of the two models), corresponding to performance on the well- and ill-structured post-tests. In addition to controlling for confounding factors (e.g., gender, school, problem order etc.), several individual- and group-level predictors were entered, one-by-one. Single degree-of-freedom log-likelihood tests determined the significance of each predictor in the model. For modeling the performance on the well-structured post-test, individual-level variables included pre-test score and the level of participation in group discussion (operationalized as the proportion of all interaction units contributed by a group member). Group-level predictors included problem type, group prior knowledge, and group solution quality.

Results suggested that participants from IS groups performed significantly better on the well-structured post-test than their counterparts from the WS groups ($\chi^2 = 22.82$, $p < .001$). The hierarchical model for performance on the ill-structured problems post-test was the same except that the performance on the preceding well-structured post-test was included as an individual-level predictor. Again, findings suggested that participants from IS groups outperformed their counterparts from the WS groups on the ill-structured post-test ($\chi^2 = 27.21$, $p < .001$). Importantly, individual performance on well-structured post-test was a significant predictor of performance on ill-structured post-test ($\chi^2 = 30.76$, $p < .001$).

Discussion of HLM Results

As hypothesized, the contrast between (un-scaffolded) ill-structured followed by (scaffolded) well-structured problems helped participants separate the relevant from the irrelevant components of ill-structured problems, thereby facilitating a spontaneous transfer of problem-solving skills, which, in the absence of the contrast, might have remained unrealized. Therefore, despite the greater struggle, complexity, and divergence in the discussions of IS groups resulting in failure initially, participants from IS groups outperformed those in WS groups on both the well-structured problems and ill-structured problems post-test. This demonstrated that the productive failure hypothesis holds up. It is of course reasonable to argue that this may very well have been a chance finding. However, given the scale of the study and the fact that the research design, procedures, and findings were replicated 7 times (in the 7 participating schools) gives this study sufficient weight.

Ontologies of Learning & Problem Solving

Here is the counter-intuitive result in this study: how did students from the seemingly unproductive IS groups outperform those from the productive WS groups on the well-structured problem-solving post-test? If nothing else, one would expect students from the WS groups to be at least as good if not better on solving well-structured problems. After all, they had just solved two such problems in groups before attempting similar ones individually. To answer this, one would have to reexamine the ontology of how we learn to solve problems.

It is reasonable to argue that the ontology of learning and problem solving in structured environments is one that is linear and incremental: one engages in scaffolded, structured tasks first, the scaffolds are then gradually faded as the tasks are incrementally increased in their degrees of freedom. Thus, the development of problem-solving expertise becomes a *gradual incremental* process. Indeed, this process forms the basis of research on scaffolding.

This study shows opens the door to an alternative ontology of learning and problem solving. It could be that the development of problem-solving expertise is an ontologically emergent process; problem solving expertise could come about as a *sudden phase shift* as opposed to a *gradual incremental* change. From a complexity theory perspective, such an event is called a self-organizing phase transition or critical point, i.e., over time as sufficient complexity builds up in a system, there comes a critical point where order emerges spontaneously and for free (Kauffman, 1995). As argued earlier, perhaps what was happening in the seemingly unproductive production phase of IS groups was this build up cognitive complexity (at the individual and group levels) through a more exhaustive albeit chaotic exploration of the problem and solution spaces. If this is plausible, important implications for the development of adaptive problem-solving expertise follow.

Productive Failure: Implications for the Development of Adaptive Expertise

This study's data provide evidence that one need not necessarily scaffold processes *within* ill-structured, problem-solving activities because such processes, even if they lead to failure, have a hidden efficacy embedded in them. Not scaffolding learners and leaving them to struggle and fail at tasks that are ill-structured and beyond their skills and abilities can be a productive exercise in failure. The implication is *not* that ill-structured problem-solving groups should not be scaffolded, but that scaffolding is not necessarily the only option. Of course, believing in the efficacy of scaffolding what might otherwise be a complex, divergent, and unproductive process is indeed well-placed. However, allowing for the concomitant possibility that even un-scaffolded, complex, divergent, and seemingly unproductive processes have a hidden efficacy about them requires a paradigm shift. In other words, both possibilities may co-exist.

Both possibilities may co-exist, but are they equally good? One must wonder. Could it be that one is better than the other, especially in the longer run? Given an ill-structured problem, would it be better to scaffold the problem-solving process or let it evolve naturally without any scaffolds, and extract the hidden efficacy later? Asked more generally, on the continuum between ordered and chaotic problem-solving processes, where are the optimal compromises made?

Again, Kauffman's (1995) work on the laws of self-organization and complexity may be leveraged to provide insight. Kauffman presents strong theoretical and empirical arguments to support the following claim: In any sufficiently complex system (e.g., chemical, social, cognitive, economic, etc.), optimal compromises on the continuum between

deterministic order and chaos are made on the *edge of chaos*. The reason for this, Kauffman argues, is that sufficient levels of complexity provide systems with the flexibility to adapt and evolve toward increasing fitness levels. In the shorter-term, such systems (such as un-scaffolded problem solving) may be inefficient, but in the longer-term, they are more flexible, adaptive, and innovative. On the other hand, systems that lean on the ordered side of the continuum (such as scaffolded problem solving) tend to be highly efficient in the shorter term, but lose out in the longer run as they lack the flexibility to adapt and innovate.

Thus, when Kauffman's laws of self-organization and complexity are applied to the question of whether or not scaffolding ill-structured, problem-solving processes is better in the longer run, the answer leans in favor of not scaffolding them and extracting the efficacy later on. This study shows that one way in which this may be done is by contrasting ill- with well-structured problems; the contrast not only extracts the hidden efficacy but also helps move the activity system as well as the corresponding cognitive system near the edge of chaos, without which the system might have remained nothing more than a chaotic, unproductive problem-solving effort.

