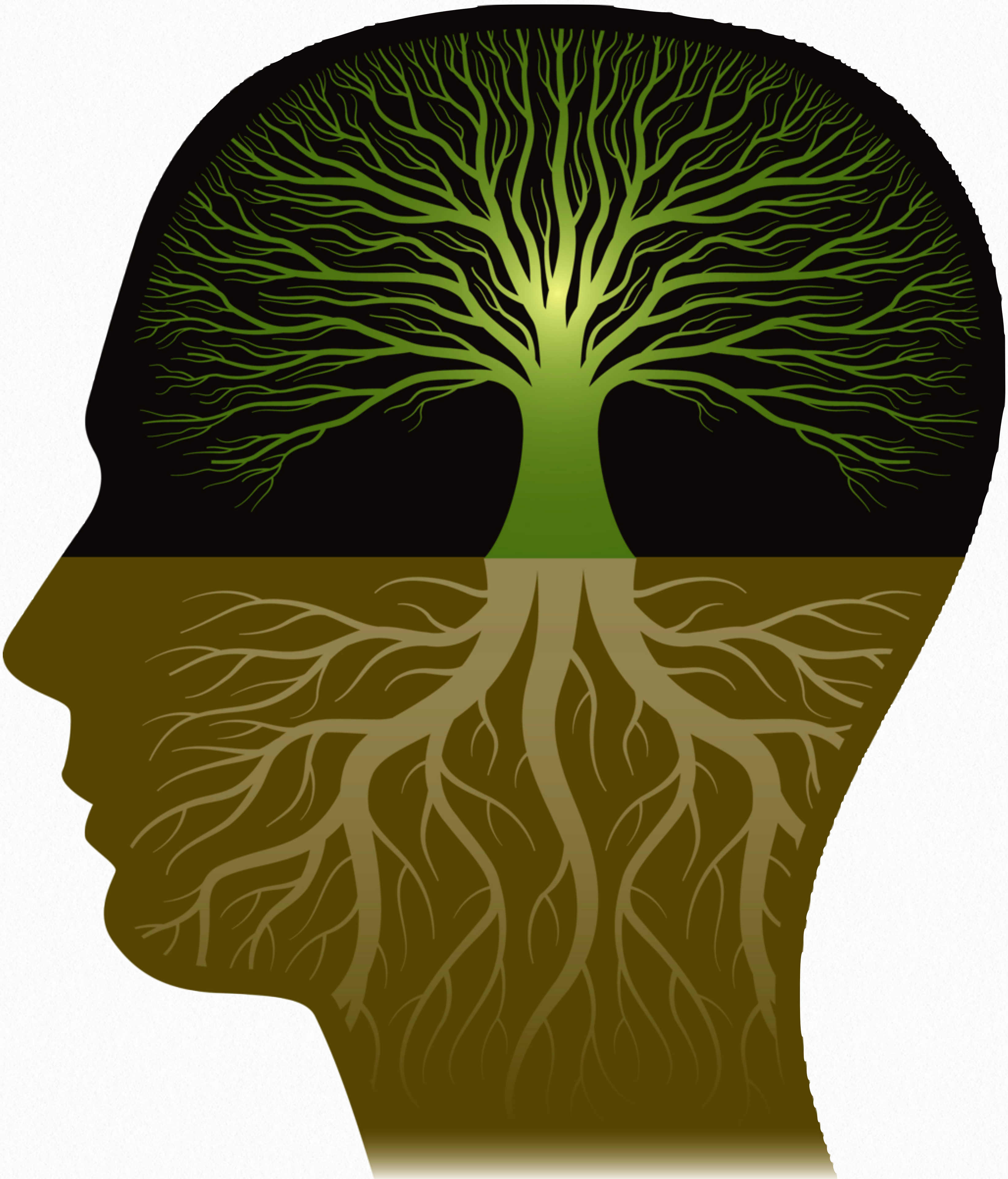
Daniel Novak, M.A.
University of Washington

Augmenting Minds



Augmented Minds Portfolio, 2011-2012

Four papers in search of a theme.

Dedicated to the following:

Dr. Mark and Mrs. Mona Novak

and the newest additions

Scarlett, Lina, & Charlie

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Mechanics of the Self

The Mechanics of the Self:

The Use of Problem Solving Simulations as a Means of Short-Circuiting Stereotype Threat

Abstract

At present, policy makers, business leaders, and educators are engaged in the important work of reorienting American educational system towards science, technology, engineering, and math (STEM) disciplines. Touted as "jobs of the future," STEM disciplines are also predominantly occupied by white, male workers in the domestic labor market. Thus, a degree of inequity has emerged in the workforce, as a homogenous group of students advances into these fields, while some minorities and female students do not. It is possible that this achievement discrepancy could be partially attributed to students' self-perceptions and their math anxiety.

One possible strategy for helping to abridge the effects of stereotype threat and math anxiety for young female learners involves the use of simulation systems that encourage the growth of confidence in problem-solving skills in a low-risk environment for situated problem solving. These types of solutions may include the use of games for focused, directed skill acquisition. Games such as Go (Chinese: Weixi) may also provide substantial opportunities for young math learners of both genders to develop balanced affective and adaptive problem-solving skills by setting up conditions for 'positive psychological' learning states such as Flow.

The title of this paper, Mechanics of the Self, alludes to the possibility of synthesis of game play mechanics with problem solving in ways that improve cognitive control mechanics, such as self-regulation and self-efficacy, in other settings. Thus, the paper posits that mastering a game's mechanics can help learners master their implicit and explicit cognition.

Keywords: Math anxiety, stereotype threat, problem solving, simulations, universal design for learning

Epigraph: Go Play

Go, an ancient Chinese game, is played on the perpendicular intersections of a 19x19 grid. Players place black and white stones on these intersections to 'encircle' territory on the board, with the primary goal of creating controllable boundaries around their opponent's pieces and territory. Pieces can be placed on any of the free intersections, and a successful encirclement strategy enables players to remove the opposing player's piece son the board.

I watch via Skype as my niece and nephew engage in a negotiation over a territory in the upper-right corner of the Go board. Shea, 5, leans over the board and assesses her situation, while Tobin, 8, considers his next sequence of moves.

Shea decides to attack Tobin in the board's upper-right quadrant, placing a piece at a critical juncture in Tobin's territory. Tobin begins to set up his next sequence of moves in another area of the board, ignoring Shea's move for the time being. As play continues, Shea mounts a credible threat to Tobin's core territory in the upper-right by building walls and protected zones ('eyes') around his pieces.

As Tobin recognizes this threat, he shores up this territory, leading to a rapid placement of pieces by both parties as they try to bracket the 'liberties' (geometrical degrees of freedom) of the other player. At the end of the sequence (12 moves total), the upper-right of the board has reached equilibrium, and Tobin retains control of the region. However, this sequence has interrupted his defensive strategy in the lower-right of the board, giving Shea an opportunity to define territory there and interrupt his plan before he can mount an assay on her territory.

-Reconstruction from field observations, November 4th, 2011

Jobs of the Future

At present, policy makers, business leaders, and educators are engaged in the important work of reorienting American educational system towards science, technology, engineering, and math (STEM) disciplines. Touted as "jobs of the future," STEM disciplines are also predominantly occupied by white, male workers in the domestic labor market. Thus, a degree of inequity has emerged in the workforce, as a homogenous group of students continues to advance into these fields, while some minorities and female students do not.

The reasons for lower rates of minority and female STEM professionals are complicated by larger societal, cultural, and environmental issues in American schools and homes. However, this paper will endeavor to create a multidimensional picture of this circumstance through the synthesis of several studies on the role of affective influences on the mathematical problem solving skills of female students. This synthesis provides the basis for recommendations on the use of a simulation-based learning experience that provides low-risk problem solving practice and affective control strategies for many kinds of learners. These simulated problem solving experiences may help all math learners achieve greater control over their emotional and identity-based perceptions of themselves as effective problem solving individuals.

The first part of this discussion will define three perspectives on affective factors that contribute to the depression of problem solving skills during the formative years of young students. It examines selected studies on the impact of stereotype threat and math anxiety, followed by a review of recent neuro-cognitive research regarding the effect of the affective domain on cognitive performance. Then, the paper will examine the performative realities related to the scope of the current achievement gap in mathematics from elementary through secondary school. This review of the cognitive, neuro-cognitive, and performative influences of the affective domain will provide us with an understanding of some of the constraints imposed by implicit cognitive phenomena.

This will provide the necessary background for the paper's second segment: a discussion of theoretical avenues for minimizing the effects of certain affective cognitive phenomena through the application of the principles of Universal Learning Environments (ULE). The guidelines provided by the Universal Design for Learning Center (UDLC) presents a vision of future learners as resourceful, knowledgeable, strategic, goal-directed, purposeful, and motivated (CAST, 2011). These qualities may match the kinds of cognitive mechanics that learners encounter during problem solving trials in the STEM fields. The application of UDL design principles to the problem of affective interference in math and problem solving skills opens a host of possibilities for instructional designers who must account for these issues in their programs.

One possible strategy for navigating these waters involves the use of simulation systems that encourage the growth of confidence in problem-solving skills in young female players by providing a low-risk environment for situated problem solving. These types of solutions may include the use of games for focused, directed skill acquisition. Games such as Go (Chinese: Weixi) may also provide substantial opportunities for young math learners of both genders to develop balanced affective and adaptive problem-solving skills by setting up conditions for 'positive psychological' learning states such as Flow (Csikszentmihalyi, 1990). Through the use of the Flow framework, problem solving simulations such as Go represent a new opportunity for dispelling stereotype threat and math anxiety.

Instructional designers may use this framework to design learning systems that coopt this ancient game to simultaneously teach task-based problem solving activities and affective control strategies. Research in the Learning Sciences indicates that these affective control strategies may transfer from game-play to other aspects of academic and social life. In part three, the paper will conclude with a discussion of the strengths and weakness of the use of games in developing problem solving skills in a low-risk environment, questions that require future empirical observation, and potential research designs for a small-scale study of adolescent play.

The title of this paper, Mechanics of the Self, alludes to the possibility of synthesis of game play mechanics with problem solving in ways that improve cognitive control mechanics, such as self-regulation and self-efficacy, in other settings. Thus, the paper posits that mastering a game's mechanics can help learners master their own implicit and explicit cognition. Now, let us examine the challenges posed by current math teaching and learning environments.

Part 1: Cognitive, Neuro-cognitive, and Performance Research on Affective Phenomena and Math

Affective Cognitive Phenomena

At the outset of this complex discussion, it is important to identify the meaning, provenance, and relationships of some of the concepts that we shall employ throughout the paper. Our first step is to provide a satisfactory definition for the concepts of gender and stereotype. Gender, as distinct from the various phenotypic representations of physical sex (Novak, Wang, Oristian, 2008), involves the social construction and integration of a number of broad generalizations about the roles of men and women (stereotypes) into a malleable but consistent sense of self-perception. Children develop early stereotype imprints about the roles and skills of men and women from their mothers (Tomasetto, Alparone, Cadinu, 2011), who have themselves internalized these cultural and social phenomena. These imprints become some of the earliest stereotypes about the roles of men and women. In the broader social realm, children learn about the normative differences between males and females from their teachers, media figures, and their market environment (Eccles & Jacobs, 1986).

The definitions of gender and stereotype are broadly agreeable. However, the literatures on the psychology of mathematics, problem solving, and stereotype threat contain a number of definitions and conceptualizations of the same cognitive and performative realities. Differences exist among these models of mathematical thinking and problem solving, but substantial similarities exist as well. This part of the paper provides an opportunity to 'call-out' the specific formulations for consistency's sake.

For the purposes of this paper, 'cognitive phenomena' is a technical term that refers to the structures of consciousness, experience, and thought that exist in a learner's mind (Smith, 2011). This concept comes from sociological and philosophical writings in applied Phenomenology, a philosophical stance that examines the subject's view of the world (Petitot, Varela, Pachoud, and Roy, 1999). The study of the components and patterns of affective cognition provides us with a learner-centered stance towards affective (non-conscious emotional) phenomena from the outset.

Two of the specific cognitive phenomena in the affective domain that we will examine are ‘stereotype threat’ and ‘math anxiety.’ These concepts may belong to a larger category of non-conscious processes known as ‘implicit cognition.’ Implicit cognition is characterized by a lack of intention, awareness, or control over cognitive phenomena (Nosek & Smyth, 2011). This contrasts with explicit cognition’s constructs of awareness, efficiency, intention, and control (Bargh, 1994). However, as the cognitive literature on stereotype threat and math anxiety indicates, these forms of implicit cognition can have significant implications for explicit cognitive phenomena such as self-regulation and self-efficacy.

Mathematics and Problem Solving

The following studies of the affective domain’s effects on math performance take a broad view of ‘math learning,’ and examine a number of definitions and contexts of mathematics as a content area. However, future parts of this paper focus more specifically on environments that promote non-linear problem solving and control of affective phenomena. In past literature, models of problem solving processes were depicted as linear sequences of events that involved reading, knowing, planning, solving, and checking (Polya, 1973). However, Wilson, Fernandez, & Hadaway (1993) provide a definition that treats mathematical problem solving as an actively constructed process that integrates domain specific knowledge, algorithms, heuristics, self-management, and reflection.

The broader literature on mathematical problem solving has found that most problem solving strategies are domain specific and do not transfer to other areas of thought (Shoenfeld, 1988). Still, researchers (Geary, 2011) have found that the students that succeed in mathematics employ a number of conscious strategies that are not strictly limited to the content domain. These domain general skills include self-monitoring and self-efficacy (Jain & Dowson, 2009), as well as the regulation of affective phenomena and emotions. Still, the question of the transferability of affective management skills from one problem solving environment to another remains a matter of open debate.

One recent study in the area of cognitive training (Schweizer, Hampshire, and Dalgleish, 2011) provides some preliminary evidence for the transfer of domain-general skills like self-regulation and self-efficacy, as well as their value in defusing stereotype threat and anxiety. In their study, Schewizer et al. (2011) suggest that individuals can learn self-regulation skills that improve executive control of affective material in one task and use those skills to process affective material in other settings.

This paper's primary concern is not the employment of specific problem solving skills, but rather the creation of an environment wherein students self-identify as 'problem solvers' who have the capability and confidence to solve problems. The domain general sense of a 'problem solver' identity could be harnessed to traverse the hazards that confront female math learners in the current school environment. As we shall see, an environment that focuses on engagement and self-efficacy may help to subvert the dangers posed by stereotype threat and math anxiety that affect female students throughout their academic lives.

Research on Stereotype Threat and Math Anxiety

Stereotype threat has gained increased focus in the education literature on the strength of the research performed by Claude Steele and associates during the 1990s. In his research on female and African American students, Steele uncovered a significant decrease in performance when students were exposed to the possibility of reinforcing stereotypes about their identity-group. In their study of the effects of stereotype threat on advanced female math students, Spencer, Steele, and Quinn (1999) specify that stereotype threat can be understood as a "situational predicament – felt in situations where one can be judged by, treated in terms of, or self-fulfill negative stereotypes about one's group" (p.6). To test for the presence of this phenomenon, Spencer et al. (1999) designed a series of experiments that showed a statistically significant deficit in female math scores compared to male scores in advanced math tests when a 'threat' was presented.

The researchers also reported a significant interaction between gender and test difficulty when the female students were primed with a stereotype threat (e.g. identifying themselves as female on the first screen of the test, and fearing that they will be judged by negative stereotypes about the math skills of females). This suggests that the socially-situated threats experienced by women (and not by men, in most situations) can directly impact math performance on standardized tests.

In a final experiment, the researchers further isolated this phenomenon from other potential threat-inducing variables (i.e. math anxiety) through the use of an anxiety questionnaire. In their factor analysis of the results, Spencer et al. (1999) divided the questions into three scales (evaluation apprehension, self-efficacy, and anxiety). The researchers then ran a contrast test to test the effect of the mediation of these factors on test performance, with the goal of understanding the interaction between the three factors, the observed stereotype threat phenomenon, and test performance. While the researchers stress that these factors do not provide a perfect understanding of the mediating variables of stereotype threat, they do provide evidence that stereotype threat itself accounts for a substantial amount of the variance in test performance, regardless of evaluation apprehension, self-efficacy, and anxiety.

The literature on stereotype threat provides insight into a host of realities about the origins and activation of stereotypes. But while stereotype threat involves an individual's fear of being judged by the negative aspects of deeply held identity-oriented stereotypes, this concept is distinct from the more specific math anxiety. The literature on math anxiety describes it in terms of the tensions and anxiety that interfere with a student's ability to manipulate numbers and solve problems in school and everyday life (Richardson & Suinn, 1972). Nosek and Smyth (2011) found that math anxiety comes from a students' non-consciously held belief about themselves and their math abilities. For young girls, stereotypes created and perpetuated in their social environment may produce long-term personal beliefs about their abilities in math and science. These may also lead female students to self-select out of STEM careers because of anxiety-induced poor performance in math.

The sources of stereotypes and anxiety are complex and diverse, with one study (Beilock, Gunderson, Ramirez, and Levine, 2010) noting that mathematically-anxious female teachers in early grades may imprint this anxiety onto their female students. In the study, the researchers compared a measure of the math anxiety of female first and second grade teachers against their students' math performance. Male and female students did not show a significant difference in attitudes or scores at the beginning of the year. However, by year's end, the female students were much more likely to believe that “boys are good at math, and girls are good at reading” (p.1). This belief accompanies a drop in female students' math performance, but no corresponding drop in the performance of male students. Thus, a young girl in a classroom with a math-anxious female teacher may grow up with an implicit belief that math courses are not arenas where women (and the student herself, as a woman) should participate confidently, and math itself becomes a threat trigger.

This would indicate an interesting crossing-point in the constructs of stereotype threat and math anxiety. In the case of Beilock et al. (2010), a female teacher who is math anxious (perhaps due to their own internalized stereotypes, or perhaps due to the poor quality of their own early instruction on the subject matter) can implicitly reinforce a negative stereotype in the mind of a young female math learner. This intersection of stereotype threat and math anxiety may lead to what Pronin, Steele, and Ross (2003) call ‘identity bifurcation.’ In identity bifurcation (a type of double-bind), learners divide their identity in ways that reject certain stereotypes but retain others in an attempt to deflect stereotype threat. In observing this phenomenon, the researchers found that female learners reject negative stereotypes that are strongly associated with women and math (e.g. flirtatiousness), but still identify with other kinds of female stereotypes that are weakly associated with math (e.g. empathy and nurturance). That is, the women rejected stereotypes associated with a threat to their identities as math-confident students, and retained those that did not present a threat.

It is possible to attribute this ‘defeminization’ of a female student’s identity during math time (as either a chronic or acute phenomenon) to the ‘masculine-orientation’ (Hofstede, 2001) of the national culture of the United States. Several studies have shown that the ‘equality of genders’ in the US requires that women adopt more ‘masculine’ traits such as competitiveness (Hofstede, 1986; Hofstede, 1996). However, Pronin et al. (2003) found that the rejection of certain female stereotypes does not indicate an increased association with male stereotypes. This shows that stereotype threat does not require the wholesale rejection of all female identities and positive stereotypes. In this way, a learner may be female and good at math, but at the cost of a piece of her identity.

Pronin et al. (2003) conclude their argument with this realization, noting that one should not necessarily endorse this adaptive strategy in the classroom, and offer the idea that “subtler adaptations are available” (p. 166). They emphasize the need for finding strategies for attenuating the consequences of stereotype threat, possibly through the presentation of strong role models that can help female students form new stereotypes. This suggestion is well founded, but it is possible that successful female students in the STEM disciplines will also need to learn a greater degree of conscious regulatory control over their affective processes. As we shall see, these kinds of metacognitive control mechanisms will be essential in confronting the neuro-cognitive elements of stereotype threat.

The Neuro-Cognitive Evidence for Threat

Scientific analyses of the brain have been used to justify all manner of atrocities in modern history, so this segment begins with a clear disclaimer: The author of this paper is biased towards the hope that all children can learn the kinds of mathematical problem solving skills that lead to success in STEM fields, regardless of gender, ethnicity, or socio-economic status. This hope is tempered by the realization that not all children have the same cognitive starting point. Some children may begin life with clinical-level learning disabilities, affective disabilities, and environmental pressures that could (if left undiagnosed) prevent them from achieving their full potential. Specialists should continue working with these children using scientifically validated practices and treatments. However, for the purposes of this paper, it is possible to draw certain lessons from the literature about brain-based differences in mathematics cognition between conventionally-developing boys and girls.

Keller and Menon (2009), for example, used a voxel-based morphometry and fMRI system to examine differences in the activation of brain regions in adult female and male subjects (N=49, mean age 23.99 years old). Female subjects demonstrated a more efficient use of neural processing resources than males when examined through fMRI scans during a math computation task. Females also showed a greater density of gray matter, and a higher degree of functional activation in males. It is possible to interpret this finding as an indication that the female learners' neural efficiency allows them to compensate for the differences in activation.

However, it is possible that these findings might also indicate that the greater activation (i.e. stronger electrochemical signal) produced in the posterior parietal cortex, right parahippocapal cortex, and the angular gyrus of males might overwhelm and dampen the signal produced by negative affective phenomena in other areas of working memory. Equally, the greater efficiency (and lower current) found in female gray matter regions might provide a lower signal-to-noise ratio in working memory circuits. At present, these are merely suppositions, and will require further specific research to verify or discount.

Fortunately, Mattarella-Micke, Matco, Kozak, Foster, and Beilock (2011) provide some further ideas on the relationship between neuro-cognitive functions and working memory in mathematics. In their study, the researchers examined the release of the stress hormone cortisol during math performance. Mattarella-Micke et al. (2011) found that the presence of cortisol mediated the working memory performance of individuals with stronger working memories, diminishing their performance. At the same time, cortisol levels did not mediate the performance of those with weaker working memories, and even improved their performance to a small degree. Thus, it is plausible to argue that corisol (and its cognitive correlate, math anxiety) has an effect on the delicate circuitry of high performers' working memory.

While this study did not directly measure gender or stereotype, it does provide evidence for the idea that high-performing individuals under conditions of anxiety and threat (such as female math students) may not be able to operate at their full potential in the current math learning environment. And as the literature on achievement gaps between male and female math students illustrates, female students are in need of new strategies to help them achieve their goals in the STEM disciplines.

Achievement Gaps

In addition to the growing literature on the effects of stereotype threat on math performance, research on the achievement gaps between male and female math students at the elementary level has revealed some unusual patterns. In their longitudinal study of student performance scores in math and reading, Robinson and Lubienski (2011) use a data set drawn from national standardized test scores to gauge the scope of the achievement gap between male and female students. As they rightly note, the question of the existence of a gender-based achievement gap in math scores must be qualified by questions that explore the magnitude of the problem, as well as when a gap first appears.

The study examined the math and reading performance of 7075 individuals in three distribution groups from Kindergarten through eighth grade. In each distribution, the authors found minor but statistically significant deficit (SD=.24 at the widest point in the middle distribution group) between the math performance of female students from late-first grade through fifth grade, with a convergence towards late-seventh grade. However, Robinson and Lubienski note that the relative proportions of males-to-females in the higher distributions decline over time, with female students composing only 40% of the top 10% of math scores. The authors find that there is significant room for improvement along a number of dimensions, but that the results are not as stark as others (such as Carol Gilligan, author of the now-controversial 1982 text In a Different Voice) would maintain.

It is certainly good news that female students close the achievement gap before the end of middle school, and it is clear that steps must be taken to ameliorate the performance gap where it exists. However, the issue grows more complex with continued scrutiny. In addition to their initial examination of student math scores, Robinson and Lubienski also ran a series of comparisons of teacher ratings of the students' math and reading scores. They found that teachers consistently rated female students' math knowledge more highly than that of male students, though male students frequently received higher scores on the math tests. Robinson and Lubienski propose a number of reasons for this pattern, including the importance of homework in higher grades, when girls report spending a greater amount of time on homework than boys (Lubienski, McGraw, & Strutchens, 2004). While Robinson and Lubienski bring to light a number of current issues in the math education of young girls, the study does not explain why so few girls proceed into the STEM fields.

In a 2003 longitudinal study of Canadian secondary students, Shapka and Keating provide further insight into inequities that exist in math classrooms through a discussion of single-sex math classrooms in co-educational schools. Shapka and Keating used a series of hierarchical multiple regressions to examine the effects of single-sex classrooms on the math engagement, performance, and persistence demonstrated by female students from ninth through tenth grade, controlling for parental education and expectations, teacher effectiveness, and schools (among other qualities). The researchers report that having at least one same-sex math or science class improved female performance, persistence, and effort in those disciplines. However, the researchers' treatment did not affect their perceived math anxiety.

Shapka and Keating speculate that a longer intervention would be necessary to counteract deeply-held stereotypes and to defuse math anxiety. However, one could interpret these results as indicating that the improvement of persistence, performance, and engagement could arise from the promotion of collaboration and bonding amongst female members in the context of a coed math community. The development of an environment that promotes collaboration amongst girls in a community of math practice is an admirable lodestar, and research in Universal Learning Environments may help us navigate closer to a solution.

Part 2: Universal Learning Environments as a Means of Abrogating Stereotype Threat Through Problem Solving Simulations: A Design Agenda for Equity

As we have seen, the affective domain has broad implications for female achievement in math and science from a number of directions. However, the matter is further complicated by the lack of clear solutions to such complex, behavior-mediating cognitive phenomena. As Shapka and Keating note, the most obvious solution to the problem of stereotype threat in classrooms is the segregation of math classes by sex, thus removing the source of threat from the girls' environment. Still, they recognize that this solution is not a tenable policy in most public schools, and that it has potential negative implications for the social development of adolescents.

Further, research indicates that a diverse learning environment leads to greater cognitive adaptation, enhanced self-efficacy and self-esteem, as well as innovation in problem solving (Crisp & Turner, 2011). This author agrees that sex-segregation is not a practical or ethical solution, and believes that it is unacceptable to divide students based on their gender, or for any other reason. The world is a wide and diverse place, and students should learn to develop their skills within the context of that diversity. This author asserts that there must be a better way forward that serves all people. To uncover clues about this better way, this segment of the paper will present literature from the Learning Sciences that may illuminate the path.

The design and development of a sustainable, equitable learning environment that proposes to diminish the impact of performance-reducing affective phenomena and close math achievement gaps must provide adequately for all learners, regardless of gender. This goal is summarized by Barab, Dodge, Thomas, Jackson, and Tuzun (2007) in their description of critical design work. As they note, the desired end state of critical design work is the development of "sociotechnical structures that facilitate individuals in critiquing and improving themselves and the societies in which they function" (p.264).

This design-based research philosophy casts a critical eye on the kinds of social and technological systems that learners interact with on a regular basis. It also opens a space for instructional designers to imagine interventions that achieve specific purposes that exist beyond the scope of the current knowledge acquisition and testing climate of education. This provides for the possibility of developing instructional ecosystems (Barab and Roth, 2006; Barab, Thomas, Dodge, Squire, Newell, 2004) with broad goals that include the integration of affective domain controls with the mutually constructed environments' content, function, setting, and actions. That is, our designs for learning environments can carry a social development agenda (Barab et al., 2007) that develops the cognitive, affective, and social habits of learners.

One means for achieving the goal of a universal, equitable math learning environment for both genders is through the inclusion of learning activities that involve multiple kinds of representation, action and expression, and engagement (CAST, 2011). Toward this end, the use of problem solving simulations could provide instructional designers with the opportunity to offer rich problem solving opportunities to students in the context of a multi-faceted mediated environment (Clark, 2008). Fogg (2003), among others, points out that these mediated simulation environments have the possibility to shape learner behaviors in ways that extend beyond the boundaries of the learning experience. Within the broader world of simulations, one variety known as 'games' could help students short-circuit stereotype threat triggers through the use of focused demands on cognitive load, the development of task engagement, and the learning of affective control.

Any argument for the use of games in math education should be met with skepticism, as much of the existing 'edutainment' is neither fun nor educational. However, it is possible to envision the use of games as a means of augmenting engagement, self-efficacy, and affective self-control in problem solving situations. As Annetta (2010) writes, a serious educational game would build from the learner's personal identity and goals towards immersion, interactivity, increasing complexity, informed teaching, and instructional purposes. This is a theoretically plausible model, as games allow for the unique employment of a cognitive attitude that Gee (2003) calls the 'projective stance,' or the inhabitation of a game-self. The concept of a projective stance allows us to understand how learners develop their identity within the context of a game.

In most commercial video games, learners inhabit worlds where they may move confidently. As Gee points out, a player's game avatar possesses the necessary abilities and skills to achieve their goals, as the challenges have all been designed to use these skills. They are, from the outset, set up with the tools for success. It is possible that the 'projective stance' cultivated by games could transfer to other environments (such as the classroom), where struggling students do not currently feel the same sense of self-efficacy and agency that they may feel as their game selves. Thus, the same self-efficacy and self-monitoring activities that defuse stereotype threat and math anxiety could be cultivated through play and transferred to other settings.

This idea of domain general self-efficacy and self-monitoring echoes Csikszentmihalyi's Conditions of Flow (1990), a psychological state that provides another way of understanding the impact of cognitive load on the suppression of affective phenomena. Csikszentmihalyi describes Flow as a state of focused motivation and engagement, wherein the user harnesses their emotional and affective processes in the service of their task. Equally, learners in a state of Flow may find ways to block out certain kinds of affective phenomena through a deep focus on their activity.

In qualitative studies of this state, Csikszentmihalyi describes the common qualities of the Flow experience in the context of a performance environment:

1. Learners can identify clear goals, expectations, and rules for the activity. This relates to self-efficacy, and the belief that a problem is solvable.

2. Concentration on a limited field of attention, and absorption into the activity. This focused attention can be difficult to obtain in ordinary classroom environments, where boredom and anxiety can disrupt the students' focus.

3. A loss of self-consciousness. This relates to the previous concepts of self-regulation.

4. The activity, environment, or facilitator provides direct and immediate feedback to the learner.

5. The activity provides a shifting balance between the learner's ability level and the activity's challenge, where the activities become more difficult as the learner's skills improves.

6. The learner has a sense of personal control over the activity and situation. This relates to agency and self-efficacy.

7. The activity is intrinsically rewarding to the learner. When the learner deeply invests their attention into a task that they consider intrinsically rewarding, Csikszentmihalyi describes the result as a state of 'Joy.' Joy is seldom discussed in the literature on mathematics, perhaps to students' detriment.

These conditions of Flow have been observed in a number of high-performance arenas (like chess, athletic activities, and artistic endeavors). Learning environments and games built around engagement models like Flow also appear to have real benefits in a classroom context. Instructional designers have found that the integration of motivating game mechanics with subject-area content, known as intrinsic integration (Habgood & Ainsworth, 2011) can develop basic math skills (such as numerical magnitudes) that transfer from the game environment to other areas (Siegler & Ramani, 2009). In a design-based experiment, Annetta, Minogue, Holmes, & Chang (2009) found that high school genetics students reported more engagement when a challenging game environment was employed to teach them content as compared against standard classroom activities (though scores on classroom assignments remained equal).

Recent neuro-cognitive studies also show that the cognitive load encountered during engagement conditions like Flow may enable students to 'tune down' their emotional impulses. Van Dillen, Heslenfeld, and Koole (2009) found evidence for a link between decreases in emotional responses and increases in cognitive load in their study of fMRI results from thirteen adult women. In the study, the researchers stimulated an individual's emotional responses (through an emotionally affective picture), then asked the participant to solve an arithmetic equation.

The researchers reported that the brain regions associated with arithmetic (the right dorsolateral frontal cortext, right superior parietal cortex, and the dorsal occipital cortex) increased in activity in response to the affective stimuli along with the emotional regions (bilateral amygdalae, right insula). However, the increased task load from the arithmetic problem (given after the affective image) appeared to reduce activity in the emotional regions. These findings could support the idea that games give learners the opportunity to control and regulate their affective states in the context of a complex problem solving situation like a serious educational game (Annetta, 2010).

While the use of games and simulations does provide new avenues for understanding how to develop self-efficacy and intrinsic motivation, there are risks associated with the use of games as a means of teaching math to young female children. Moffatt, Anderson, Anderson, and Shapiro (2009) studied the interactions of parents and children as they played a collaborative math game. Moffatt et al. (2009) report that parents modeled mathematical procedures equally for daughters and sons, but prompted their sons to complete mathematical procedures almost twice as frequently as they prompted their daughters.

These findings serve to warn us of a difficult problem. On one hand, Moffatt et al. (2009) notes that parents appeared to communicate to their preschool male and female children that they have a fairly equal potential for understanding math. On the other, they also appeared to communicate the belief that their sons were currently capable mathematicians, while their daughters were not as currently capable. This subtext communicated by parents (boys are capable, girls are not yet capable) could have damaging effects on a female child's sense of self-efficacy in problem solving. However, parents are the primary shapers of their child's self-identity, so it is unwise and unethical to recommend excluding them from play with their children. Instead, instructional designers who are responsible for integrating games into classroom experiences may find it possible to train parents to avoid behaviors that could increase anxiety and disrupt Flow experiences. For example, a 30 minute instructional session (perhaps provided online) could teach parents how to play games with their children in ways that promote engagement and perceptions of self-efficacy.

This section has examined ways of developing universal learning environments that could promote math problem solving skills in an engaging context. We have seen evidence that promoting engagement through the use of games may help students develop their skills self-efficacy and self-regulation. To further examine how this might be used to promote the development of problem solving skills, we shall use a worked example in the form of the ancient Chinese game of Go.

Part 3: Worked Example: The Use of Go as a Low-Risk Problem-Solving Environment

Go, a traditional Chinese board game, provides an opportunity to develop a worked example (in the style of Gee, 2010) of the development of a game-based learning environment that simultaneously teaches affective control and problem solving skills. In this game, the player must enclose as much territory as possible while simultaneously preventing their opponent from doing the same. The game is popular across Asia, with large competitive communities in China, Japan, and South Korea. The competitive communities in Asia are almost exclusively male, with Go retaining a strong masculine association in the national culture. At the competitive level, the game also has a formal educational apparatus that serves to integrate male learners into a community of practice and play.

This contrasts with the United States, where Go has no strongly gendered cultural connotation. A Go club located in Seattle, for example, has many female members who play at American competitive levels. Equally, anecdotal reports from their community outreach program would indicate that young female players take a strong interest in the game prior to middle school. Thus, Go presents an opportunity to understand and envision the role of a low-risk problem solving experience within the context of a larger educational ecosystem (including peers, parents, schools, and mentors). First, we will examine the underlying metaphors and mechanics of Go to see the opportunities for learning and self-regulation. Then, we shall examine some of the neuro-cognitive evidence for the game's use, followed by the description of the game's context in the larger learning environment.

The Western literature on Go tends toward issues of strategy and game mechanics, as opposed to education, philosophy, and heuristics. However, Deleuze and Guattari's A Thousand Plateaus (1987) provides an excellent description of the conceptual meanings of the game and its mechanics. This is a non-trivial matter, as game play and game pieces carry symbolic and metaphorical connotations that begin with (and extend beyond) their mechanical function.

In their discussion , Deleuze and Guattari contrast Go with another complex strategy simulation that has been the subject of serious psychological scrutiny for decades (e.g. DeGroot, 1965): chess. In chess, the authors note that each piece has distinct semiotic meanings, and that pieces are "like a subject of the statement endowed with a relative power." That is, chess pieces represent both a game mechanic (i.e. bishops are pieces that move diagonally), an affordance (i.e. bishops enable certain kinds of strategic goals and effects, as in Gee, 2010), a metaphor (knights ride into battle for a king), and a representation of the employment of a particular strategy by a player (i.e. a player uses a bishop to influence the environment in situationally responsive ways).

Unlike chess, however, the pieces used in Go are undifferentiated, other than through color (indicating the player). In this way, Go is free from the battle metaphors of chess (an explicitly male construct in the West). As Deleuze and Guattari* note, "… Go is a war without battle lines, with neither confrontation nor retreat, without bat-

*The passage is brief, complex, and fascinating, and I have presented it in full to provide an important element of thought: *Chess pieces are coded; they have an internal nature and intrinsic properties from which their movements, situations, and confrontations derive. They have qualities; a knight remains a knight, a pawn a pawn, a bishop a bishop. Each is like a subject of the statement endowed with a relative power, and these relative powers combine in a subject of enunciation, that is, the chess player or the game's form of interiority. Go pieces, in contrast are pellets, disks, simple arithmetic units, and have only an anonymous, collective, or third person function: "It" makes a move. "It" could be a man, a woman, a louse, an elephant. Go pieces are elements of a nonsubjectified machine assemblage with no intrinsic properties, only situational ones. Thus, the relations are very different in the two cases. Within their milieu of interiority, chess pieces entertain biunivocal relations with one another, and with the adversary's pieces: their functioning is structural. On the other hand, a Go piece has only a milieu of exeriority, or extrinsic relations with nebulas or constellations, according to which it fulfills functions of situation, such as bordering, encircling, shattering. All by itself, a Go piece can destroy an entire constellation synchronically; a chess piece cannot (or can do so diachronically only). Chess is indeed a war, but an institutionalized, regulated, coded war, with a front, a rear, battles. But what is proper to Go is war without battle lines, with neither confrontation nor retreat, without battles even: pure strategy, whereas chess is a semiology. Finally, the space is not at all the same: in chess, it is a question of arranging a closed space for oneself, thus of going from one point to another, of occupying the maximum number of squares with the minimum number of pieces. In Go, it is a question of arraying oneself in an open space, of holding space, of maintaining the possibility of springing up at any point: the movement is not from one point to another, but becomes perpetual, without aim or destination, without departure or arrival. The "smooth" space of Go, as against the "striated" space of chess. (p.352-353)* tles even; pure strategy, whereas chess is a semiology." Like Hesse's Glass Bead Game (1943), the purely strategic nature of the game may make it a suitable play space for both male and female math learners to practice competitive problem solving without the burdensome metaphor of 'war.'

Further, the differences in pieces and gameplay between chess and Go also reflect observed differences in the cognitive behavior of learners. The pieces and board used in chess cultivate heuristic decision trees that are domain specific to chess play (Atherton, Zhuang, Bart, Hu, & He, 2003). That is, players can infer the potential odds of success and failure for any given move based on the limitations and capacities of the pieces in play. In contrast, Go pieces do not possess a distinct semiotic meaning. They possess only situational meaning, as they are "elements of a nonsubjectified machine assemblage with no intrinsic properties" (Deleuze and Guattari, p. 353). The larger scope of the Go board and the context-specific nature of its pieces suggest that Go play provides a much richer and more flexible set of problem circumstances, as the game's decision trees are too complex to calculate (Chen, Zhang, Zhang, Li, Meng, He, & Hu, 2003).

Despite its vast complexity, Go's play system allows experts to rank players according to Dan, or player strength. On the face of it, one might imagine that a score-based ranking system might create anxiety in players. However, video games that are popular with both genders assign scores as a means of providing the player with motivating information about their play. The desire to reach a higher score also keeps players engaged through difficult early periods of play. Equally, players can use these rankings to derive a 'handicap' that adjusts the game's difficulty to the player's level. If a player has a 'four handicap,' four go pieces of their color are placed at predefined locations on the boards, allowing a weaker player to play against a stronger player. The neutrality of the game's metaphors, its complexity, scoring and adjustability difficulty make it a good candidate for a Flow-promoting activity.

In their analysis of the effects of Go play on neurological activation, Chen et al. (2003) note that Go activates many of the same reasoning centers as chess (described in Atherton et al., 2003) , and that Go may also activate Broadmann Areas 44 and 45 in ways that chess does not. These areas are linked to working memory through semantic loops. This suggests that learners use language processing centers to help them verbalize their problem-solving strategies. This is a cognitive process that may be valuable in other areas of mathematical problem solving. The complexity and challenge of Go, as well as its potential for activating problem solving regions of the brain, make it a strong candidate for Flow states that could help combat anxiety and self-consciousness.

To close out this discussion of Go as a means of creating a low-risk environment for the development of problem solving skills, we should consider the relationship of the game to its social actors. In its Asian social space, Go is taught by masters to disciples (all male) in a historically important lineage. However, since this structure does not exist in a formal way in America, it may be possible to create gender-equal communities of play around the game. Thus, children, parents, and mentors may exist in a community of situated legitimate peripheral participation (Lave & Wenger, 1991). In this community, mentors would provide children with focused Go problems that are appropriate to their level of play, parents would teach and learn through play with their children, and children would be encouraged to learn from one another.

These kinds of learning communities create strong social bonds amongst the participants in ways that may promote friendly, engaged competition that may mimic the kinds of strong social communities created in single-sex classrooms However, for the space to be truly effective, adults and children must consciously develop and enforce norms that promote a safe space for play. This is the essence of 'low-risk practice', a shared community stance that minimizes the importance of failure in practice, and promotes self-efficacy and a positive self-image as a problem solver.

Research Issues Associated With Research in the Go/Problem-Solving Space

Now that we have examined some of the affordances of Go play for the purposes of elevating players' perceptions of self-efficacy and reducing their susceptibility to interfering affective phenomena, let us conclude this article with four small-scale research design recommendations. The purpose of this research is to understand the social structures that have arisen around Go in existing American afterschool programs and community centers. Also, this research could provide valuable lessons about the design of afterschool game programs that promote self-efficacy and engagement with problem solving activities. The following qualitative and quantitative studies would help to further illuminate the possibilities that lie ahead.

Study 1: Who currently plays Go in America?

Data required: Demographic data, interviews with players at local club

Sample: 3 male and 3 female players (ideally ages 6-18, 19-30, and 31-60)

This first case study would enable researchers to better understand the kinds of individuals that play Go in the United States. The interview protocol would ask questions about the individual's math and science backgrounds, career goals, and educational opportunities. It would also contain relevant questions related to problem solving, and the player's self-perceptions as a problem solver. These questions are particularly pertinent to the female players, who presumably have a lower level of math anxiety than other populations. However, other psychometric studies will be necessary to validate this hypothesis.

Study 2: How is Go currently taught by Club mentors?

Data required: Interviews, review of translated works on Go teaching, observation of mentoring/teaching interventions

Sample: Club mentors (presumably mostly male) and parent volunteers

Go, in its current American form, has an existing teaching methodology that requires documentation and analysis. What kinds of problems are presented to children, and how are they scaffolded? How do Club mentors engage with children? Do they create a positive environment for all players, and if so, how?

Study 3: Does Go play have an effect on an individual's sense of self-efficacy? On their perceptions of stereotype threat?

Data required: Demographic data, results of sMARS anxiety instrument, longitudinal data collection of grades and self-efficacy data (anonymous, with parental consent)

Sample: 5 males and 5 females (five participants of each gender, ages 6-18, and 19 and above)

In some ways, this is the crux of the study. Does Go have a positive effect on female children over the long term? Can it reduce math anxiety and stereotype threat? Or are there other mediating factors that prevent the improvement of their affective states?

Study 4: How do children engage in Go play in school clubs? Do clubs provide a positive, diverse atmosphere?

Data required: Interviews, qualitative observation, demographics, academic histories (anonymous, with parental consent)

Sample: 5 male and 5 female Go players in K-12, ideally of an ethnically representative mix

This study would examine the kinds of social interactions that arise around game play. This includes student-to-student interactions, as well as Club-student interactions. The goal is to determine whether these environments are conducive to student engagement, or if further development of social procedures is necessary.

Conclusion

As we have seen, the effects of stereotype threat and math anxiety on female learners have a substantial impact on their long-term ability to succeed in math, a key factor in long-term success in the STEM fields. While the causes of stereotype threat and math anxiety are complex, it is possible that the use of problem solving simulations may enable students to build confidence and affective control in a low-risk environment. It is also possible that the confidence built during the play of problem-solving games, such as Go, could transfer to other aspects of their lives and academic careers. Further research will be necessary to determine exactly how the use of games and simulations affects confidence in the long-term.