Therefore, if optimality of learning experiences and processes is defined in terms of shorter-term gains, then scaffolded processes that are more efficient may be employed. If, however, optimality takes a longer-term view, then un-scaffolded processes that are more flexible, adaptive, and innovative may be more suitable, provided there are means to extract the hidden efficacies in these processes. If the above argument holds up, then it follows that un-scaffolded processes in the longer term may in fact provide a more optimal compromise between *efficiency* and *innovation*.

I believe this presents a significant theoretical and paradigmatic shift in the way we conceive and study cognition and learning, especially with regard to the development of *adaptive expertise* (Hatano & Inagaki, 1986). The preceding discussion used Kauffman's work to characterize the question—whether or not to scaffold ill-structured, problem-solving processes—in terms of a tension between order and chaos. This tension, in turn, was reduced to a corresponding tension between efficiency and innovation. It is interesting to note that theorizations of "*adaptive expertise*" vs. "*routine expertise*" (Hatano & Inagaki, 1986) have also been characterized as a tension between efficiency and innovation (Schwartz et al., 2005).

Hatano and Inagaki (1986) characterized "routine experts" as ones trained more heavily along the efficiency dimension. "Adaptive experts" are those whose learning experiences incorporate a balance between the efficiency and the innovation dimensions. Schwartz et al. (2005) propose that achieving this balance between efficient and innovative experiences is critical to the development of adaptive expertise.

To advance this proposal, Schwartz et al. (2005) hypothesized an optimal adaptability corridor (OAC) (see Figure 1 adapted from Schwartz et al., 2005, p. 28 & p. 38). By plotting learning experiences in the innovation-efficiency space, they suggest that the development of adaptive expertise is cultivated by designing learning experiences that fall within the OAC. For instance, novices start out with little experience along either dimension. Subsequently, if their experiences lean toward the efficiency dimension, they are more likely to become routine experts. However, if they experience a more balanced set of opportunities for engaging in efficient as well as innovative processes, they are more likely to become adaptive experts.

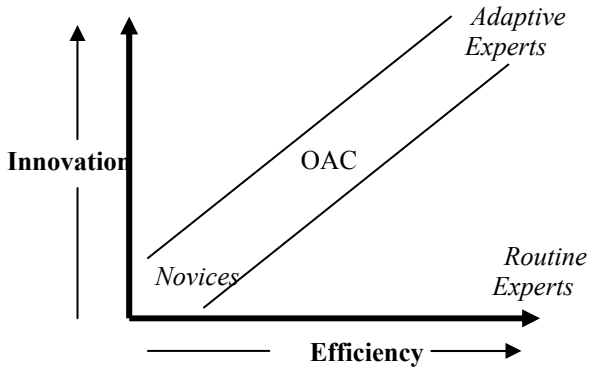

Figure 1. Balancing innovation with efficiency by designing learning experiences in the OAC

Schwartz et al. (2005) make a compelling argument that there has been an overemphasis in educational research on efficiency outcomes, often at the expense of innovation. However, their proposal does well not to eliminate the emphasis on efficiency, but to balance it with an equal emphasis on innovation, thereby ensuring a trajectory in the learning and performance space that falls within the OAC.

This study agrees with the view that both innovation and efficiency dimensions are important, but it does not agree that they are about *equally* important. As a result, it presents a departure from Schwartz et al.'s (2005) balanced view to one that favors the innovation dimension. In other words, learning experiences that provide *greater* opportunities for innovation over efficiency will be better off in the longer run than those that provide a balanced set of opportunities.

At first, this shift may seem to come at the expense of efficiency. After all, if learning experiences provided more opportunities for innovative experiences, then learners may not develop the necessary efficient processes and mechanisms. The development of these efficient mechanisms is important in reducing cognitive load when faced with a non-routine situation or problem, potentially freeing learners to be more adaptive and innovative. Indeed, as Schwartz et al. (2005) succinctly allude, "innovation favors the prepared mind."

However, while efficiency certainly bolsters the potential for innovation, innovation in turn drives efficiency. This of course is but obvious. Even in this study, for example, participants in the un-scaffolded, IS groups outperformed their counterparts in the WS groups on the well-structured problems post-test—a measure of efficiency. It is a significant finding that participants who engaged in innovative (un-scaffolded) processes beat those engaged in efficient (scaffolded) processes at their own game! Thus, the study provides empirical evidence, on a fairly large scale, showing that innovation drives efficiency, resulting in a *co-*

evolutionary trajectory through the learning and performance space. If it is true that "innovation favors the prepared mind," then it is also true that "innovation prepares the favored mind."

Perhaps an even more compelling argument for shifting the emphasis toward innovation comes from Kauffman's work (1995) on the laws of self-organization and complexity. Recall that, in the long run, optimal compromises between order and chaos happen not in the middle but closer to the *edge* of chaos. Equivalently, it may be argued that, in the longer run, optimal compromises between efficiency and innovation may happen not by designing for a balanced set of experiences, but by designing for more innovative experiences than efficient ones, although designing for a balanced set of experiences is better than designing for efficiency-dominant experiences. Schwartz et al.'s (2005) work is very timely, as it provides a much needed shift from the efficiency-dominant paradigm to a balanced paradigm. Based on the laws of self-organization and complexity and this study's data, I propose an even greater shift (and possibly an uncomfortable one) from the balanced paradigm to an innovation-dominant paradigm articulated in the following working hypothesis: *in the longer run, designing for innovation-dominant experiences is more optimal for the development of adaptive expertise than the balanced approach*.

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