Bibliography

Annetta, L. A. (2010). The “I’s” have it: A framework for serious educational game design. Review of General Psychology, 14(2), 105-112

Annetta, L. A., & Holmes, S. (2006). Creating presence and community in a synchronous virtual learning environment using avatars. International Journal of Instructional Technology and Distance Learning, 3(8), 27–43.

Annetta, L. A., Minogue, J., Holmes, S. Y., & Cheng, M.-T. (2009). Investigating the impact of video games on high school students’ engagement and learning about genetics. Computers & Education, 53(1), 74-85. Elsevier Ltd.

Atherton, M., Zhuang, J., Bart, W. M., Hu, X., & He, S. (2003). A functional MRI study of high-level cognition. I. The game of chess. Cognitive Brain Research, 16(1), 26-31.

Barab, S. A, & Roth, W.M. (2006). Curriculum-based ecosystems: Supporting knowing from an ecological perspective. Educational Researcher, 35(5), 3-13.

Barab, S. A., Thomas, M. K., Dodge, T., Squire, K., & Newell, M. (2004). Critical design ethnography: Designing for change. Education, 35(2), 254-268.

Barab, S.A., Dodge, T., Thomas, M. K., Jackson, C., & Tuzun, H. (2007). Our designs and the social agendas they carry. The Journal of the Learning Sciences, 16(2), 263-305.

Bargh, J.A. (1994). The Four Horsemen of automaticity: Awareness, efficiency, intention, and control in social cognition. In R.S. Wyer, Jr., & T.K. Srull (Eds.), Handbook of Social Cognition (2nd ed., pp. 1-40). Hillsdale, NJ: Erlbaum

CAST (2011). Universal design for learning guidelines version 2.0. Wakefield, MA: CAST.

Chen, X., Zhang, D., Zhang, X., Li, Z., Meng, X., He, S., & Hu, X. (2003). A functional MRI study of high-level cognition. II. The game of GO. Cognitive Brain Research, 16(1), 32-37.

Clark, R. C. (2008). Building Expertise. San Francisco: Pfeiffer.

Crisp, R. J., & Turner, R. N. (2011). Cognitive adaptation to the experience of social and cultural diversity. Psychological Bulletin, 137(2), 242-266.

Csikszentmihalyi, M. (1990). Flow: The Psychology of Optimal Experience. New York: Harper and Row.

De Groot, A. D. (1965). Thought and Choice in Chess. Paris: Mouton & Co.

Dehaene, S., Molko, N., Cohen, L., Wilson, A.J. (2004). Arithmetic and the brain. Current Opinions in Neurobiology. 14, 218–224.

Deleuze, G., & Guattari, F. (1987). A Thousand Plateaus: Capitalism and Schizophrenia. Minneapolis: University of Minnesota Press.

Geary, D. C. (2011, In Press). Cognitive predictors of achievement growth in mathematics: A 5-year longitudinal study. Developmental Psychology, 1-15.

Gee, J. P. (2010). New Digital Media and Learning as an Emerging Area and "Worked Examples" as One Way Forward. Cambridge, MA: The MIT Press.

Hesse, H. (1943). The Glass Bead Game. New York: Vintage Classics.

Hofstede, G. (1986). Cultural differences in teaching and learning. International journal of Intercultural Relations , 10, 301-320.

Hofstede, G. (2001). Culture's Consequences (2nd ed.). Thousand Oaks, CA: Sage Publications.

Hofstede, G. (1998). Masculinity and Femininity. Thousand Oaks, CA: SAGE Publications.

Jain, S., & Dowson, M. (2009). Mathematics anxiety as a function of multidimensional self-regulation and self-efficacy. Contemporary Educational Psychology, 34(3), 240-249. Elsevier Inc.

Lesh, R. (2011). Applied mathematical problem solving. Educational Studies, 12(2), 235-264.

Lubienski, S. T., McGraw, R., & Strutchens, M. (2004). NAEP findings regarding gender: Mathematics achievement, student affect, and learning practices. In P. Kloosterman, & F. K. Lester Jr. (Eds.), Results and interpretations of the 1990 through 2000 mathematics assessments of the National Assessment of Educational Progress (pp. 305–336). Reston, VA: National Council of Teachers of Mathematics.

Mattarella-Micke, A., Mateo, J., Kozak, M. N., Foster, K., & Beilock, S. L. (2011). Choke or thrive? The relation between salivary cortisol and math performance depends on individual differences in working memory and math-anxiety. Emotion, 11(4), 1000-5.

Nosek, B. a, & Smyth, F. L. (2011). Implicit social cognitions predict sex differences in math engagement and achievement. American Educational Research Journal, 48(5), 1125-1156.

Petitot, J., Varela, F. J., Pachoud, B., and Roy, J.-M., (eds.), 1999, Naturalizing Phenomenology: Issues in Contemporary Phenmenology and Cognitive Science. Stanford, California: Stanford University Press.

Polya, G. (1973). How to solve it. Princeton, NJ: Princeton University Press.

Pronin, E., Steele, C. M., & Ross, L. (2004). Identity bifurcation in response to stereotype threat: Women and mathematics. Journal of Experimental Social Psychology, 40(2), 152-168.

Richardson, F. C., & Suinn, R. M. (1972). The mathematics anxiety rating scale: Psychometric data. Journal of Counseling Psychology, 19(6), 551–554.

Robinson, J. P., & Lubienski, S. T. (2010). The development of gender achievement gaps in mathematics and reading during elementary and middle school: Examining direct cognitive assessments and teacher ratings. American Educational Research Journal, 48(2), 268-302.

Schoenfeld, A. (1988). When good teaching leads to bad results: The disasters of ’well-taught" mathematics courses. Educational Psychologist, 23(2), 145-166.

Shapka, J.D., Keating, D.P. (2003). Effects of a girls-only curriculum during adolescence: Performance, persistence, and engagement in mathematics and science. American Educational Research Journal 40(4) 929-60.

Smith, D.W., "Phenomenology", The Stanford Encyclopedia of Philosophy (Fall 2011 Edition), Edward N. Zalta (ed.), URL: http://plato.stanford.edu/archives/fall2011/entries/phenomenology

Tomasetto, C., Alparone, F. R., & Cadinu, M. (2011). Girls’ math performance under stereotype threat: The moderating role of mothers' gender stereotypes. Developmental psychology, 47(4), 943-9.

Van Dillen, L. F., Heslenfeld, D. J., & Koole, S. L. (2009). Tuning down the emotional brain: an fMRI study of the effects of cognitive load on the processing of affective images. NeuroImage, 45(4), 1212-19. Elsevier Inc.

Wilson, J. W., Fernandez, M. L., & Hadaway, N. (1993). Mathematical Problem Solving. In P. S. Wilson (Ed.), Research Ideas for the Classroom: High School Mathematics. New York: MacMillan. (pp. 1-20).

2

Technologies of Reflection

The Technologies of Reflection:
Investigations of Professional Vision in Video-based Professional Learning Communities

Introduction

The Alternative Teacher Education Program (ATEP) Program at a university in the Pacific Northwest is currently engaged in an effort to augment the development of novice teacher candidates from a national service organization (NSO). In this alternative teacher education program, Teacher Candidates begin to work as full-time teachers in classrooms after completing an intensive five week course of study in beginning classroom practices (as hosted by the NSO). Over the following year, the university-based component of the program integrates these teacher candidates into a professional learning community designed around a holistic and situated view of teacher practice. The activities and program of the university-based professional learning community were designed and implemented by Team Leads, or master teachers hired to serve as facilitator-mentor-coach-evaluators for the Teacher Candidates.

The ATEP program's end vision for the Teacher Candidate is proficiency in the enactment of instructional routines, the elicitation of deeper domain-based thinking from students, and the development of the Teacher Candidate's long-term ability to learn in the context of their practice. In addition to these visions for high quality teaching, the ATEP program must also provide Teacher Candidates with the skills and knowledge necessary for the teachers to pass the state's high-stakes Teacher Preparation Assessment (TPA) and receive a teaching credential. Due to the extreme time pressures associated with beginning teaching, the Program's Teacher Candidates would need to confront both of these needs at the same time. To further complicate matters, the Teacher Candidates were also responsible to the NSO, schools, and districts for a variety of performance and assessment observations, metrics, and assignments. Given these time pressures, the leaders of the ATEP Program decided to make the development of a holistic technological support system central to their strategy for providing novice candidates with a meaningful and relevant teacher education experience.

Context and Program Design

Technology Use During the First Year

From the outset of the endeavor, the ATEP Program's leaders prioritized the use of video technologies as a means of routinely reviewing and improving practice. The author of this paper joined the ATEP Program in the spring of 2011 to develop a plan for the use of technological systems for the program. The project to provide a novel professional learning context, a unique population, and a rare opportunity to study the development of professional expertise through the use of video-based content management system and professional learning community called Odin. (Fig.1) The shared goal for the technological system was the facilitation of the evolving, co-constructed learning process of the Team Leads and the novice Teacher Candidates. At the start of the year, the Team Leads introduced their Candidates to the beta version of Odin with a description of the tool's role in the larger instructional plan and its relevance to their work as teachers:

We want you to "practice" using Odin as a tool for making our practice public with each other prior to your next class session...Using Odin will become routine for us, so we need to build our confidence and competence in engaging with it and each other through it. (10/15/12)

After introducing the tool and its place in their learning community, users were then asked to could engage in self-commenting and peer-commenting on videos of practice, and sometimes received direct feedback from the Team Leads on their video. In a way, the Odin system serves as a sheltered version of YouTube, augmented with the ability to place comments on specific moments in the video timeline, as well as in a threaded format.

The creation of a video-based social network was of great interest to the Team Leads, as was the ability to give direct feedback on videos of candidate' classroom performance within a centralized workspace. Over the course of the year, the Team Leads would use Odin as a tool for developing Teacher Candidates' ability to notice features of their practice from self-submitted videos, as well as the features of other teachers' practice. In a typical Odin assignment from November, the Elementary Team Leads asked candidates to reflect back on their performance, and directed the novice learners towards various features of their work that they might improve on next time:

When watching your video respond to the following question: If you could teach these lessons to the same group of students again, what are two or three things you would do differently to improve the learning of these students based on their varied needs and characteristics? Consider missed opportunities and other aspects of planning, instruction and/or assessment and/or student voice.. Also, think about questions you might have for the group when we watch our videos together on Friday. (11/5/11)

In considering these assignments and their responses, the researcher became interested in the ways that Candidates and Team Leads selected and made meaning from video. In essence, the researcher wondered how the participants alchemized a video-representation into meaningful evidence of practice that supported specific decisions for future action. He reasoned that a close analysis of the actual use of the Odin video platform by the Team Leads and Teacher Candidates might yield results that could inform future projects' use of online video commenting as a reasoning practice networks in professional education. Further, small-scale studies of the communication patterns of the participants might inform designs for new, holistic learning systems for any profession where performance, reflection, and feedback are valued.

Preliminary Research Question

To guide the qualitative exploration of the ATEP Program's use of this new technology in a unique context, the researcher drafted a preliminary research question:

How did novice teachers turn video into evidence while participating in reflective writing exercises in an online video sharing network?

The researcher proposes to use a Grounded Theory approach to develop data-based activity parameters for the use of video-based written reflective activities in the context of a professional learning community (similar to the Critical Design Ethnography advocated by Barab, Thomas, Dodge, Squire, and Newell, 2004). These small-scale design parameters can serve as a type of 'basic research' on video-based program activities that may further inform the decisions of instructional designers and teacher educators as they begin to implement these new technologies.

Literature Review

This study's interest in the reflective practices of its participants comes from two key themes in the body of research literature in Education. First, we will examine reflection as a learning phenomenon, as this will be necessary to establish the definitional, procedural, and practical parameters of certain activities that might be called 'reflective.' Then, we will examine video-based practices in teacher education, so that we may understand the kinds of knowledge that are possible to build through the use of video-based reflection. The research from this area can provide a starting point for an understanding of the ATEP Program's use of mediated representations of practice in first year of practice. Then, we will place the ATEP Program's online commenting activities in relationship to these two areas of research, and providing a basis for further investigations.

Reflection as Learning

At the most theoretical level, the ATEP Program's decisions surrounding the use of reflection as a means of synthesizing knowledge shares thematic similarities with the work of Lee Shulman in teacher education. Shulman's Model of Pedagogical Reasoning and Action (1987) places reflective practices at a key phase in the continuous process of learning, as a means of developing professional expertise. Through this model, Shulman provides a working definition for reflection as "what a teacher does when he or she looks back at the teaching and learning that has occurred, and reconstructs, reenacts, and/or recaptures the events, the emotions, and the accomplishments" (p.19). Shulman (1998) further contends that reflection (as a form of learning from experience, p.519) is a necessary bridge between the "universal principles of theory and the narratives of lived practice" that characterize professional bodies of knowledge. However, Shulman's implicit distinction between theory and practice brings forth two further questions: Whose theories are applied in practice, and how should practice be used to inform theory? These are complex and murky questions, and Shulman grapples with them throughout his work (e.g. 1986; 1987). However, the work of Chris Argyris's in organizational psychology and K. Anders Ericsson in the field of cognitive science can help to develop more particular and operational answers for the purposes of this study.

Argyris (1997; Argyris, Putnam, Smith, 1965; Argyris and Schon, 1974) locates the importance of reflection in its role as a key component of the 'double-loop learning' cycles that characterize expert learning. In double-loop learning, professionals plan, act, analyze, and retry solutions in their environment using the constructed identity, knowledge tools, and practices available to them as part of their 'theory of action.' According to Argyris, the double-loop learning model can help teachers and learners understand and calibrate their behaviors relative to their desired outcomes, existing knowledge, role-identity, and available tools. Equally, a learner's theory of action can be seen as a means of exerting control over and bracketing complex problems, another component of cognitive perspectives on expert behavior. However as Argyris notes, the specifics of the individual's theory of action can reveal information about the context of its creation. This is important, as the 'double-loop' feature of reflective learning requires learners to evaluate the underlying assumptions, strengths, and deficiencies in their theories of action in hopes of improving their performance between their initial effort and their future iterations of efforts. This construct is also supported by Schon (1983), who describes this process as 'reflection-in-action,' and "Research not about or for practice, but in practice." (Schon, 1988, p.19) While Shulman disagrees with Schon's dichotomy of technical rationality and reflection-in-action (Shulman, 1988), both agree on the intrinsic value of reflection as a type of learning. In analyzing their assumptions, actions, and decisions for continued areas of improvement, Teacher Candidates might learn to become autonomous and self-directed in their learning, a key element of professional disciplines (similar to Abbot, 1988).

Thus far, Shulman has provided a definition of reflection and Argyris' has provided an agreeable description of the role of the process of reflection in an actor's theory of action. We may now look to Ericsson's model of deliberate practice (2006) to provide the means, or techniques of practice, necessary to put Shulman's definition and Argyris' process to work improving the reflective capacities of teachers. As Ericsson notes, optimal practice involves a balance of four variables: 1) the learner must focus on specific skill deficits; 2) the learner must receive explanatory feedback and active support; 3) the learner must practice in a sheltered practice environment; and 4) practice in ways that promote skill transfer from the practice environment to the performance environment. In the literatures associated with cognitive neuroscience, the implementation of deliberate practice is known to enhance the myelination (a protein that insulates neural pathways) of neurons when applied rigorously (Ericsson, 2006; Wlodkowski, 2008). That is, deliberate practice applied over time has the capacity to help practitioners make decisions more quickly, more consistently, and with less strain on cognitive load and attention (Clark, 2008).

In concluding this brief examination of the relationships of reflection and professional learning, the author offers the idea that in definition, process, and practice, reflection provides teachers with the hope for continuous improvement and development from within. That is, a professional stance that demands concerted, analytic, and regular adjustments to classroom performances. In exchange for this dedication, teachers may expect greater agency and control over the long-term development of their practice.

Video-based Teacher Education

As we move into the realm of literature on video-based reflection for professional development, it is important to understand the historical and present uses of video technologies themselves in the context of teacher education. The production and use of video representations of practice have become a standard component of teacher education programs. As Sherin (2004) describes, video has become an endemic technology from pre-service through professional development. She also enumerates some of the ways that teacher educators have employed these technologies to uncover unique possibilities afforded by practices built around the use of video as a pedagogical tool. She traces the evolution of these practices through the changes in teacher education pedagogy from microteaching to interaction analysis, the modeling of expert teaching, video-based cases, field recordings, and hypermedia.

Sherrin's overview of these technologies also discusses three of the core affordances provided by the use of video. These include the durability of video as a record of practice, the ability to collect and edit videos together, and the 'out-of-the-moment' discussions that video can facilitate in the professional development environment. Rich and Hannafin (2009) extend this idea further, noting that asynchronous video annotation tools "make possible the documentation and support self-analysis using verifiable evidence as well as to examine changes in development over time (p.52)."

However, the ATEP Program's blend of in-class and online video-based assignments does not fall neatly into these categories.

Rather, to understand the purpose of video-based commenting in the context of the Program requires that we place several literatures on the use of representations of practice (Grossman, Compton, Igra, Williamson, 2009) into juxtaposition. While some studies indicate that online social networks provide timely mentoring (e.g. Moir, 2009), and other studies (e.g. Rich and Hannafin, 2009) have described the affordances of video annotation tools, no one study has yet taken up the issue of online video-based teacher professional development networks, this brief review will attempt to draw from three areas of literature that can provide a basis for the development of analytical tools for this pilot study: Situated Professional Vision, the Social Activities of Video-based Discussions, and Teacher Noticing. These three areas of research will provide the necessary background in the current discussions of mediated professional education for teachers.

Since video is primarily associated with the concept of seeing (videre is Latin for seeing), an understanding of the concept of professional vision is essential in this examination of the utility of video-based teacher education. In the more cognition-oriented literature (NSF, 2000; Clark and Mayer, 2008; Darling-Hammond and Bransford, 2005), professional vision is ascribed to expert cognition, or the observable and reported mental processes associated with individual expert performers. However, the existing literature on the development of teacher's professional vision (e.g. Grossman et al., 2009) most frequently cites Goodwin's (1994) formulation of professional vision. Goodwin develops his formulation of professional vision from observations of expert testimony during the O.J. Simpson trial in early the 1990s. In analyzing the discourses, he proposes that an expert's ability to notice particular features of a problem comes from an active ability to make observations (Coding), reason about those observations (Highlighting), and use discipline-specific discourse strategies (often graphical) to describe conclusions to others in their peripheral community (Lave and Wenger, 1991). That is, Goodwin frames an expert's ability to see (and the legitimacy of their 'vision') as an active component of engagement with their larger community of practice.

This situated formulation fits with the current socio-cultural views of expert development (e.g. Engstrom, 2004), as well as the emerging body of research on teacher professional development communities like ATEP. This is an important area to consider, because (as Figure 2 represents), if one imagines Argyris' double-loop learning

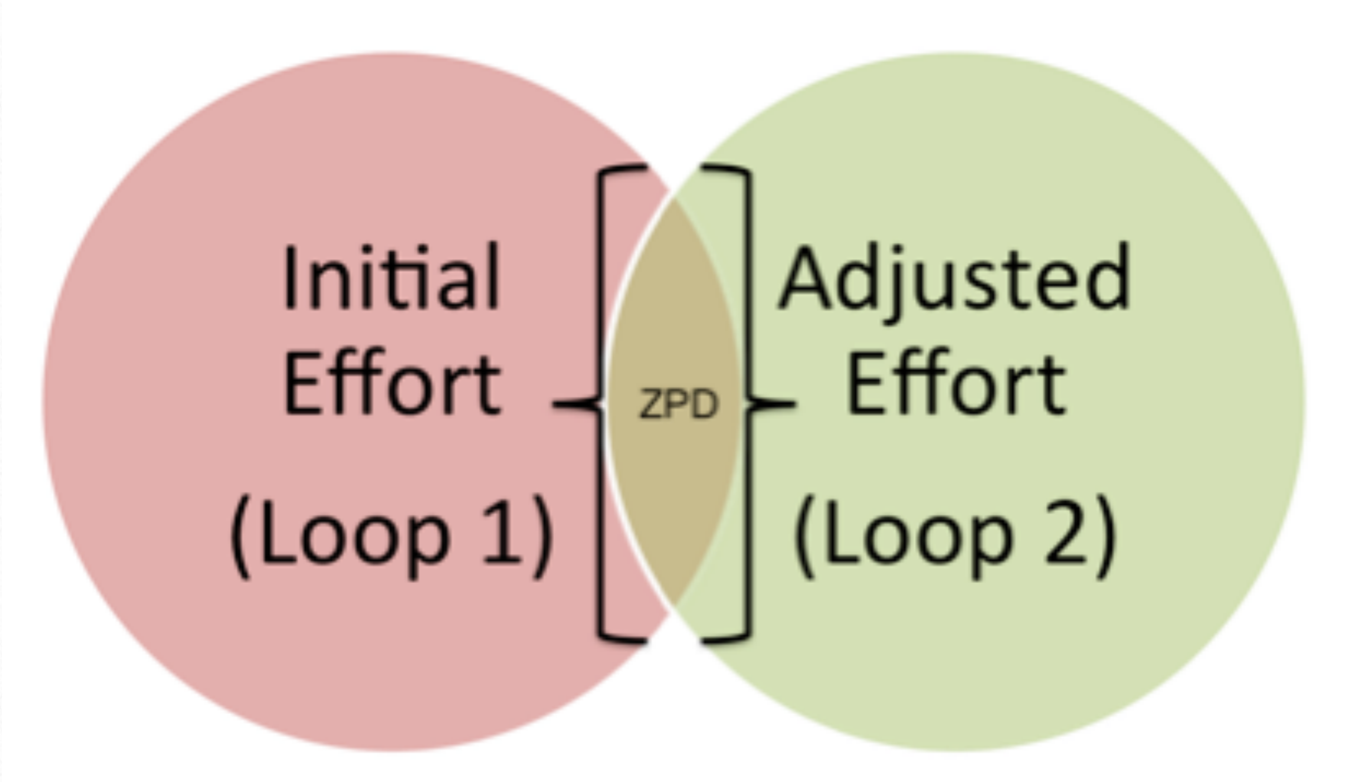


Figure 2 – Argyris and Vygotsky

cycle as a pair of overlapping sequences, then the area of union represents a potential zone of proximal development (Vygotsky, 1978) for learners. However, in order to realize the value of professional vision to this interstitial ZPD, one must consider a participant's location within a larger community of teachers and learners. A ZPD, by definition, must exist in relationship to an entity or community that has the necessary local expertise (NSF, 2000) to alter the participants" professional vision as they transition from Loop 1 to Loop 2 and beyond. Thus, the use of video is essential for providing a representation of practice for the community to engage.

The situated view of the development of professional vision is visible in current research on the use of video, video papers, and other video-based reflective learning community experiences. For example, Van Es and Sherin (2002) and Sherin and Van Es (2005) note that to develop professional vision and 'noticing' abilities, teachers must also be prepared to make connections between the specific examples they see and larger theoretical principles as well as to their own classrooms and social contexts.

In considering the role of technology in this process, Rosaen, Lundeberg, Cooper, Fritzen, and Terpstra (2011) observed that their teacher interns wrote more specific, instruction-oriented, and student-centered comments and reflections when they examined video representations of practice than when they tried to reflect from memory. Further, interns were able to use video-based reflection to “unpack” the complexities of their teaching practice in ways that were consistent with the important role of inductive and abductive reasoning to their noticings.

These connections from a teacher’s local store of expertise to the available video evidence is further mediated by the social structure of the video club itself, as noted in Van Es (2009). In addition to having a situated view of their own practice, Van Es found that teachers’ situative experience within a video club (Sherin, 2004) professional learning community influenced their expression and discussion style. Van Es performed an analysis of the professional vision exhibited by participants’ in various roles in a face-to-face video club, and the different kinds of vision displayed by students as they took those roles. Some students became Proposers (who offer Judge-Observe-Prescribe-Reason type comments), Builders (who perform Tagging and Connecting functions), Critics (who Counter and Question), Blockers, and so forth.

As the community evolved, Van Es describes the differences in the kinds of language used by the participants as they developed different roles in the club, and how these roles shape the kinds of dialog that were possible in the community. Van Es also notes that the development and ownership of a virtual community was itself a powerful mediating factor in the kinds of professional vision and noticing that occurred in the community. As the group proceeded through the process of developing social norms and practices (Tuckman, 1965), the forms of expression and discourse changed and altered along with the roles of the participants. Thus, it may be possible to contend that discussion communities affect the content and structure dialog and learning in ways that are qualitatively visible and non trivial.

Now that we have defined the dually-situated nature of professional vision (the individual’s situation within a larger community of practice, and their situation within a professional learning community), it is possible to begin to uncover some of the community pedagogical practices that are necessary to prepare students to reflect on their practice and connect their knowledge across environments. Hiebert, Morris, Berk, and Jansen (2007) believe that students must possess two core analytic competences in order to make use of video as a means of learning about their practice. The first competency is the individual teacher's pool of pedagogical content knowledge. As one might imagine, a teacher cannot notice or critique a phenomena in a video if they do not have the ability to recognize the particular strategies of their discipline's knowledge (similar to Whorf, 1956). Therefore, a teacher candidate with a novice level of pedagogical content knowledge (might have difficulty Hiebert et al. also point to a need for a reflective framework of practices that they decompose into four skills: 1) the teacher's willingness to set goals, 2) assess whether the goals are achieved during a lesson, 3) specify hypotheses for why the lesson did or did not work well, and 4) use hypotheses to revise their lessons. While Hiebert et al. note that these analytic skills are rarely explicitly taught, they find that it is theoretically possible for novice teacher candidates to bring related analytic lenses with them to teaching from other fields and experiences (Van Es and Shrin, 2002). As we shall see in the Methods section of this paper, the Teacher Candidates in the ATEP Program naturally made use of a similar set of reflective skills in ways that provide further evidence for Hiebert et al.'s competencies of teacher noticing.

Research Methods

Qualitative Approach

Drawing from the author's experience as a participant observer on the project, this study will use Grounded Theory (Glaser and Strauss, 1967) to understand the relationship of the practical and theoretical lessons learned from the implementation of the Program's instructional technology armature. Grounded Theory is most appropriate for this project, as the phenomena under observation occur in a variety of venues (formal and informal), across several media (visual, audial, and textual), and were collected in different ways (observations, interviews, class recordings, submitted artifacts).

In particular, Glaser's idea that "All is Data" allows for the use of multiple methods of analysis to create meaning. This perspective allows theory to emerge from the artifacts, discussions, trends, and solutions that were produced in a particular socio-historical context. In many ways, the cycles of investigation and theory development that occur in Grounded Theory are ideal for the study of participants' uses of technology in authentic contexts. Technological tools are deeply bound to local actors, social structures, and resources (Engstrom, 2004), and Grounded Theory's technique of thematic analysis (Glesne, 2011) can help to identify recurring trends in interactions and tool use.

The use of the Grounded Theory approach to data analysis also serves three larger purposes. First, Grounded Theory may provide a valuable framework for the analysis of learners' behavior as they interact with the digital and non-digital technologies in their environment. The close analysis of artifacts produced by Teacher Candidates, as well as close observations of the effects of media on their products, can help to determine future uses for the technology. Second, Grounded Theory's generative approach to the development of research questions can help to maintain an open stance towards alternative and conflicting explanations of phenomenon. Finally, Grounded Theory's compatibility with constant case comparison strategies will enable preliminary theories to grow to encompass a variety of settings and actors. This is especially important in cross-content area comparisons of discussions and activities that may follow the pilot study.

Sampling of Settings and Participants

At present, the ATEP Project has a total of 11 Teacher Candidates and six Team Leads in four Content Areas. The Teacher Candidates are first year, pre-service teachers engaged in a residency-based alternative teacher credential program. Candidates are simultaneously responsible for their regular, full-time teaching duties in local public schools as well as their ATEP coursework, and the training, coaching, and evaluative events run by their NSO coordinators. This pilot study will focus on the video-based comments produced by two Teacher Candidates from the Elementary Content Area during their year of participation in the ATEP Program. During that year, Jessica (a fifth-grade teacher) and Michael (a fourth-grade elementary teacher) were both teachers of record in their own classrooms for the first time. These two candidates were chosen for this pilot study because interviews with Team Leads characterized Jessica and Michael as motivated, thoughtful, caring, and serious Teacher Candidates. Thus, this project would examine star performers through their writing and video-based discussions.

This study also examined some of the discussions produced by Team Leads in their role as coach-teacher-mentors for the Candidates within their content group. These threads provide formative and summative feedback, resources, encouragement, and suggestions for further improvement. For the purposes of the study, these

Data Collection

The present iteration of this paper will draw select evidence from the project's substantial corpus of collected data collected from the first cohort of the program (2011-2012). In the past nine months, the project has recorded more than two hundred hours of video from weekly professional learning community meetings, collected more than 80 Candidate-generated videos, and conducted numerous interviews (one protocol is included in Appendix 1) and observations of program participants. The project has also collected samples of Candidates' lesson plans and student artifacts, as well as written responses and 'workfolios' that were produced in anticipation of the TPA exam.

These various forms of data provide a very detailed picture of the development of the program and candidates. However, this study will draw 12 online video comment threads from the Odin platform (7 from Jessica Larson, and 5 from Michael Arroyo), one thread of Team Lead video comments for comparison (also from Odin), as well as one IPC writing assignment from each candidate. These artifacts were submitted over the course of one year (six from October-December, and six more from January-March), a fact that could help to understand the changes in Teacher Candidate thinking and writing that occurred over the course of the Program.

Development of Coding Scheme and Initial Observations

In accordance with the theory development methodologies within Grounded Theory, this study proceeded through a four-phase coding procedure for data analysis. In the first phase, the researcher organized the sampled data in an online qualitative data management program (Dedoose) and tagged it with a series of 'Base' Codes. Base Codes provide important factual information (date, location, teacher candidate, etc.) associated with the selected artifacts, and serve as controller/delimiter tags for data management and visualization. While the number of artifacts in this pilot is small, the number of relationships and occurrences of participants and phenomena across the artifacts is great, and the online software helped to manage the complex task of indexing these relationships.

The second phase involved the process of Open Coding. This phase attempted to discern the underlying technological factors that influenced the creation of the artifact. The identification of these factors is predicated on the idea that the participant's understanding of the affordances, limitations, and theorizations of tools (digital and non-digital) directly influences the products that they create (as in the relationship between media and messages, McLuhan, 1964).

At this point, the researcher had performed an open-coding round on the Candidates' more polished IPC Assignments as a calibrating document for the later analysis of the video comment threads. IPC Assignments were chosen as the starting point for the coding as they bear a great deal of similarity to the comment thread assignments due to the required use of specific video evidence, but were thought to be more representative of a candidate's ability to write about their own work. Also, the IPC Assignment was produced after the Candidates had used the Odin system for several months, so they had already been exposed to several rounds of commenting on videos. As such, the researcher theorized that the IPC Assignment video papers would exhibit some of the same writing structures as the individual online video comment threads, but would engender more effort from the Candidates due to its formal and summative nature.

One early feature observed by the researcher emerged from an analysis of the IPC Assignments collected from the Teacher Candidates in December of 2011 was the presence (and non-presence) of time codes in the IPC assignments. The following passage from Jessica Larson's IPC assignment serves as evidence of a unique discourse phenomena that eventually inspired the broader coding scheme:

At 5:11 I try to emphasize the idea that the questions should be applied to more than just one sentence from our writing. I try to reinvest the students in the lesson by having them guide me through the revision of a sentence at 5:36 but In the foreground at 6:07 I appear to have lost Isaac and Angelo as they are playing. What I think would have helped at this point would have been for them to turn and talk with a partner in order to write a new sentence for my piece. I could have provided them with a few details then had them pick and choose from them to create a new sentence so that they would have had more practice writing. (JL, IPC Assignment 1, Dec. 2011)

In this passage (and others like it throughout the video thread comments, IPC assignments, and workfolios), Jessica makes a series of observations that are pegged to specific timeline events. She locates her own behavior at 5:11, describes a specific student behavior located at 5:36, makes an inference about student thinking at 6:07, and a closes with a specific suggestion for improving her future practice. This mode of expressing their observations mirrors the reflective competencies discussed by Hiebert et al., including the competency model's focus on student improvement. While it is possible that Jessica naturally wrote her comments in this fashion, it is more likely that she learned this way of displaying her thinking from the Team Leads, the NSO, or her local community of practice in her school. In theory, future studies could trace the development of a teacher's noticing competency across the ATEP Program's curriculum and in other spaces to see how the Teacher Candidate's community of practice influences their ability to notice in the professional learning community.

In contrast to Jessica's assignment, Michael's IPC Assignment did not use time codes in the IPC video paper. The following passage contrasts in tone and number of specific references to student thinking:

The biggest indicator for me that they understood the lesson was their focus during independent working time. I walked around and there were maybe three or four students that didn't get it, but overall the lesson was a success. Also, I maintained a consistent level of focus and engagement during the lesson that was evident in their participation and also in the fact that all of the side conversations were about the topic at hand. There are two students in particular, M-and K-, who worried me the most. While the whole class had written something, they had a hard time thinking about something to write. I will follow up with them tomorrow and see if a more guided time would work better for them. (MA, IPC Assignment 1, Dec. 2011)

As noted in Rosaen, et al. (2004), the use of specific video evidence (e.g. time codes) appears to accompany more specific noticings about the nature of student learning compared to the candidate who did not use time codes. While Michael appears to have put some reflective thought into the assignment, it still lacks the specificity of description and frequency of suggestions for improvement that appears in Jessica's assignment. However, while Jessica's essay appeared to focus on suggestions for improvement, Michael's less specific essay appears to focus on 'what worked,' an admirable goal. This presents a quandary of values (e.g. is a suggestion for improvement of a higher learning value than a 'what worked' noticing? If so, why would this be the case?)

Code	Working Definition
Noticing Teacher Behavior	An observation of a teacher’s speech, actions, or pedagogical choices
Noticing Student Behavior	An observation of a student’s visible behavior, including their speech, writing, or interactions
References to Specific Students	An observation that contains a specific reference to a student in the classroom, either in the context of a description of a lesson, or as a representation of a specific instance of a larger phenomenon
Inference About Student Thinking	An inference about a students’ internal mental state
What Worked	A teacher’s behavioral routine or choice that resulted in what they perceive as a positive outcome (also known as a ‘wow’)
Suggestions for Improvement	A specific recommendation for future performance changes, in either statement or question form (also known as a ‘wonder’)

Table 1 - Core Axial Codes

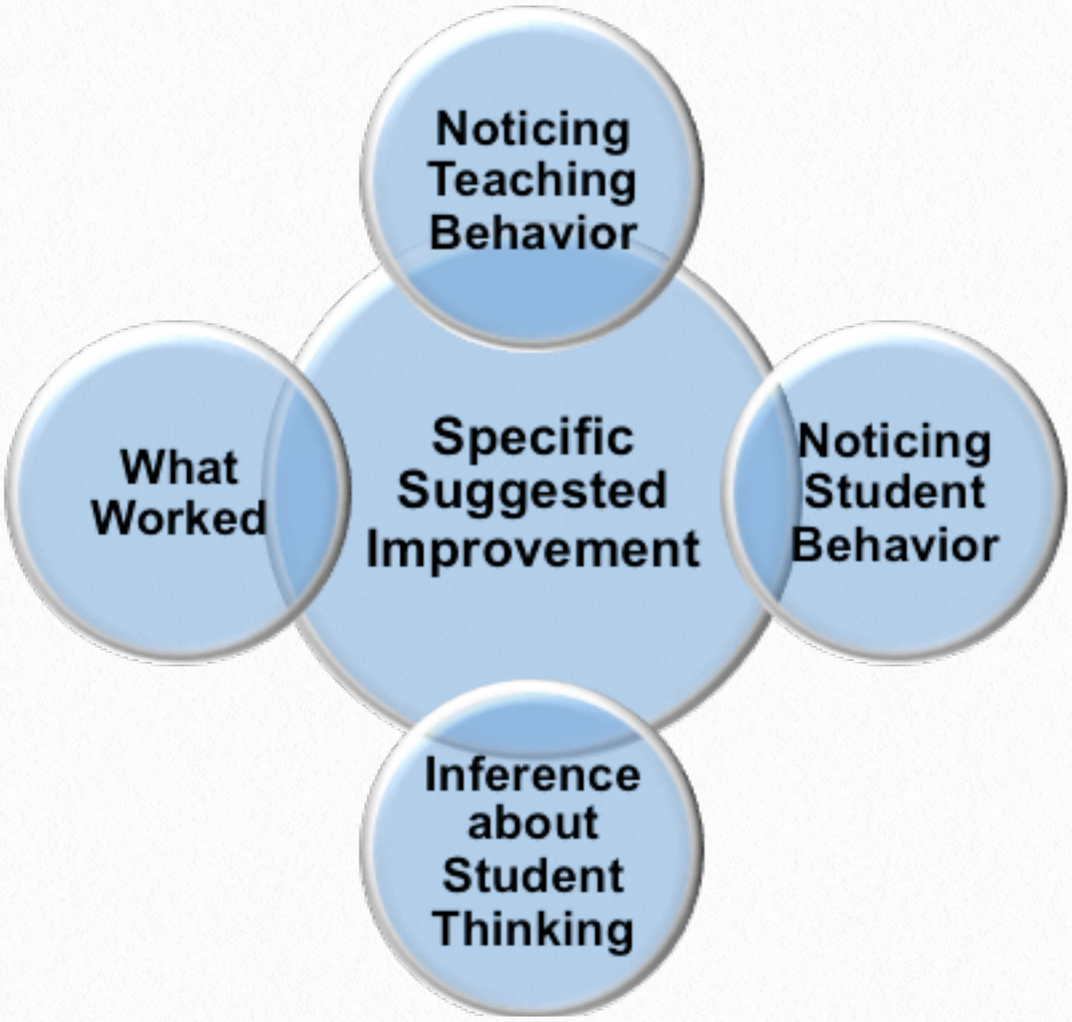
In reflecting on the qualitative differences between these two blocks of text, the researcher observed that Jessica used time codes more frequently than Michael in this assignment, but found a need to describe the relationship between the proximity of video evidence and observation using a set of metrics. To do this, he formalized the results of the Open Coding phase into Axial Codes that represented phenomena, causal conditions, context, intervening conditions, with a specific focus on action strategies, and consequences (Glesne, 2010). The development of 14 axial codes led to the selection of a set of thematic codes that reflected the core themes for this pilot study. These codes are summarized in the table above.

Participant	Time codes	Teacher Behavior	Student Thinking	Suggestions for Improvement
Michael (7)	0	3	4	1
Jessica (12)	12	4	9	6

Table 2 - Code Occurrence in IPC Assignments

After developing the code structure from the IPC assignments, the researcher began to apply the five codes above to the text supplied by the two candidates. This occurred after the researcher began to identify discrete boundaries between the observations in the IPC assignments. Despite their varying length (usually less than 80 words), these ‘noticings’ contained what might be thought of as a ‘complete idea’ about a specific point in a video, but did not always include all of the themes in any given noticing. However, in the interest of keeping results comparable with studies like Hiebert et al. and Rosaen et al., this pilot study will only report results that include Teacher Behavior, Student Thinking and Suggestions for Improvement. The application of the codes to the IPC assignment noticings appears in the table below:

To clarify the data contained in the table: Out of Michael’s 7 total ‘noticings’ (and zero timecodes), three of those contained an observation of Teacher Behavior, four contained student thinking, and 1 contained a suggestion for improvement (the last noticing of the reflection). Jessica’s noticings contained 12 references to timecodes in her video, with four observations of teacher behavior, nine references to student thinking, and six suggestions for improvement. Thus, it appears that (in this pair of cases), the candidates responded in ways that were consistent with the observations presented in Hiebert et al. and Rosaen et al. regarding competencies and benefits associated with video-based commenting.



Initial Observations and Evidence

With this coding structure in place, this study will now expand to provide preliminary observations on four factors involved the online threaded comments left by candidates on their video commenting threads. These observations provide initial sketches for future program wide studies that could help to provide future guidance for the implementation of video-based commenting in the context of other programs.

Observation 1: Emerging Grounded Theory of Noticings in the ATEP Program

In moving toward the analysis phase, the researcher chose a central theme and assembled the relevant coding themes around it, leading to a preliminary theory about the relationship between the various features of noticings. For the purposes of this study, the researcher chose to follow the assertion of Hiebert et al. that the primary goal of noticings should be the generation of specific suggestions for improvement. Thus, the researcher oriented the remaining features into alignment with this prime category (as detailed in Strauss and Glaser). The resulting model (pictured above) abstracts the early coding themes into an ideal-type of noticing; that is, an ideal noticing should contain all of those variables. This alignment towards Suggestion for Improvement made the following observations possible, but at the cost of obscuring other kinds of potential noticings (e.g. a noticing that focuses on What Worked). Therefore, it is important to acknowledge the possibility of other alternative models that may fit other kinds of discussion activities or discourse models.

Kersting, Givvin, Sotelo, and Stigler (2010) provide statistical evidence to support this assertion as well. In their study, Kersting et al. asked 19 experienced teachers to observe videos of teacher practice using a validated video analysis rubric. The rubric measured the observers' comments on Mathematical Content, Student Thinking, Depth of Interpretation, and Suggestions for Improvement. The researchers in the study also collected student test data from the observer-teachers' classrooms. As a result, Kersting et al. were able to identify a uniquely predictive relationship between the frequency of teacher noticings related to Suggestions for Improvement and student gains in math achievement. As they note, "Providing suggestions for improvement unprompted may be an indication that teachers have internalized this process to the extent that it has become routine." Thus, the following observations will attempt to identify the conditions necessary for the emergence of unprompted Suggestions for improvement.

Observation Two: Emergence of Thread Assignment Genres

In looking back at the available comment threads from the Odin system, a set of interesting variations in the use case by the Elementary team. It would appear that over time, the Elementary Team Leads varied the format of the commenting in the online video threads. Four primary categories of assignment thread genres (or communicative purposes that shape the features and meaning of the text, as in Swales' Genre Analysis, 1990; also, Knobel and Lankshear, 2007) recurred throughout the year. These included:

1. **Team Lead Comment Threads:** Team Leads would model the commenting process by annotating Teacher Candidates' videos early on (October), and providing encouragement and further discussion later in the year. Only Team Leads commented on these videos.

2. **Self-Comment Threads:** Teacher Candidates upload their video and annotate the timeline with their observations (Yearlong).

3. **Cross-Comment Threads:** Candidates comment on the videos of others, sometimes in response to a self-comment thread (Yearlong – excluded from certain studies).

4. **Team-Lead/Candidate Co-Commenting Threads:** Candidates post a video and leave preliminary comments, followed by a round of noticings and encouragement from the Team Leads.

5. **Exemplar Comment Thread**: Team Leads would post videos of exemplary performers on the website, and asking each candidate to contribute comments to a collaborative discussion thread (October – not included in the pilot study).

These comment thread types became valuable as a means of evaluating the kinds of discussions complete selection of data, and may serve as future templates for activity design parameters in video-based professional development. However, these taxa of thread types may continue to grow and expand as the pilot study grows to include other Content Area and Team Lead projects. Equally, they may continue to grow and expand as the project seeks new avenues for the use of video to cultivate evidence-use.

	Teacher Behavior	Student Thinking	Total Applications
Teacher Behavior			**92**
Student Thinking	50		**84**
Suggestions for Improvement	26	24	**46**

Table 3 - Code Occurrence of Reflective Codes (n=156 noticings)

Observation Three: Overview of the Code Co-Occurences

In the course of coding the documents, the researcher used the data management program to manage the calculation of code co-occurrences by indexing all of the video comments and codes in the tool's online archive. Then, the researcher used a set of Boolean parameters to filter and compare the occurrences of two or more tags in the dataset. After applying the correct Boolean filters to specify the Teacher Candidates and Odin-based assignments, and using the built-in visualization software, the researcher was able to obtain the above metrics for the frequency of co-occurrence of tags across 156 noticings from Michael and Jessica. The table indicates that, in the aggregate, the two candidates made substantially more comments related to Teacher Behavior and Student Thinking than Suggestions for Improvement in the 156 available comments sampled. These three codes were chosen from the complete coding list because the researcher believed that they provide a parsimonious skeleton for a noticing. That is, the candidate must be able to recognize their own activity, make an inference related to student thinking, and provide a suggestion for future improvement in order to pass completely through from the first experiential loop to the second. However, the incomplete code coverage may imply that the two candidates' did not regularly make the necessary Suggestion for Improvement that would help them continue through their double-loop learning opportunity. The researcher feels that more cases and participants are necessary in order to make more specific claims about ways , but that this potential phenomena is worthy of future consideration.

Observation Four: TeacherBehavior x StudentThinking x SuggestionsforImprovement Hit Ratios

While the co-occurrence (or lack of occurrence) of two codes does not provide adequate resolution for understanding coding patterns. As such, the researcher conducted a second set of contrasts to compare the code application across the two Teacher Candidates and their Team Leads (who serve as an expert baseline). The table below outlines the finding of these contrasts, including a feature called a 'Hit Ratio,' or the ratio of the number of co-applications of all three codes to one noticing compared to the total number of noticings (represented as a percentage). This value can be important as a way of understanding how accurately a Candidate formed the simplest hypothetical complete noticing (Teacher's Behavior, an inference about Student Thinking, and a specific Suggestion for improvement) in the task.

As the table illustrates, the Team Leads (serving as an expert-control group) made a total of 20 noticings, including 19 on Teacher Behavior, 18 on Student Thinking, and 12 that contained Suggestions for Improvement. The Hit Ratio in the final column then provides the rate of co-occurrence of all three constructs. In this

Participant	Teacher Behavior	Student Thinking	Suggestions for Improvement	Co-Occurrence Hit Ratio
Team Leads (20)	19	18	12	12/20 = 60%
Michael (50)	33	23	17	9/50 = 18%
Jessica (99)	57	56	28	8/99 = 8%

Table 4 - TeacherBehavior x StudentThinking x SuggestionsforImprovement Hit Ratios

case, Team Leads provided all three pieces of information in 60% of their noticings.

While a goal of a 100% hit ratio is not necessarily desirable (e.g. learners may make comments that are valuable that do not adhere to this pattern), the Teacher Candidates only made these 'complete' comments in 18% and 14% of the noticings respectively. Thus, if it is possible that this particular reflective pattern can help professionals learn from their own practices, then it appears that the candidates may need more specific instruction on ways to write video comments at the level of precision demonstrated by the Team Leads.

Observation Five: Differences from Quarter 1 to Quarter 2

Before the above observation can be advanced as a hypothesis suitable for future qualitative study, it is reasonable to ask whether there are fluctuations within the above aggregations that reflect a change in the Candidates noticings over time. That is, do candidates get better at commenting over time? To answer that question, the researcher divided the noticings by quarter, Autumn (Oct-Dec, 2011, Table 5) and Winter (Jan-March, 2012, Table 6). While the number of overall comments from the Candidates declined from Autumn to Winter, the data below indicates a remarkable increase in the number of three-way co-occurrences across the quarters. This may indicate improvement in the Candidates' ability to notice features of practice and articulate specific suggestions for improvement over time, but it is not possible to determine a cause for this improvement from the data below. Further study of in-class discussions and interviews will be necessary to determine the qualitative nature of changes in these Candidates' thinking over time.

Participant	Teacher Behavior	Student Thinking	Suggestions For Improvement	Co-Occurrence Hit Ratio
Oct-Nov-Dec				
Michael (20)	12	3	3	1/20 = 5%
Jessica (66)	34	27	20	1/64 = 2%

Table 5 - Quarter 1 Co-Occurence Hit Ratios

Participant	Teacher Behavior	Student Thinking	Suggestions For Improvement	Co-Occurrence Hit Ratio
Jan-Feb-Mar				
Michael (30)	21	20	14	8/30 = 27%
Jessica (33)	23	29	8	7/33 = 21%

Table 6 - Quarter 2 Co-Occurence Hit Ratios

Observation Six: Hits by Assignment Type

In addition to chronological concerns, the researcher began to wonder about the role of thread types in relation to the hit ratios identified above. This stems from Hiebert et al.'s assertion that candidates must have an available store of pedagogical content knowledge in order to make effective comments. Since the Candidates began the ATEP Program with limited abilities to decompose their practices and identify features of their teaching, it is worthwhile to ask whether the kinds of reflection (on their own practice or the practice of others) has some bearing on their ability to generate Suggestions for Improvement. This led the researcher to create a Hit Ratio table that aggregated the data across three assignment types (Self-Commenting, Cross-Commenting, with Team-Lead threads as an expert-control group).

As shown in the table below (Table 7), Hit Ratios between the Self- and Cross-comment assignments are not substantially different when represented by percentages. However, it appears that Candidates provided more references Student Thinking comments (by proportion) in com-

Participant	Teacher Behavior	Student Thinking	Suggestions For Improvement	Co-Occurrence Hit Ratio
Self (123)	66	68	35	14/123 = 11%
Cross (39)	30	13	9	4/39 = 10%
Team Leads (20)	19	18	12	12/20 = 60%

Table 7 - Hits by Assignment Type

menting on their own videos. This might indicate that professionals who do not have a broad knowledge of the language and features of their fields may find it easier to comment on videos of their own, familiar contexts (in this case, with students they know) before moving on to generalizing their knowledge to other, strange contexts. Since the reason for this dramatic is impossible to infer from this observation, further qualitative research and comparisons from other content areas may provide further information in the future.

Validity

Grounded Theory's place as a post-positivist methodology frees researchers from the assumptions of positivistic quantitative research about the ability of the researcher to establish validity in universal ways. Since there is no single 'Truth' in a study with so many intersecting actors and stakeholders, the issue of validity in Grounded Theory must be addressed through the probabilistic and qualitative conditions of Fit, Relevance, Workability, and Modifiability (Glaser and Strauss, 1967). That is, any theory developed through this study must fit the evidence and population, deal with the relevant and real-world concerns of the participants, account for common and uncommon occurrences, and provide opportunities for change as new evidence emerges. However, since there is no single Truth, it can be difficult to determine whether the author's interpretation of events and theory can fulfill these criteria. For the purposes of this study, researchers will employ three strategies to establish the validity of the analysis, findings, and recommendations by using three strategies to address the four conditions.

First, future iterations of this project will employ Grounded Theory's technique of constant case comparison to help establish the Fitness and Workability of the theories. In this technique, cases of comparable grain-sizes (in this study, two candidates within one Content Team) are compared against one another to determine what they hold in common and how they are different. As noted earlier, this can help to provide evidence and substantiation of the thematic analysis through the examination of variations in activities, structures, and outcomes. Constant case comparison is also essential for identifying potential differences in Content Areas' use of the reflective video technologies.

Second, the study will use frequent member checks to solicit feedback about the study's analytical findings from the Program's Team Leads. While member checks can help to determine the fit of a theory, they can also help to maintain the relevance of the theoretical representations in the real-world context of the study. Equally, member checks improve the Modifiability by ensuring that the theory grows and changes to accommodate new data from the participants. Equally, member interviews will help to uncover some of the reasoning behind the use (or non-use) of video reflection technologies

Finally, the study will attempt to substantiate the developed theory through the use of triangulating data sources. The triangulation of data is a key technique in this study, as it will have a substantial effect on the breadth of the analysis' effects on Fit, Relevance, Workability, and Modifiability. In order to ensure that the generated theories are tenable and provide a multi-faceted view of events, triangulation should take place at both the within-subject and cross-case comparison level.

Limitations

Due to the author's interest in the socio-technical interactions of the project's participants, this exploratory study purposely excludes any discussion of the educational outcomes for the Teacher Candidates involved in the project and any judgment on their practices. Thus, future researchers may use the collected corpus of data to create rich case studies about the development of individual project participants over a short time. Equally, limiting the project's dataset to the use of online information ignores a host of artifacts and assignments that were used in the ATEP Program's in-person classes. Future studies may grow to include relevant artifacts (such as action plans, student work, etc.) that are not included in the digital realm.

Future Questions and Directions

In analyzing the preliminary data from the study, the researcher has developed five new directions for research questions that can be further investigated using the available corpus of qualitative data produced by the ATEP Project:

1. In what ways must the preliminary theoretical model of online teacher noticings continue to grow as new data and cases are added to the dataset, or does it require further revision or change? Are there other structures for dialog in the data that have not been examined?

2. Do Teacher Candidates in other teams also make more comments on Teacher Behavior and Student Thinking than Sugges-

tions for Improvement? How does this affect the preliminary theoretical noticings model?

3. What kinds of specific practices and instructional techniques can help Candidates more consistently ‘hit’ the target of a complete Teacher Behavior/Student Thinking/Suggestions for Improvement comment?

4. What in-class activities or influences could account for the improvement in the hit-ratios of these two candidates from Autumn to Winter? Do other candidates exhibit a similar trend of improvement?

5. Does this trend of increased attention to Student Thinking in self-comment threads appear in other participants, content areas and contexts?

The core goal of the investigation of these research questions is the further development of theories related to the use of media in the development of professional expertise. In investigating the specific uses of video comment threads reflection in the context of the ATEP Program, it may be possible to envision more powerful tools that develop professional vision and expert noticing in a systematic and satisfying way. Further, the performance tools developed from the findings of this study may generalize to other professional contexts (e.g. Medicine, Law, and Architecture), providing new opportunities for professional development activities that support learners in the context of their practice.

In addition to these specific questions, future papers and research could use data collected from the first, organic phase of system development to explore three emerging research themes in the Learning Sciences: Design-based Research, Digitally Mediated Practice Spaces, and Research-by-Design. First, a future study could attempt to outline a methodological argument for the utility of design-based research as a means of organizing the long-term study of digital tool use in an active and evolving system. Further, the dual-scale nature that results from the synthesis of design-based research and Grounded Theory may provide a new working model for the relationship between large-scale theoretical questions (e.g. what is the role of reflection in the process of professional education?) and small-scale practical questions (e.g. what kinds of instructional procedures should be employed during this process?). The practical-theoretical nature of the study of technology could benefit greatly from the demonstration of a dual-scale model (akin to hermeneutic circling, in Kvale, 1996).

The purpose of this design-based research component would be to develop more elegant, efficient, and motivating technological systems for the process of cultivating in-service practitioner reflection during video-based activities. This segment would include the analysis of a prototype 'virtual workspace' system that will provide a technological armature for the reflective processes co-configured by the Team Leads and Teacher Candidates. The primary concerns of this type of study are related to the development of a holistic virtual workspace that facilitates the program's reflective activities through a centralized virtual environment. The design itself (a product of the author's experience as a consultant on the project) and its grounding in the expressed and observed needs of Team Leads and Teacher Candidates (the program's clients) may provide a structure for the analysis of meta-design principles for similar systems in other contexts (as described by Collins, Joseph, and Bielaczyc, 2004).

This study would also outline a longer-term Research-by-Design agenda that will help to organize future basic-research initiatives related to the development of reflective practice and professional expertise in synchronous, asynchronous, and blended online learning environments (akin to the Effective Design described by McDonald and Klein, 2003, and the changes described by Collins and Halverson, 2009). In this way, the design-based research prototype (developed to research meta-design questions) becomes an organizing tool for the generation of a number of small-scale research questions that surround the use of video as a means of reflection. Further, the prototype workspace design would become a means of continuous investigation and improvement, much like the practices of those it is intended to serve.

References

Abbot, A. (1988). The System of Professions. Chicago: University of Chicago Press.

Argyris, C. (1997). Learning and Teaching: A Theory of Action Perspective. Journal of Management Education, 21(1), 9-26.

Argyris, C., Putnam, R., Smith, D.M. (1965). Action Science. Jossey-Bass: San Francisco.

Argyris, C., and Schon, D. (1974). Theory in Practice: Increasing professional effectiveness. Jossey-Bass: San Francisco.

Barab, S. A., Thomas, M. K., Dodge, T., Squire, K., & Newell, M. (2004). Critical Design Ethnography: Designing for Change. Anthropology and Education Quarterly, 35(2), 254-268.

Clark, R. C. (2008). Building Expertise. San Francisco: Pfeiffer.

Clark, R. C., & Mayer, R. E. (2008). e-Learning and the Science of Instruction. San Francisco: Pfeiffer.

Collins, A., & Halverson, R. (2009). Rethinking Education in the Age of Technology. New York: Teachers College Press.

Collins, A., Joseph, D., & Bielaczyc, K. (2004). Design Research: Theoretical and Methodological Issues. Journal of the Learning Sciences, 13(1), 15-42.

Darling-Hammond, L., & Bransford, J. (2005). Preparing Teachers for a Changing World. San Francisco: Jossey-Bass.

Engstrom, Y. (2004). The New Generation of Expertise: Seven Theses. In H. Rainbird, & A. Munro, Workplace Learning in Context (pp. 146-164). New York: Routledge.

Ericsson, K. A. (2009). Development of Professional Expertise. New York: Cambridge University Press.

Glaser, B.G., and Strauss, A.L. (1967). The discovery of grounded theory: strategies for qualitative research. Chicago: Aldine.

Glesne, C. (2011). Becoming qualitative researchers: An introduction. New York: Pearson.

Goodwin, C. (1994). Professional Vision. American Anthropologist, 96(3), 606-633.

Grossman, P., Compton, C., Igra, D., & Williamson, P. W. (2009). Teaching Practice: A Cross-Professional Perspective. Teachers College Record, 111(9), 2055-2100.

Hiebert, J., Morris, A. K., Berk, D., & Jansen, A. (2007). Preparing Teachers to Learn from Teaching. Journal of Teacher Education, 58(1), 47-61.

Knobel, M., & Lankshear, C. (2007). A New Literacies Sampler. New York: Peter Lang Publishing.

Kvale, S. (1996). Interviews: An introduction to qualitative research interviewing. Thousand Oaks, CA: Sage.

Lave, J., & Wenger, E. (1991). Situated Learning: Legitimate Peripheral Participation. New York: Cambridge University Press.

Mason, J. Researching Your Own Practice: The Discipline of Noticing. London: RoutledgeFalmer, 2001.

McDonald, J. P., & Klein, E. J. (2003). Networking for Teacher Learning: Toward a Theory of Effective Design. Teachers College Record, 105(8), 1606-1621.

McLuhan, M. (2003). Understanding Media: The Extensions of Man. Boston: MIT Press.

Moir, E. (2009). Accelerating Teacher Effectiveness : Lessons Learned from Two Decades of New Teacher Induction. Phi Delta Kappa International, 91(2), 14-20.

National Research Council. (2000). How People Learn: Brain, Mind, Experience, and School. Washington, D.C.: National Academy Press.

Rich, P. J., & Hannafin, M. (2008). Video Annotation Tools: Technologies to Scaffold, Structure, and Transform Teacher Reflection. Journal of Teacher Education, 60(1), 52-67.

Rosaen, C. L., Lundeberg, M., Cooper, M., Fritzen, A., & Terpstra, M. (2008). Noticing Noticing: How does investigation of video records change how teachers reflect on their experiences?.Journal of Teacher Education, 59(4): 347-360.

Schon, D. (1983). The Reflective Practitioner: How Professionals Think in Action. New York: Basic Books.

Schon, D. (1988). Coaching Reflective Teaching. In P. P. Grimmett, & G. L. Erickson, Reflection in Teacher Education (pp. 19-29). New York: Teachers College Press.

Sherin, M.G. (2004). New Perspectives on the Role of Video in Teacher Education. Advances in Research on Teaching, 10(3), 1-27.

Sherin, M., and van Es, E. (2009) Effects of Video Club Participation on Teachers' Professional Vision. Journal of Teacher Education. 60(1): 20-37.

Sherin, M. G., & van Es, E. (2005). Using video to support teachers’ ability to notice classroom interactions. Journal of Technology and Teacher Education, 13(3), 475-491.

Shulman, L. S. (1988). The Dangers of Dichotomous Thinking in Education. In P. P. Grimmett, & G. L. Erickson, Reflection in Teacher Education (pp. 31-38). New York: Teachers College Press.

Shulman, L. S. (1986). Those who understand: Knowledge growth in teaching. Educational Researcher, 15(2), 4- 31.

Shulman, L. (1987). Knowledge and Teaching: Foundations of the New Reform. Harvard Educational Review, 57(1), 1-21.

Shulman, L. S. (1998). Theory, Practice, and the Education of Professionals. Elementary School Journal, 98(5), 511-526.

Strauss, A. (1990). Basics of qualitative research. Thousand Oaks, CA: Sage Publications.

Tuckman, Bruce (1965). "Developmental sequence in small groups". Psychological Bulletin 63 (6): 384–99.

Swales, J. (1990). Genre Analysis. Cambridge: Cambridge University Press.

Van Es, E. A. (2009). Participants ’ Roles in the Context of a Video Club. Journal of the Learning Sciences, (December 2011), 37-41.

Van Es, E., & Sherin, M. (2002). Learning to notice: Scaffolding new teachers’ interpretations of classroom interactions. Journal of Technology and Teacher Education, 10(4), 571-596.

Vygotsky, L., Cole, M., John-Steiner, V., Scribner, S., & Souberman, E. (1978). Mind in Society: The Development of Higher Psychological Processes. Cambridge, MA: Harvard University Press.

Whorf, B. (1956), Carroll, J.B. (ed.), Language, Thought, and Reality: Selected Writings of Benjamin Lee Whorf, MIT Press

Wlodkowski, R. J. (2008). Enhancing Adult Motivation to Learn: A Comprehensive Guide for Teaching All Adults. San Francisco: Josey-Bass.

3

The Ecological Development of Professional Expertise

The Ecological Development of Professional Expertise

Exam Question 1

Can a synthesis between cognitive and situated theories of expertise provide a framework for understanding the development of expert cognition in the context of work?

0.0 The Animus

Consider this for a moment: A company's most valuable asset leaves the workspace every evening at quitting time. Every night, machines and computers sit idle, assembly lines go still, and the company's lights go out until the next morning. All of these physical attributes remain within the building's walls, but they cannot produce value without the vast pools of organizational and individual expertise that exist in the company's workforce. That expertise is the thing that transforms a company from a collection of metal, brick, and silicon pieces into a machine that produces valuable products and services.

Expertise is akin to what Aristotle terms "the Animus," or animating force of an entity. Organizations live and die based on the kinds of expertise they possess at key moments of change, as well as their ability to continuously develop and improve their existing expertise. For this reason, every organization that employs specialized labor holds a stake in the cultivation of expertise in adult populations through continuing education, professional development, performance improvement technologies, and life-long learning programs.

At present, educational psychology holds a diametric view of expertise, where some studies focus on the cognitive properties of individual experts, while others focus on the interactions and social knowledge of experts within the context of larger groups and communities (e.g. in the area of organizational development). This author contends that the duality of these research models reduces the complexity of expertise by locating the phenomenon of expertise in the mind or in the social world around the expert. A more complex model is necessary to relate and unify these two perspectives, and to reveal the boundless possibilities for learning contained within this unity.

The search for a sufficiently complex model of expert cognition that enables us to understand the cognitive, environmental, and social knowledge dimensions of the phenomenon begins with the concepts of reification and scale (as seen in Wenger, 1998). As Wenger recounts in his situative theory of learning, reification (or 'real-making') is the 'instantiation' of learning, as described by Vygotsky. That is, experience, knowledge, and learning only come into existence in the shared-world through a social process of participation in activities within a community of practice. Equally, this process of reification occurs at multiple levels of the human experience (for example, individual, group, organizational, and institutional). These twin ideas inscribe a circle around the questions at the heart of the cognitive and situative research trends: how do people instantiate their expertise in the real world, and how do the demands and instantiations of expertise change at different units of analysis?

In examining the phenomenon of expertise at multiple points of interaction and reification between the individual and their learning-performance environment, we may begin to envision new possibilities for supporting these individuals in real and relevant ways. The goal of this essay is to produce a working, blended cognitive/situative framework of expert cognition from existing literatures that instructional designers, learning scientists, policy makers, managers, and other stakeholders can use to guide their thinking and designs. However, we must first take some time to understand the purpose and provenance of this intellectual heritage, so that we can better understand the limitations of existing theories of expertise in complex environments. Thus, this paper is composed of three segments, with each part providing a new way of understanding the importance and features of a cognitive-situative synthetic framework.

In the first segment, this paper will trace existing research on expertise developed through cognitive psychology, education, and anthropology. This will include a summary of the current research on expertise, and provide a working outline of the empirical facets of the phenomenon at the attributional, cognitive, and situative levels. This will allow us to define a particular flavor of expertise that is exhibited in the activities and thinking of professionals. This analysis will allow us to see the potential for building bridges between the perspectives, as well as the necessity of the endeavor.

In the second section, we will briefly examine the points of convergence in three existing perspectives on the cognitive and social locations of knowledge: Ecological views of learning environments, wild cognition, and design thinking. These three approaches to the understanding of human learning and expert behavior share a common bond that can inform our understanding of the unique relationships amongst the body, the mind, and society that are expressed through expertise. This can be achieved by relating these ideas through two new perspectives that relate the largest and smallest scales of human experience: embodied cognition and ecological design thinking. At the conclusion of this discussion, we will have constructed a vision of how to theorize the construct of professional expertise in a way that is rich, adaptive, and purposefully delimited.

In the third section, we will examine one formulation of a multi-scale model of professional expertise in greater detail, focusing on primary (cognitive), secondary (metacognitive), and tertiary (socially situated) constructs as a means of building a more nuanced understanding of the relationships between cognition and environmental situation. The resulting model, the Theory-of-Action framework, will provide an understanding the development of professional expertise from a lived perspective. That is, we will attempt to represent the professional expert's cognitive and social knowledge as a constantly reifying phenomenon, instantiated from moment to moment like an electrical current in a circuit. This crucial step allows us to better understand opportunities for developing technologies to support the enactment of the professional's theory of action.

The goal of this synthesis is to develop an operational definition of professional expertise that functions at the ecological level. That is, to understand how learners turn experience into expertise, we must understand both their internal cognitive development and their reified performance within their complex work system. Since expertise develops in response to environmental challenges, it is necessarily tied to the individual's experiential history. Thus, the possibility for a third way of understanding and cultivating expertise emerges at the level of individuals' journey toward making sense of their environment and its demands, a story told through metacognition.

Part 1: Why Expertise?

1.0 What is Expertise?

There are many tools that one can use to describe the learning and behavior of highly skilled individuals in the context of their work, but research on the psychology of expertise provides us with a century's worth of tools and definitions for describing the phenomenon. We will briefly construct a meta-narrative of the history of the concept of expertise, so that we might locate its place and boundaries.

The search for definitions of 'expertise' in the activities of superior performers (a workable definition provided by Mieg, 2009) has roots in the early Twentieth Century. At the time, business professionals began to scientifically study the development of work-related skill through the use of time -and-motion studies (Taylor, 1908; N.B: The Gilbreths' and Taylor's 'scientific' research is thought to be questionable, as in Lepore, 2009). The intervening century has seen a substantial growth in the body of literature on expertise and its properties. Educational and psychological researchers approach definitions of expertise through three core epistemological lenses. The first lens, attributional definitions, attempts to define expertise by the empirically identifiable attributes of experts that researchers can study through experimentation. The second, cognitive study, examines the unique psychological and cognitive components of an expert in action. The third lens, socially situated expertise, takes a broader, community-based approach to defining the behaviors associated with expertise development and learning. This section will look at representative studies of these three lenses, and the potential contributions of each to a broader understanding of expertise.

As we shall see, one unique outcome of this research is the idea that expertise is not a single, reified element. That is, it a complex construct, the sum of a number of visible and invisible qualities specific to the individual and the environments they inhabit. And like an electrical current, expertise cannot be said to exist until it is called into existence by the individual's environmentally-situated needs. Unlike domain content knowledge or a knowledge of processes, the thing we call ‘expertise’ cannot be passed procedurally from expert to novice. Expert individuals are not automatons, and their behaviors resist attempts at codification. Rather, the story of the theorization of the development of expertise reveals a central discovery: Like building a ship in a bottle, learners must painstakingly construct expert behaviors and knowledge in their minds through interaction with a performance environment, and constantly refine and improve their theories of action through practice.

1.1 Attributional Definitions of Expertise

While one can observe experts in action in an array of disciplines, descriptions of expertise can describe only slivers of the complex whole of expert cognition. These slivers are attributes, used to describe and abstract the observable and reportable behavior (physical and cognitive) of experts into a generalizable rubric for evaluating the multiple facets of expertise. In this mode of inquiry, researchers define the attributes of expertise and study them individually or in concert. For example, attributional descriptions allow researchers the ability to select certain components of expertise for study and create experimental designs to test for the presence and degree of the attributes.

The National Research Council’s How People Learn (2000) and Mieg’s article on expertise (2009) offer complimentary descriptions of expert attributes as identified in the literature of cognitive science, psychology, and education. For the purposes of this discussion, we will confine our attributional definitions of expert behavior to an adapted series of constructs discussed by the NRC and Mieg. These include:

• **Superior Performance:** Experts demonstrate reliably superior performance in representative tasks. (Mieg, 2009)

• **Domain Specific Knowledge:** Experts possess a substantial body of conditionalized, organized, and context-specific content knowledge. (NRC, 2000)

• **Pattern Recognition:** The ability to notice meaningful patterns of and features of domain knowledge that are not noticed by novices. (NRC, 2000)

• **Automaticity and Fluency:** The ability to flexibly retrieve contextually important content knowledge and skills with little attentional effort. (NRC, 2000)

• **Approach Selection:** The ability to select, adapt, or innovate approaches for new problems and situations. This can also include personalized approaches generated through expert creativity (NRC, 2000)

• **Deliberate Practice:** The ability to identify new problem types and actively work towards a solution over an extended period of time. Expert-level performance may require 10 years of deliberate practice to achieve. (Mieg, 2009)

• **Metacognition:** Experts will use more elaborate metacognitive techniques to guide practice, approach selection, and promote pattern recognition. (NRC, 2000)

• **Professionalism:** Mieg (2009) asserts that experts tend to organize themselves into self-selecting, self-governing bodies that gate-keep and advance the field (i.e. professions). This is particularly valuable as a marker when 'reliably superior performance' is not easy to measure.

Though the literature's agreement on the attributes of expertise are a lynchpin in this history, these traits are not necessarily conscious or explicitly described and codified in all expert communities, and the list above is neither universal nor comprehensive. Further, the particulation of expertise can cause some problems for researchers who forget that the above list is merely a heuristic guide. As the NRC report notes regarding their six-fold principles of expertise, "the six principles of expertise need to be considered simultaneously, as parts of an overall system."

1.2 The Cognitive Study of Experts

The attributional lens of expertise provides us with a good starting definition for describing expertise, but the above descriptions of expert behavior and cognition imply that expertise forms in ways that are unique to individual learners, their context and experience, and their social and physical environments. In addition to the general elements of expertise illustrated above, researchers in the field of expertise study have historically attempted to describe the functioning of experts through the use of case studies in cognition.

Thought and Choice in Chess (1965) by De Groot provides a deep understanding of the individual and idiosyncratic nature of the cognitive elements of expertise. De Groot, a chessmaster and psychologist, analyzes the nature of chess expertise through a series of interviews, discussions about and between masters regarding their thoughts, and cognitively-oriented experiments. Part ethnography and part experimental psychological research, De Groot attempts to provide a balanced view of expertise in both experiential and objective terms through several interaction-based exercises with other chess masters.

One of De Groot's key experimental protocols involved elliciting 'think-aloud' descriptions of thought processes from expert players as they worked through chess problems that were for the most part chosen in such a way as to require some 'real' chess thinking of the subjects; that is, the positions posed problems difficult enough to expect thought processes of 10, 20, or even 30 minutes duration. (p.80)

When describing his selection of methods, De Groot explains the decisions that lead to his selection of the think-aloud method of examining expert cognition:

For such processes retrospection is out of the question as a technique: one cannot reproduce the course of the process with any reliability as soon as thinking time exceepds a few minutes. The only way of working with 'systematic introspection' would have been to interrupt the process…Apart from being unpleasant for the subject the technique is highly artificial in that it disrupts the unity of the thought process. So it was discarded in favor of 'thinking aloud.'… (p.80)

This type of experiment is substantially different from those conducted under the attributional research models. In this case, the interior mental state of the expert is emphasized, and their outward performance is reduced in importance (though not at all discounted).

Later, De Groot describes the limitations of this method by recognizing that the think-aloud method can only explore conscious phenonmena, and that some ideas are not easily placed into words. Further, the expectation to think aloud places an extra burden on experts that may not exist in ordinary practice. As he notes, "…verbalizing one's thoughts unequivocally adds an extra burden to the subject's task." (p.82) As a method of expert study, qualitative and cognitive studies like De Groots are very valuable, and can incrementally improve our understanding of how knowledge is constructed, contextualized, and recalled.

1.3 The Social Production of Experts and Expertise

Over the last 20 years, the attributional and cognitive studies of expertise have grown limited in their ability to fully explain the development of expertise, or to provide tools to make new and better experts. A more recent trend in the literature frames experts as socially produced entities that gather expertise through interaction with a community of interest. These communities contain experts and novices of varying degrees of proficiency who engage in meaningful practice, provide mentoring, and teach one another new knowledge. Through their interactions with the learning community, experts and novices develop their skills and advance their field.

One example of this perspective on expertise comes from Lave and Wenger's Situated Learning: Legitimate Peripheral Participation (1991). In the text, the authors propose legitimate peripheral participation (LPP) as a means of understanding how learning integrates into human social spheres, and how learning shapes those spheres. Though the book does not limit its scope to expertise, the authors make frequent reference to the question of how 'newcomers' become 'old-timers' in a community:

…in situations where learning-in-practice takes the form of apprenticeship, succeeding generations of participants give rise to what in its simplest form is a triadic set of relations: The community of practice encompasses apprentices, young masters with apprentices, and masters some of whose apprentices have themselves become masters. (p.56)

Through this line of reasoning, the authors establish the concept of LPP and its unity: it is simultaneously about the individual's efforts towards legitimacy (as in Maslow, 1954), their degree of peripherality (or relationship) to social activities, and their participation in a social sphere. To this end, the authors study the activities and social constructs that emerge in several different kinds of participatory communities, and how learning and mastery happen in those social enclaves.

In their shift from considering situated learning to "legitimate peripheral participation," the authors found that learning was not only a situated activity: "…learning is not merely situated in practice – as if it were some independently reifiable process that just happened to be located somewhere; learning is an integral part of generative social practice in the lived in world."

Thus, the study of these 'generative social practices' can tell us much about the ways that these communities of experts and novices form and evolve. In discussing the complexities of the evolution of these communities (their 'generation'), Lave and Wenger observe that:

One implication of the inherently problematic character of the social reproduction of communities of practice is that the sustained participation of newcomers, becoming old-timers, must involve conflict between the forces that support processes of learning and those that work against them. (p.57)

The existence of ‘forces that support processes of learning’ and ‘those that work against them’ imply that not all community-based learning is benign or beneficial for novice and expert development. However, the observation of expert communities from an ethnographic perspective may allow researchers to continue to observe communities of professional practice in action, and to design more effective learning communities.

1.4 Limitations Imposed by the Cognitive-Situative Divide, and New Opportunities

This brings us to the present day, where the bulk of the discussions of the phenomena of adult expertise in the academic literature place the cognitive (including attributional) and situative positions in a binary relationship. On the one hand, cognitive psychology has presented a highly detailed image of the various components of expert cognition as it appears in the minds and actions of individual performers and learners. This line of inquiry largely derives its data from quantitative experimental designs that trace particular facets of expert thinking in given domains. (Dreyfus and Dreyfus, 1986) On the other, educational philosophers and psychologists developed a socially situated view of expertise that examines the manifestations of expertise by individuals within a social environment. This research is qualitative in nature, and contains a number of excellent ethnographic studies of experts as they exist in groups and communities (Engstrom, 2003). These two ways of viewing the phenomena of expertise are powerful and broadly documented in terms of theory and method, and highly regarded within their respective research communities. However, researchers in the field must now work to close the theoretical gaps between these bodies of literature, or risk perpetuating a fractured field into the next century.

Part 2:
The Ecological Development of Expertise

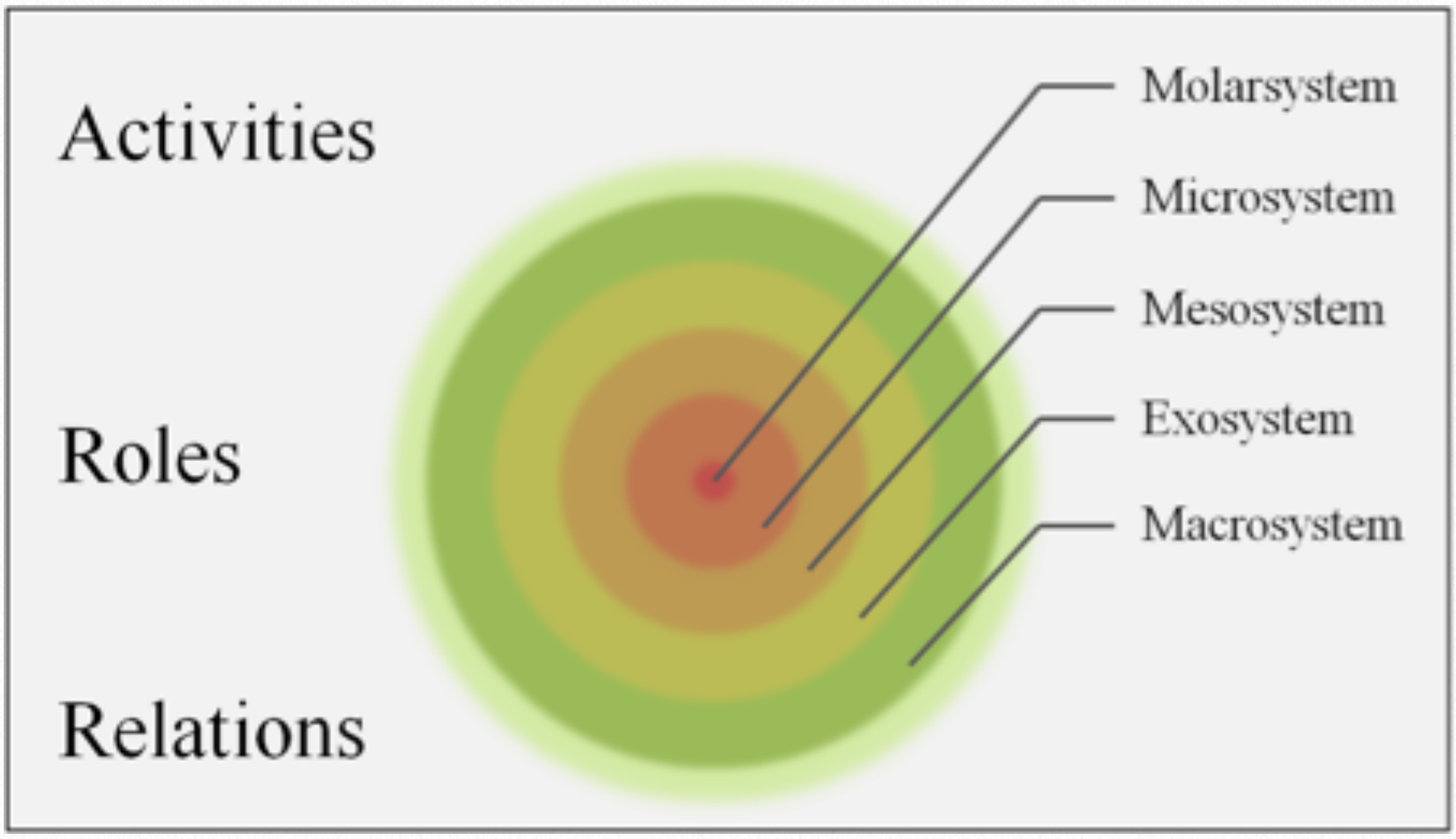


Figure 1 – Ecological Layers (Bronfenbrenner, 1979)

2.0 A Framework for the Ecological Perspective of Professional Expertise

This part of the paper posits a model of professional expertise that operates at multiple levels of the individual's experience. The idea of an ecological perspective of human development (advanced by Bronfenbrenner, 1979, and represented in Fig. 1) allows us to examine the reciprocal developmental relationships that occur between the professional. More importantly, the ecological perspective of the professional environment allows us to the different levels of learning that give the ability to reify their expertise without developing occluded or distorted lenses at different levels. Thus, our goal for this section is develop an understanding of the various interlocking levels and components of learning that influence the development of professional expertise at the Cognitive, Metacognitive, and Situative levels (Fig. 2).

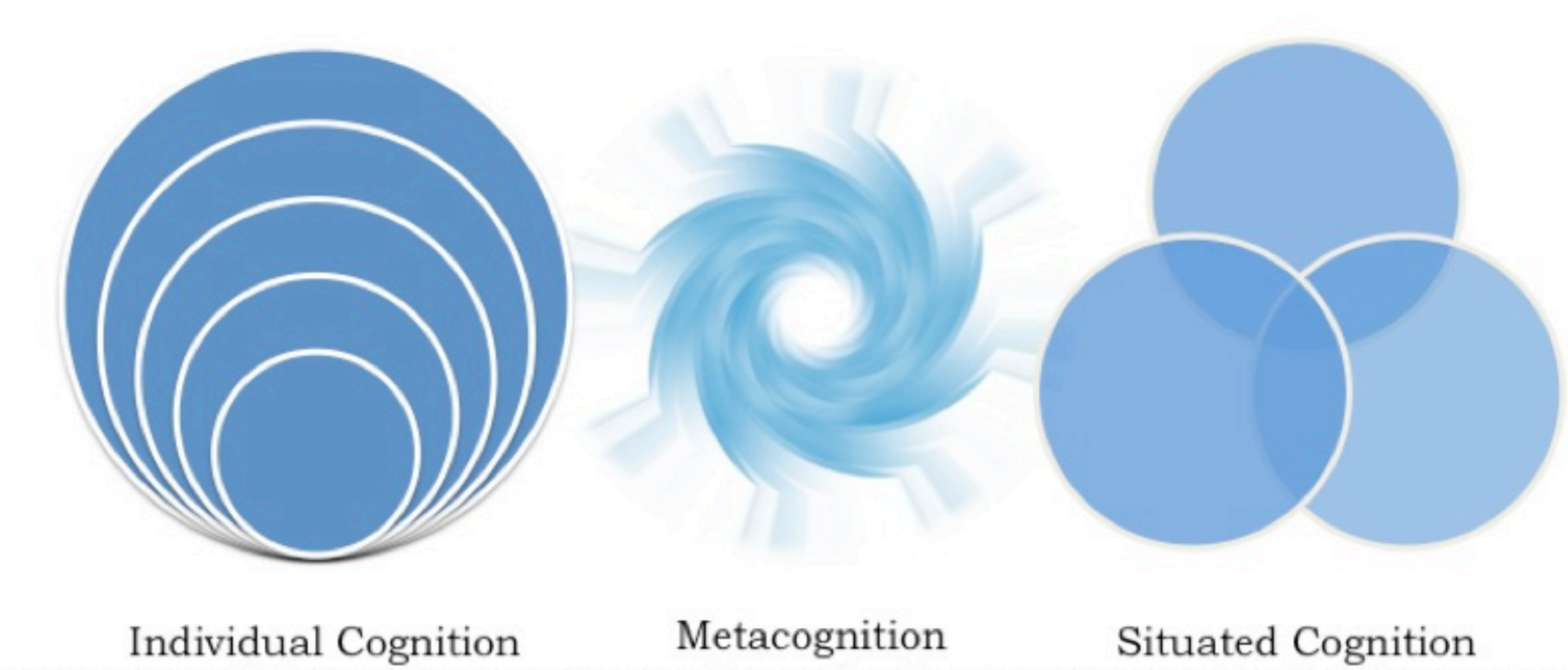
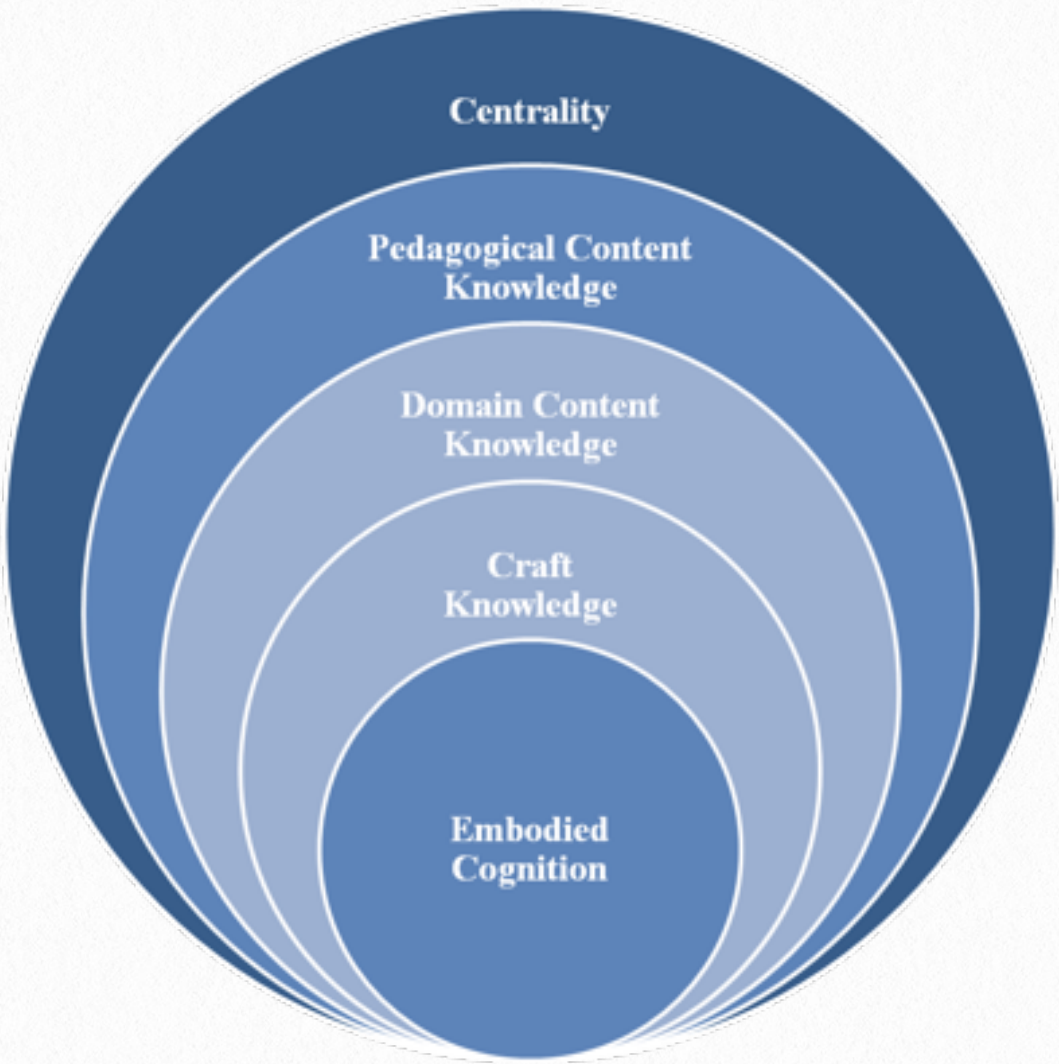


Figure 2 – Layers of the Expert Professional Ecosystem

This goal will culminate in the identification of an operational framework for understanding the interactions of internal and external processes that influence the mind and ecology of professional practitioners. This framework will allow us to imagine new questions and new opportunities for the development of life-long learning systems (as described in Collins and Halverson, 2008)

The complexity of this problem will require the synthesis of both perspectives, as expertise is a non-reified phenomenon, but one that is visible in different forms in both individualistic and social dimensions, as well as the ways that metacognitive strategies mediate this relationship. First, we will examine the relevant cognitive literature on expertise to identify some of the consistently visible constructs in expert cognition, so that we might later understand how to prepare appropriate training and performance support tools that grow these structures. Second, we will examine the Metacognitive construct, so that we can understand how people make meaning of their own knowledge, experience, and emotions (Briñol and DeMarree, 2012). Third, we will examine a possible map of a professional learner's socially situated Theories-of-Action (Argyris, 1965) that will help us to understand the kinds of social phenomena that influence the practice of learners in high-trust performance environments. This will help us to imagine and design future tools that are aligned with the social pressures from the professional expert's larger world. A Situated Theory-of-Action perspective on learning implies the development of a capacity for self-knowledge, a quality common to the set of skills that we will define in the expert metacognition construct. With this construct definition in hand, we will be able to confront the larger challenge of understanding the role of technological interventions in cultivating professional expertise.

2.0 Cognition



2.1.1 Embodied Cognition

Embodied cognition (Glenberg, 1997; Johnson, 1987) has been placed at the core of this construct to challenge institutional notions about the nature of the origins of professional knowledge. As the theory states, all humans come with certain kinds of knowledge that exist as a result of the body's role in mediating the brain's thinking, and vice versa. This core knowledge of the body, time, space, movement, and affective domain (Damasio, 1994; Moulyn, 1991) are 'pre-programmed' into the human body, but many share reciprocal relationships with other phenomena (including language, socio-cultural context, and in-group/out-group behaviors) and must be learned over time. However, this construct also contains physio-affective phenomenon that exist beyond the confines of cognition, including bodily functions like hunger, performance anxiety, and emotional responses that can influence cognition and behavior in high-stakes performance environments like those inhabited by professionals.

From this perspective, the organization of particular biological structures of the brain and body exert a co-constructive influence on cognition at all levels of the individual's experience. For example, contemporary research in neuroscience indicates that an individual's capacity for empathy is enabled by the formation of a specific brain region (potentially the anterior cingulate gyrus), and that the phenomenon 'appears' suddenly in the minds of children when the region forms inside their brain. In another contemporary example, neuroscientists have found that nerve cells in the intestines (Watzke, 2010) inform the brain's thinking at non-conscious levels. The further identification of specific 'neural correlates' for various phenomena in the brain is an ongoing quest, but one that should yield substantial benefits as increased computing power makes the naturalistic simulations of neurons possible in the next ten years.

Studies of neurons in the stomach are well and good, but what role does the theory of embodied cognition play in this framework, and what do we gain by placing it at the center of the Primary Cognition construct? In applying the perspective of embodied cognition to the phenomenon of professional expertise, this section will bracket-in five kinds of knowledge that professionals gather from their body during the course of their years of practice. Conventional forms of professional education (e.g. universities and professional development programs) ignore the essential nature of these body-based forms of cognition, and do so at their peril. By including these embodied phenomena in our understanding of professional expertise, we may hope to develop forms of education and learning that engage these overlooked facets and integrate them into a powerful whole:

• **Homeostasis:** At the core of embodied cognition is a simple fact: Homeostatic needs influence cognition at every level. Hunger-thirst, fatigue, warmth, stress, safety, and other bodily needs have profound effects on the individual's ability to concentrate and perform. These non-conscious neural events release hormones and neural transmitters (such as cortisol and norepinephrin) that can have immediate and delayed effects on cognition, memory, attention, and problem-solving skills (Mattarella-Micke, Mateo, Kozak, Foster, & Beilock, 2011). This parallels Maslow's Hierarchy of Needs (1954), a framework that also begins with the body's physical states and perceived physiological and psychological 'safety.' For these reasons, professionals learn to manage their homeostatic drives as they perform in their environment, finding ways to cope with stress, uncertainty, uncomfortable environments, and fatigue required by high-trust work.

• **Affective States and Attitudes:** The connections between the brain's long-term memory storage regions in the hippocampus and executive processing regions in the neocortex run directly through the thalamoid region. That is, memory, higher-order cognition, and emotion are related through physiology, by virtue of the electro-chemical circuitry of the brain. This leads to a new adage about the nature of thought and knowledge: There is no cognition without emotion (Lazarus, 1982). When emotions are coupled with various forms of memory and cognition, we may term these phenomena attitudes (Forgas, 2008) and dispositions (Bourdieu, 1977; Hilgers, 2009; Hulbert, 2009), or general orientations towards specific stimuli in a domain that persist over time. The management and interpretation of one's 'feelings' (including fluid affective phenomena like emotions and long-term crystalline attitudes) in a complex environment has significant implications for professionals, as affective orientations can expand or bracket opportunities and expressions of thoughts. Equally, the lag between the individual's emotional reaction and the cognitive identification of the source of that emotion can lead to the Misattribution Effect (Krull, 2001), or the assignation of emotional value to the wrong stimuli. As we shall see later, the correct and rapid interpretation and management of emotional responses is a key factor in the kinds of metacognition undertaken by professionals.

• **Values and Valence:** Fargas (2008) notes the importance of attitudes and emotion towards users' perceptions of phenomena and objects in his discussion of the concepts of value judgments and valence. Liberman, Trope, and Rim (2011), note that values provide continuity and meaning in changing circumstances, and can serve to inform predictive behaviors in complex performance environments. Equally, Niedenthal and Halberstadt (2000) observed that individuals in experimental conditions tended to organize their knowledge around the 'goodness' and 'badness' (valence) of otherwise unrelated phenomena, and to make judgments based on these perceptions. In this way, non-verbal 'feelings' about goodness/badness may guide any number of key components of expert cognition in professions, and may express themselves as emotional or physiological feelings (e.g. Watzke, 2010). For example, a doctor's sense of value and valence in regard to chiropractics may hinge on their non-conscious feelings towards the field. These feelings may cause individuals to group it with other kinds of desirable or undesirable practices, warranted or not (Krull, 2001; Hurlburt, 2001). While valence and value may contribute to the speed of a professional's thinking and diagnosis, these kinds of knowledge may also have real-world consequences for clients if the professional's values are misaligned with those of the field.

• **Kinesthetic Senses:** Kinesthetic knowledge contains the body's intrinsic knowledge of the relationships between gravity, time, space, motion, and the body's interactions (e.g. balance) with these forces (Gardner, 2004). This phenomenon occurs at the level of interpersonal communications most regularly in the projection of an individual's emotional and psychological state in the in the form of body language (Beattie, 2004; Matsumoto, Frank, and Hwang, 2013). The importance of these senses to human activity are further emphasized by the existence of specific neural substrates, known as mirror neurons, that allow humans to feel, process, and interpret the intentions of others (Meltzoff & Decety, 2003).

2.1.2 Craft Knowledge

Beyond the individual's knowledge of the uses and capabilities of their bodies and emotions, the Craft Knowledge construct of professional expertise includes contains two core areas of expertise. First, it involves a knowledge of the tools and environments that interact with the body in the individual's experience, from chairs to stethoscopes, and second, a knowledge of the social meaning of these tools. All of these tools (from black boards to computers) are symbolic in nature (Vygotsky, 1975), and imply certain kinds of activities and uses. For example, the height of a desk and a seat communicates to the individual how they should interact with the surface of the desk (for example, a lack of seating implies that they should stand, or perch on a high stool, or sit in a chair; as in Petroski, 1992).

The development and operation of specialized tools that fit into these performance environments is a core feature of the specialized knowledge contained within professional practice and guarded by professional bodies. For example, any person with ears and hands may operate a stethoscope, but in legal and moral terms, only a doctor may use this device to make a diagnosis. Further, the professional's 'feelings' and judgments about the use of tools in an environment can have significant implications for the professional's performance of a task in the environment (Rose, 1999; Rose 2005; Crawford 2010). The knowledge of tool use is also essential because it is the product of extended socio-historic situational development, and derives its power from the passing of one legitimate participant to another.

Professional environments, from laboratories to hospitals to courtrooms, are also defined by the relationships and processions of bodies in space and time, and are imbued with significant social meaning. Social and cultural metaphors have been inscribed into these spaces, as in the elevation of a judge's bench (e.g. that the judge's authority is greater, and thus 'higher,' Lakoff and Johnson, 1980). Thus, a professional's knowledge must also contain knowledge of where they must stand, how they must move, where they may access physical resources or sources of authority, as well as how to 'read' and relate these constellations of environmental data.

2.1.3 Domain Content Knowledge

Domain content knowledge represents the totality of the individual's existing knowledge about the actors, resources, and processes that occur in a particular field of human endeavor (NRC, 2000). These domains exist on a continuum from 'highly-structured' to 'ill-structured' depending on the parameters of the skills and knowledge involved. Highly structured domains are described in terms of objective processes performed by known actors using known resources, as is the case with some areas of aircraft maintenance. They are marked by a finite number of contexts where one can apply a finite number of rules. The learner's existing level of expertise (including their prior knowledge) and the structure of the knowledge domain are key mediating variables that determine the process that guides learners' construction and deployment of knowledge and skills. These variables also tell us much about how experts in professions order content in their minds, apply strategies, and integrate tools into the training environment.

In her essential text on technical training, Clark (2008b) defines five classic knowledge types, given in order from most domain-content specific to most metacognitive: 1) Facts, 2) Concepts, 3) Processes, 4) Procedures, and 5) Principles. In a larger sense, these forms of knowledge roughly correlate with two forms of long-term storage in the brain: declarative memory and procedural memory.

Knowledge stored in declarative memory (typically facts and concepts) is easy to articulate verbally, and may involve concrete or metaphorical descriptions. Declarative knowledge can also refer to a learner's ability to construct a meaningful understanding of facts, concepts and principles, through the organization of information into schemata in memory (Anderson, 1983; NRC, 2000). While declarative knowledge describes how schemata and mental models are constructed, humans use procedural knowledge (including processes and procedures) to deploy cognitive strategies based on those mental models. Procedural knowledge (typically individual processes and larger groups of processes called procedures) holds information about how to do things. Procedural knowledge (Anderson, 1983; Glaser & Chi, 1988) comes about through the utilization of two cognitive strategies, proceduralization and composition. Proceduralization involves making comparisons of the problem state before and after the individual's attempts to solve the problem. Successful problem solving leads to the formation of a production rule (if/then). Composition involves cognitively collapsing or chunking a number of production rules into a single production (or procedure) that integrates with declarative knowledge in the domain schema.

As novice learners continue to solve problems within a particular domain, they develop sophisticated cognitive strategies that allow for greater pattern recognition of superordinatate, coordinate, and subordinate relationships between scaffolds (known as 'principles'). The proceduralization and subsequent composition of 'chunks' of knowledge frees up the space in working memory through the development of automaticity (Clark and Mayer, 2008; Clark, 2008a). The high degree of automaticity present in a professional's thinking allows him or her to process the relationships and strategies more quickly by offloading these tasks from the working memory to other subsystems. This allows for faster predictions, faster application of knowledge, and the ability to address multiple facets of a problem at once (Bar, 2011).

While domain knowledge can take a number of forms, from facts to principles, it is important to recognize that the development of the broad domain knowledge formed is a result of three factors in their environment. First, expertise in a domain comes as a result of repeated exposure over time. That is, learning all of the features and relationships of a professional domain may take more than ten thousand hours of immersion in a practice environment while engaged in routine and deliberate practice (Ericsson, 2007).

Second, it is important to remember that domain knowledge is bound to specific contexts; that is, expertise and knowledge may not necessarily apply from one domain and performance environment to another without further scaffolding and metacognitive reflection. Thus, experts in a particular field (like neurosurgery) may not perform efficiently in substantively different areas of practice (like podiatry). The ability to make cross-domain connections belongs to the realm of adaptive expertise, as we shall see later.

Finally, the continued development of a professional from novice to expert advances through the individual's ability to find more challenging tasks and harsher environmental and time constraints. That is, in order to continue developing, experts must continually find new problems to work or new ways to use resources and tools. This process can be hampered by the siloing of roles and information in organizations, as social structures and roles may prevent the professional from finding new problems in their ecosystem. However, experts may persist in their learning and development through a social process of engaging with knowledge that we typically term 'teaching.'

2.1.4 Pedagogical Content Knowledge

Common knowledge provides us with an oft-quoted maxim: "Those who can, do; those who can't, teach." As with most common knowledge, this statement is incorrect at every level. Teaching is a core means of development for growing professionals, especially as they begin to strain against a phenomenon known as the 'Expertise Reversal Effect" (Kalyuga, 2007; Leahy and Sweller, 2005). Expertise Reversal is a decrease in performance that occurs when individuals with some degree of existing content knowledge are presented with learning experiences that are too basic for their current level of knowledge. Kalyuga, Chandler and Sweller (1998) attribute this phenomenon to the increases in cognitive load that occur when an individual is presented with information that they already possess. This additional, unnecessary load on working memory depresses their ability to make decisions based on their internalized knowledge, as the uptake of redundant knowledge relies on slower, less automated processes (like reading comprehension). The benefits of conventional training programs continue to diminish as learners grow more fluid in their application of domain knowledge to their environments. It is at this point that the benefits of teaching and mentoring may help burgeoning experts to find novel problems in their domain that challenge them to apply their knowledge in new ways Thus, we may reformulate the adage: “Those who can may teach” (similar to Shulman’s “those who understand,” 1986).

This brings us to another article of common knowledge that gets to the heart of the matter. Unlike the previous foolish axiom, this one comes in the form of a question: “What is the only thing that increases as it is shared? Answer: Knowledge.” It is from this vantage that we can begin to understand the nature of teaching and learning as forms of cognition that scaffold and promote the growth of other kinds of cognition. As novice professionals continue their growth and development, pedagogical content knowledge (Shulman, 1986; Ball, 2000) takes on a key role in their continued evolution.

Pedagogical content knowledge contains the individual’s knowledge of the domain plus meta-knowledge about the common metaphors, problems, and reactions of others to the content. Experts benefit from this process by gaining access to new problem spaces within the domain where they may apply their existing knowledge, and growing experts benefit from the opportunity to watch the mind of an expert at work. In service as a more knowledgeable other for their community, emerging experts may skirt the Expertise Reversal threshold by helping others to solve nonprescriptive problems that require novel applications of domain knowledge while also finding ways to codify and verbalize those thoughts.

2.1.5 Centrality

According to Lave and Wenger (1991), the quest for centrality of participation is a key goal for communities of learners, and an important means of creating and spreading expert knowledge to the rest of a community. Thus, centrality begins to tie what is in the mind of the individual to their larger social and performance environment through the lens of social ties within a community (Wenger, McDermott, and Snyder, 2002). Centrality also describes the tendency of communities of experts within a profession to interact and trade ideas, and for experts to contextualize their new knowledge relative to the perceived centrality of the individual who has brought that knowledge to them. This is evident in the formation of professional organizations (the American Society for Training and Development, in the case of instructional designers) and informal groups that meet to share ideas and techniques, and to offer new avenues for deliberate investigation.

Within these formal and informal groups, individuals attempt to establish themselves as legitimate participants who are worthy of the attention of their peers, and thus engage in the exchange of ideas with others. These exchanges are the mechanism that promote the development of knowledge beyond the individual's own mind and into a dialog with the larger field. This can be seen in the highest levels of Maslow's Hierarchy of Needs, where the need for self-actualization intersects with the need for community-determined legitimacy, acceptance, recognition, and involvement. It is in this space, where the individual's mind begins to reach out to the minds of others in their environment, that we begin to see opportunities for the development of tools to help professionals achieve connections to their social world.

3.0 Metacognition

Figure 3 – Metacognitive Processes

Secondary Cognition: Metacognition and Expertise in the Professions

Metacognition is colloquially described as an individual's "thinking about their thinking," but this description does not begin to capture the significance or complexity and importance of the construct that we will examine in this section. Rather, we will see in this section that the human capacity for metacognition serves as a bridge between the individual's interior universe and their external environment. It is the constantly-resolving map of our internal knowledge onto the ecologies and roles that we inhabit. From this view, we may begin to understand metacognition as it manifests in action; as a set of interlocking and interconnected processes that help us make sense of the world. This conception of the phenomena echoes early trends in the study of metacognition (as in Vygotsky, 1975), but also provides us with a new avenue for understanding the role of metacognition in professional expertise.

Following this logic, metacognition serves as an important middle ground between the cognitive and situative components of professional expertise for three reasons. First, the predominantly linguistic nature of metacognition (Son, Kronell, Finn, and Cantlon, 2011; De Groot, 1965; Vygotsky and Kozulin, 1986) makes it possible to collect and analyze traces of professionals' thinking and attitudes, a feat that is not possible when analyzing other non-verbal components of expertise in this framework (e.g. 'gut feelings' in embodied cognition, Gladwell, 2007). Also, it is important to note that Son et al. also indicate the possibility that individuals' memories of their metacognitive activity are not necessarily reliable or accurate without training, and that non-verbal metacognitive constructs might exist.

Second, the research in the area has come to a broad consensus about the general features of metacognition, and the role it plays in expertise. That is, because of the breadth of the research agendas represented in the area, it is possible to construct an elaborate taxonomy of metacognition (as in the excellent work of Tarricone, 2011) that provides a broad picture of the phenomenon. These constructs can be placed into a meaningful relationship for the purposes of analysis and study. Finally, the known constructs of metacognition appear to occupy an unusual place between the internal and external world, with a number of key conceptual overlaps between the known structures in the cognitive and situative frameworks. This could indicate that a marginal increase in focus on training the relevant metacognitive skills of professionals could yield improvements in skills throughout the professional's learning ecology. This location between the internal and external world of the learner has caused some researchers in K-12 education to propose that metacognitive skills be integrated with disciplinary content across the curriculum and throughout the learner's lifetime (NRC, 2000).

Finally, metacognition will play a key role as a means of enabling researchers to understand how novice and expert professionals continue to connect their experiences in their performance environment with the ways of thinking that they develop in their learning environments (if those things are indeed separate). If metacognition is indeed a mediating factor in the development of a number of core skills that

Inward-Oriented Metacognition	Outward-Oriented Metacognition
Self-Reflection and Self-Knowledge	Theory of Mind
Self-Regulation and Affective Management	Role Taking
Strategy Selection and Deliberate Practice	Persuasion
Metamemory	Historiography
Imagination	Creativity
Design Thinking and Adaptive Expertise	

professionals employ in the context of their practice, then a contemporary understanding of the phenomenon will help us understand and predict the expertise reification events and ‘bugs’ (Wenger, 1987; Wenger, 1998) that occur in the thought environment of professional individuals.

While there are many other possible phenomena that could be included in the construct map, these ten were selected because of their direct relevance to the development of professional expertise at both the cognitive and situative level. As such, the ten constructs are divided into two categories: Inward-oriented and Outward-oriented Metacognition. This rough categorization presents some epistemological concerns, as some known components of metacognition are bracketed out, and recent discoveries from social psychology are bracketed into the framework. However, the author would contend that this model’s perspective on metacognition provides us with ways of access to some of the highest forms of intellectual activity in human life, and set them in relationship to other levels of the human ecology. Further, the combinations and interactions of these cognitive-situative phenomena allow us to create a higher-resolution view of the link between the professional’s performance environment, their thinking, and their life experiences.

The metacognitive construct map draws from existing literature to help us understand some of the known constructs in the area of metacognition, and how they can illuminate our understanding of the real-time co-development of individual minds and their ecologies.

3.1 Inward-Oriented Metacognition

The constructs embedded in Inward-thinking metacognition are concerned with the expert professional's ability to use, make sense of, and advance their knowledge an abilities based on the cognitive forms of knowledge that they have scaffolded in their minds.

3.1.1 Self-Reflection and Self-Knowledge

As noted by Tarricone (2011), the capacity for self-reflection and self- knowledge are the building blocks of metacognitive practices. Shulman's Model of Pedagogical Reasoning and Action (1987) places reflective practices at a key phase in the continuous process of learning, as a means of developing professional expertise. Through this model, Shulman provides a working definition for reflection as "what a teacher does when he or she looks back at the teaching and learning that has occurred, and reconstructs, reenacts, and/or recaptures the events, the emotions, and the accomplishments" (p.19). Shulman (1998) further contends that reflection (as a form of learning from experience, p.519) is a necessary bridge between the "universal principles of theory and the narratives of lived practice" that characterize professional bodies of knowledge. However, Shulman's implicit distinction between theory and practice brings forth two further questions: Whose theories are applied in practice, and how should practice be used to inform theory? These are complex and murky questions, and Shulman grapples with them throughout his work (e.g. 1986; 1987). However, the work of Chris Argyris's in organizational psychology and K. Anders Ericsson in the field of cognitive science can help to develop more particular and operational understandings of self-reflection as a means of knowing and learning.

Argyris (1997; Argyris, Putnam, Smith, 1965; Argyris and Schon, 1974) locates the importance of reflection in its role as a key component of the 'double-loop learning' cycles that characterize expert learning. In double-loop learning, professionals plan, act, analyze, and retry solutions in their environment using the constructed identity, knowledge tools, and practices available to them as part of their 'theory of action.' According to Argyris, the double-loop learning model can help teachers and learners understand and calibrate their behaviors relative to their desired outcomes, existing knowledge, role-identity, and available tools. Equally, a learner's theory of action can be seen as a means of exerting control over and bracketing complex problems, another component of cognitive perspectives on expert behavior. However as Argyris notes, the specifics of the individual's theory of action can reveal information about the context of its creation. This is important, as the 'double-loop' feature of reflective learning requires learners to evaluate the underlying assumptions, strengths, and deficiencies in their theories of action in hopes of improving their performance between their initial effort and their future iterations of efforts. This construct is also supported by Schon (1983), who describes this process as 'reflection-in-action,' and "Research not about or for practice, but in practice." (Schon, 1988, p.19) While Shulman disagrees with Schon's dichotomy of technical rationality and reflection-in-action (Shulman, 1998), both agree on the intrinsic value of reflection as a type of learning. In analyzing their assumptions, actions, and decisions for continued areas of improvement, professionals may learn to become autonomous and self-directed in their learning, a key element of professional disciplines (similar to Abbot, 1988).

3.1.2 Self-Regulation and Affective Management in Experience

This facet of the metacognitive construct deals with two related kinds of mental practices that individuals use to actively sense, monitor, and alter their motivational and emotional

For a learner to make use of their new declarative, procedural, metacognitive, and social knowledge, they must find an intrinsic source of motivation to put that knowledge into practice and the ability to transfer their developing expertise to their performance environment (NRC, 2000). The issue of motivation and affective regulation are deeply embedded within the literature on expertise. This is because the maintenance and management of these nonconscious phenomenon (specifically, intrinsic motivation and heuristic controls of fear responses) are an essential part of development their skills and knowledge beyond mere competence. Thus, Passion and Courage are the twin features that keep learners focused on finding new challenges and ways to explore their growing expertise in new environments.

According to Clark and Lyons (2004), motivation is a product of a learner's situational and personal interest regarding a topic. Situational interests include emotional and cognitive sources of interest, such as excitement, or the promises of clarity that are provoked by the learning materials or expeniences. These forms of interest produce 'extrinsic motivation,' so-named because it comes from an outside source. For example, it is relatively easy to capture a learner's interest using a funny or dramatic graphic. This develops a relatively shallow degree of interest that evaporates over time, and the use of purely emotional or 'interesting' content can potentially depress learning in the long-term development of expertise. Personal interest, on the other hand, comes from a learner's own inclinations, predispositions, and curiosity. Since these inclinations are personal and 'intrinsic,' they make use of the learner's own prior knowledge and past experience.

Clark and Lyons provide four guidelines for the development of interest through instructional materials and environments. First, they recommend using materials that are high in situational interest (stories, visuals, music, etc.) when learners have little personal interest in the materials; equally, do not cultivate situational interest when learners have a high degree of personal interest. If learners are intrinsically motivated, extrinsic sources of motivation may increase cognitive load and disrupt learning. Second, make the relevance of your learning experience to the learner's personal interests clear to the learner. This will help them understand the relevance of the event to their personal interests, and engage their personal motivation in a way that generates effort and persistence.

Third, Clark and Lyons recommend carefully controlling the use of emotional interest in topics, as the internal control of emotions can add an extra burden on a learner's working memory. Cognitive scientists have observed this phenomenon in the brain, and have identified several key neural pathways that directly connect memory storage points in the hippocampus to emotional centers in the brain's limbic system. Memories stored in long-term and working memory must pass through the brain's emotional processing area on the way to the frontal cortex, where they enter into conscious thought. This has led to the general axiom "There Is No Cognition Without Emotion." However, emotion must be managed in order to maximize the available 'bandwidth' in working memory (Sweller, 2011).

In this vein, Csikszentmihalyi's Conditions of Flow (2008) describes a psychological state that provides another way of understanding the impact of cognitive load on the suppression of affective phenomena. Csikszentmihalyi describes Flow as a state of focused motivation and engagement, wherein the performer harnesses their emotional and affective processes in the service of their task. Equally, learners in a state of Flow may find ways to block out certain kinds of affective phenomena through a deep focus on their activity.

In qualitative studies of this state, Csikszentmihalyi describes the common qualities of the Flow experience in the context of a performance environment:

1. Learners can identify clear goals, expectations, and rules for the activity. This relates to self-efficacy, and the belief that a problem is solvable.

2. Concentration on a limited field of attention, and absorption into the activity. This focused attention can be difficult to obtain in ordinary classroom environments, where boredom and anxiety can disrupt the students' focus.

3. A loss of self-consciousness. This relates to the previous concepts of self-regulation.

4. The activity, environment, or facilitator provides direct and immediate feedback to the learner.

5. The activity provides a shifting balance between the learner's ability level and the activity's challenge, where the activities become more difficult as the learner's skills improves.

6. The learner has a sense of personal control over the activity and situation. This relates to agency and self-efficacy.

7. The activity is intrinsically rewarding to the learner. When the learner deeply invests their attention into a task that they consider intrinsically rewarding, Csikszentmihalyi describes the result as a state of 'Joy.' Joy is seldom discussed in the literature on expertise mathematics, perhaps to learners' detriment.

These conditions of Flow have been observed in a number of high-performance arenas (like chess, athletic activities, and artistic endeavors) that involve professional expertise, but can also occur in more mundane environments. A design-based experiment by Annetta, Minogue, Holmes, & Chang (2009) found that high school genetics students reported more engagement when a challenging game environment was employed to teach them content as compared against standard classroom activities (though scores on classroom assignments remained equal). Recent neuro-cognitive studies also show that the cognitive load encountered during engagement conditions like Flow may enable students to ‘tune down’ their emotional impulses. Van Dillen, Heslenfeld, and Koole (2009) found evidence for a link between decreases in emotional responses and increases in their ability to manage cognitive load in their study of fMRI results from thirteen adult women. As we examined in the embodied cognition construct, emotion plays a deep and essential role in cognition, and the knowledge reflected by these emotional responses are key to many kinds of professional thought. However, professionals must practice and develop their self-regulation and affective control skills throughout their careers to prevent burn-out and maintain a productive disposition.

3.1.3 Strategy Selection in Domains and Deliberate Practice

Once learners have become engaged with a problem and are able to regulate their emotions during the activity, they must determine the relevant features of problems at hand (De Groot, 1965; Schoenfield, 1992) so that they may begin to align the necessary resources to achieve their goals. As professionals continue to learn and solve problems more efficiently within their specific domain and context, they develop sophisticated cognitive strategies that allow for faster pattern recognition of relationships between important variables. Moreover, the proceduralization and ‘chunking’ of knowledge frees up the space in working memory through the development of automaticity (Clark and Mayer, 2008). Automaticity is visible as both a reified, cognitive, and neurological phenomenon that can develop in tandem with the growth of domain content knowledge. Thus, it is possible to understand how learners become more efficient in their strategy selection by examining how they learn to construct strategic pathways in their mind through the use deliberate practice. That is, if strategy selection is a metacognitive component of expertise, we may understand it more efficiently by looking at how learners acquire this set of skills over time.

Ericsson’s model of deliberate practice (2006) provides the means, or techniques of practice, necessary to put Shulman’s definition and Argyris’ processes from the Self-Reflective construct to work by further improving the reflective capacities of professionals. As Ericsson notes, optimal practice involves a balance of four variables: 1) the learner must focus on specific skill deficits; 2) the learner must receive explanatory feedback and active support; 3) the learner must practice in a sheltered practice environment; and 4) practice in ways that promote skill transfer from the practice environment to the performance environment. In the literatures associated with cognitive neuroscience, the implementation of deliberate practice is known to enhance the myelination (a protein that insulates neural pathways) of neurons when applied rigorously (Ericsson, 2006; Wlodkowski, 2008). That is, deliberate practice applied over time has the capacity to help practitioners make decisions more quickly, more consistently, and with less strain on cognitive load and attention (Clark, 2008b).

As professionals of all stripes continue to develop their knowledge of domain rules and content, their decision making and strategy selection may appear to take on a form of 'gut instinct' in their performance. This 'intuition' is currently the subject of a number of fascinating studies in psychology and artificial intelligence. Glockner and Witteman (Foundations for Tracing Intuition, 2010) identify four potential kinds of intuition that may require further research and understanding in the context of professional performance. These include (from simplest to most complex): 1) Associative Intuition, 2) Matching Intuition, 3) Accumulative Intuition, and 4) Constructive Intuition. According to Glockner and Witteman, these models build on one another over time, and their overlaps and interactions are potentially the source of professionals' ability to make educated guesses about otherwise unpredictable phenomena and complex expectations in their environment.

3.1.4 Metamemory

Following on the issue of strategy selection and deliberate practice, we may begin to understand the role of memory as the system/process that helps individuals to control and order their experiences over time. Contrary to popular belief, memory is not a single, linear process; that is, our minds are not video cameras, passively absorbing information about the world and storing it in an arbitrary space (Bernecker, 2008). Rather, it is possible to argue that memory is both a neural system and a complex, delicate process that produces the illusion of the ability to recall past events by reinstantiating several kinds of data about past environmental conditions in the individual's mind at the moment of recollection. Suprenant and Neath (2009) identify five key types of memory that have been established by the literature that appear to operate according to several fairly consistent sets of rules (including Procedural, Sensory and Perceptual-Representational, Semantic, Working, and Episodic memories). These systems work in tandem with other components of the neural network to re-render memories in real-time using input from the body.

Despite their excellent work identifying the core 'principles' of memory, Suprenant and Neath do not fully explain the nature of any master-controller processes that exist in the memory-system. However, Tarricone (2011) and a litany of other researchers (e.g. Corsini, 1971; Hacker, 1998; Perlmutter, 1988) have developed a number of models to describe the interactions of the various components of memory, as well as the metacognitive component that allows the disperate memory processes to form a coherent 'narrative' in the mind of the individual. In summarizing this body of research, Tarricone describes this controller process as 'metamemory,' or the conscious recollection and reconstruction of memory in emerging circumstances. Tarricone further decomposes metamemory into three components: 1) an individual's knowledge of the presence (or absence) of their memories and the content of those memories, 2) the regulation of the formation of those memories, and 3) the selective attention to particular events in memory. These constructs work together to help the learner understand their own experience, but also to bracket out unimportant information given the current circumstances.

This conscious meta-process of 'using' memory to solve problems also involves the management of 'primer' events by the learner or another agent in their environment. Priming events can take the form of perceptual, semantic, or conceptual stimuli that influence later behavior and responses from an individual (Stanovich and West, 1983). For example, learners at all levels of performance use verbal pneumonic primers (.e.g. "Leaves of three, leave them be") to identify domain knowledge and other elements in their own memory, and to create priming cues in the memories of others. The lives and work of expert professionals are filled with such primers, from rules of thumb to idiomatic received wisdom from legitimate participants (e.g. "Form Follows Function" in Architecture, though this is frequently cited inaccurately). In addition to verbal primers, the motions (Scott, Harris, and Rothe, 2001), sights, sounds, tastes, feelings, and smells of a performer's environment can be key in priming key pathways in their memory. In this way, the professional's priming experiences in the practice environment directly mediates the memories that learners form in their minds (Rose, 1999; Greeno, 1998). However, it is possible to posit the idea that some of an expert professional's skill in action comes from mastering the control of primer phenomena in memory. That is, professional expertise may involve the active manipulation of these memory primers on the part of the individual as a means of augmenting their ability to recognize patterns in complex environments.

3.1.5 Imagination

At the borderlands of the Inward-facing metacognitive construct, we begin to encounter some of the most complex kinds of metacognitive thinking available to individuals in professional contexts. At the end of the individual's capacity for self-analysis, the individual's ability to posit "If" questions about the world becomes increasingly important. These questions may help to guide their thinking and actions in a number of ways that are essential to managing and understanding the complexity of the knowledge domain, cross-domain connections, and the performance environment. Since the metaphors for these skills are predominantly associated with sight in the English language ("vision," "seeing," and "foresight," as in Brann, 1991), this construct has been termed "Imagination." Researchers have observed the qualities of Imagination for decades, as in the work of Piaget and Vygotsky, but this work largely pertains to children. This author posits that the ability to render a vivid and naturalistic simulacrum of the performance environment in one's mind and manipulate that model mentally is also essential to the performance of adult professional experts.

Imagination is not a frivolous concept; the evocation of new worlds and possible alternative states in our present world is serious business, and it has profound impacts on an individual's understanding of both our internal and external worlds. For example, Leahy and Sweller (2005; 2008) find that the use of imaginative faculties in the brain's neocortex and thalamus have direct consequences on the development of memory and usable knowledge in the expert's mind, as well as on their ability to enact that knowledge in the world. Specifically, that the use of mental pre-visualization skills can improve recall functions by pre-priming the working memory and tapping existing automatic skills. Further, the ability to imagine alternative states is a skill that continues to grow across an individual's lifespan (Torrens, Thompson, Cramer, 1999), and supports a number of other essential cognitive processes.

The author has placed Imagination at the summit of the Inward-facing metacognitive skills for three reasons. First, Imagination's role as an executive and supervisory mental construct depends on the activation of all of the lower forms of Inward-facing metacognition in the construct. As Johnson (2007) notes, the manipulation of one's mental model of the universe in the mind requires a strong capacity for self-reflection, affective control, an operational knowledge of problem solving strategy selection in the domain, and a knowledge of one's own memory. Second, by understanding and cultivating the professional's capacity for Imagination, we may more effectively train their ability to control the complexity of their mental models of their performance environment, and integrate the various sources of information that the professional encounters. That is, the cultivation of Imagination may serve as a means of helping learners control and interpret other elements of their multiple-entry, modular memory systems (MeMS, Johnson, 2007), including high-level executive functions. Finally, Imagination's role as the pinnacle of the Inward-facing construct in professional expertise is essential for conceptualizing the Outward-facing metacognitive construct. As we shall see, Imagination is a necessary condition for creating, interpreting, and manipulating forces and actors in the larger socio-cultural ecology. Depending on the learner's knowledge of their environmental conditions and agency-driven goals, they may use multiple forms of cognitive, metacognitive, and social knowledge to imagine alternatives to the world as they see it.

The cognitive science and psychology literature describes three forms of Imagination (as synthesized from Byrne, 2005) that center on the deployment of one word: "If." In the first sense of the word, "If" denotes conditional inferences that enable the manipulation of mental representations in ways that are projected in parallel to the individual's existing worlds. This occurs when the individual attempts to imagine the outcomes, possibilities, and constraints that influence their ability to take action in their world (e.g. "If I…" and the reflective past-tense "If I had…"). One can see this capacity when experts in professions begin to play-out their designs in the world, as when lawyers or doctors begin to plan a course of action. The second form, counter-factual Imagining, involves the conscious attempts on the part of a learner to posit alternate conditions to those observed in the shared-world of the Real (Byrne, 2005). This occurs when an individual projects an "If" question that contradicts a fact in the real world, and includes activities such as thought experiments that suspend or amplify known constraints in the environment. Finally, at the edge of the Inward-facing construct, Imagination skills are invoked whenever ritual or symbolic events are instantiated in an environment as a form of Social Imagination (Shwarte, 2009). That is, all of the human social world exists in the collective imaginations of the participants that is constantly renewed, negotiated, and situated by a whirlwind of actors, institutions, and forces. Without this form of imagination, humans would be unable to understand the world outside of their own mind.

3.2 Outward-Oriented Metacognition

In the Outward-Oriented Metacognitive construct, we begin to see the interplay between the individual's internal world and their interpretations of the universe outside of the self. This will allow us to understand some of the processes that professionals use to map their expectations about the world against concrete observations that .

3.2.1 Theory of Mind

In continuing to build out from the individual minds of professional experts, we may now consider one of the unique qualities of human intelligence that is especially important to expert professionals, broadly known as Theory of Mind. An individual's capacity for Theory of Mind allows them to attribute and make suppositions about mental phenomena like intention, emotion, and knowledge to other humans and non-human actors (Wagman, 1998; Sabbagh, Bowman, Evraire, and Ito, 2009). In the context of this metacognitive construct and professional expertise, Theory of Mind draws on Imagination to enable professionals to develop a richer simulation of their performance environment in their own mind; one that includes implicit information about other actors' goals and intentions, and decisions about courses of action based on that information. One can imagine lawyers and their opposing councils, detectives and police, as well as business and financial professionals using their knowledge of the behavior of others to make inferences about future courses of events.

In addition to inferences about other actors in the environment, the interaction of Theory of Mind and domain content knowledge are essential in a professional's interpretation of the performances of others. It is this interaction that allows professionals to interpret the meanings and qualities of representations of practice performance in more or less efficient ways. Also, without the development of Theory of Mind, expert professionals could not use the various forms of decomposition and professional vision observed in the majority of professional learning programs (Grossman, Compton, Igra, and Williamson, 2009). Therefore, Theory of Mind allows professional to make sense of the experiences of others in the field, and compare that experience to their own for continued reflection and consideration.

3.2.2 Role-Taking

As participants in complex environments with ill-defined domain spaces, professions rely heavily on the continuity of social roles to help guide their workflow. Further, an individual's role in the social world by nature contains and brackets their knowledge of the world around them (Goffman, 1959). In a work environment where each participant must engage in multiple transactions with different actors and institutions, this behavior often manifests itself as 'role-taking.' In this process, individuals adopt a social role that influences their cognition in three implicit and explicit ways. First, professionals use their knowledge of the expectations and demands of their field to guide their action. That is, they possess an idea of how someone in their position should act in relationship to clients, employees, and superiors, and use this knowledge as part of their metacognitive narrative for justifications and decision-making. Second, the titles, responsibilities, and institutional demands placed on the professional are profoundly influenced by the socially-enforced boundaries of the field's knowledge and jurisdiction (Abbott, 1988). In this way, the professional must manage the expectations and requirements of the larger field as they come into tension with the demands of practice. These social boundaries of knowledge bracket and influence the decisions made in the wild.

Finally, role taking serves as a key means of integrating skills and knowledge into the performance environment. That is, in order to fulfill a role, a professional must possess sufficient domain content knowledge as well as an understanding of the social enactment of that knowledge. For example, in the course of their service to a patient, a doctor must not only know the symptoms and treatments of disease, but also how to convey this to the patient in a way that carries the authority of their role, conveys the factual and emotional importance of the diagnosis, and prepares the patient for their role in the medical/hospital social machinery.

3.2.3 Persuasion and Inoculation

Persuasion, or the conversion of an individual from one attitudinal, dispositional, or social stance to another, is an essential fact of human life that takes on greater significance in the world of the professional. Persuasion, as a phenomenon, appears to involve the creation and resolution of cognitive dissonance in the minds of one or more members of an audience, as well as the resistance encountered in the propagation of persuasive messages (Harmon-Jones, 2002). The creation of this cognitive dissonance in the minds of others may require that the individual invest substantial mental resources in the activity. That is, the persuader must make predictions about the kinds of metaphors and facts that will persuade their clients (and other professionals) to join their cause through the use of Theory of Mind skills and socio-emotional attention (Fogg, 2001).

Equally, professionals must guard themselves against maniupulative persuasion through the process of inoculation (Szabo and Pfau, 2002). For example, doctors may need to inoculate themselves against persuasion on the part of pharmaceutical companies in order to avoid over-prescribing a drug or mistreating a patient. As a metacognitive process, inoculation requires two events to abrogate the effects of a persuasive conversion. The first is a threat event, or the occurrence of a precursor event that primes the individual against potential forthcoming attacks on their existing attitudes. In the second step, the existence of a threat triggers the individual to probe their attitudes for evidence of weakness or change, a process known as refutational preemption (Pfau, Tusing, Koerner. Lee, Godbold, Penaloza, Yang, and Hong, 1997). Together, these processes can confer a resistance to the persuasion of the foreign attitude, and provide more time for consideration. A knowledge of the process of persuasion and inoculation could be crucial to the development of professionals, as these factors may place the individual at risk of breaching the trust that they hold.

3.2.4 Historiography

At the level of the professional's outward facing metacognition, we find the concept of historiography. While this word primarily refers to the study of the writing of history by professional historians, the presence of this construct proposes that all professions create historiographies to encapsulate and explain the genesis and core issues of the profession to novices. It is this narratization of the profession's history (and the role of the individual as part of that history) that creates fidelity and inspires adherence to the tenets of the profession. This is the reason that doctors state the Hippocratic oath at the start of their career and American lawyers swear an oath to the constitution. These events hearken back to a past that the contemporary body of legitimate professionals hope to pass to their incoming generations.

However, by their nature, the creation of historiographies forces the storytellers to favor certain events from the past, distort those events to suit a contemporary narrative, and fall under spells of re-interpretation and contention from members of the professional community. For this reason, Durepos and Mills (2012) posit that historiography may serve as a means of reinforcing the narratives of power of the community, or as a means of unconverging deeper truths about actor-networks. For example, histories of sub-altern groups (those 'told from below') offer new perspectives on the nature and history of the professions, especially as concerns historically unequal access to resources and discriminatory admissions practices. Thus, an understanding of the kinds of histories that expert professionals tell about their place in the world may give us a clearer vision of contemporary power structures and areas of need that require further attention.

3.2.5 Creativity and the Avant Garde

Artists, in this vision, are able to devlop "outsideness," to the extreme position that Bakhtin labeled "transgredience," and by virtue of that advantage are able to create a vision beyond what is currently understood…Their visions become templates for possible futures; their art provides texts of possibilities. – Holland, et al. (1998, p.308-309)

The author has placed Creativity at the end of the Outward-facing metacognitive construct because it is essential to the long-term growth and development of expertise in professional contexts. This is because the concept of creativity provides us with a language to describe the most elegant and exciting capacities of the human mind in psychological, humanistic, and experiential terms. It is also an essential component of professional life, as even the most routine expertise is subject to periodic mutations and shifts caused by frequent practice in changing environments. However, the literature on creativity is sprawling and mostly dubious, so this construct is bracketed in two ways that most directly pertain to a definition of creativity in professional practice. First, we must distinguish between what Kozbelt, Beghetto, and Runco (2010) call "Big-C" creativity (for cross-domain and virtuosic creativity) and "little-c" (or everyday, more personal) creativity.

Second, Kozbelt, Beghetto, and Runco provide us with six 'Ps' of manifestations or components of creativity. These include: Process, product, personality, place, persuasion, and potential. It is in the interplay of these factors with Big-C and little-c scopes in the professional world that we can begin to look for opportunities to understand how individuals come to create creative enclaves wherein the conventions of these factors may be overthrown in pursuit of a higher vision of practice.

Without diminishing the importance of everyday creativity as a key component of expert professional thought and action, this construct focuses on the role of Big-C creativity and its part in advancing disciplines through the process of innovation described in the next section. A focus on the role of Big-C creativity in professional expertise also allows us to discuss the nature of the art of practice, and how communities form to support participants' interpretations and reconceptualizations of domain activities. It is in these self-organizing communities that individuals are able to take the necessary social and psychological risks (e.g. failure, Breakwell, 2007) and develop the necessary language (Duvignaud, 1971) to expand the confines of the existing normative structures and meanings of the domain. It is in this way that creativity breaches the confines of domains and produces 'art.'

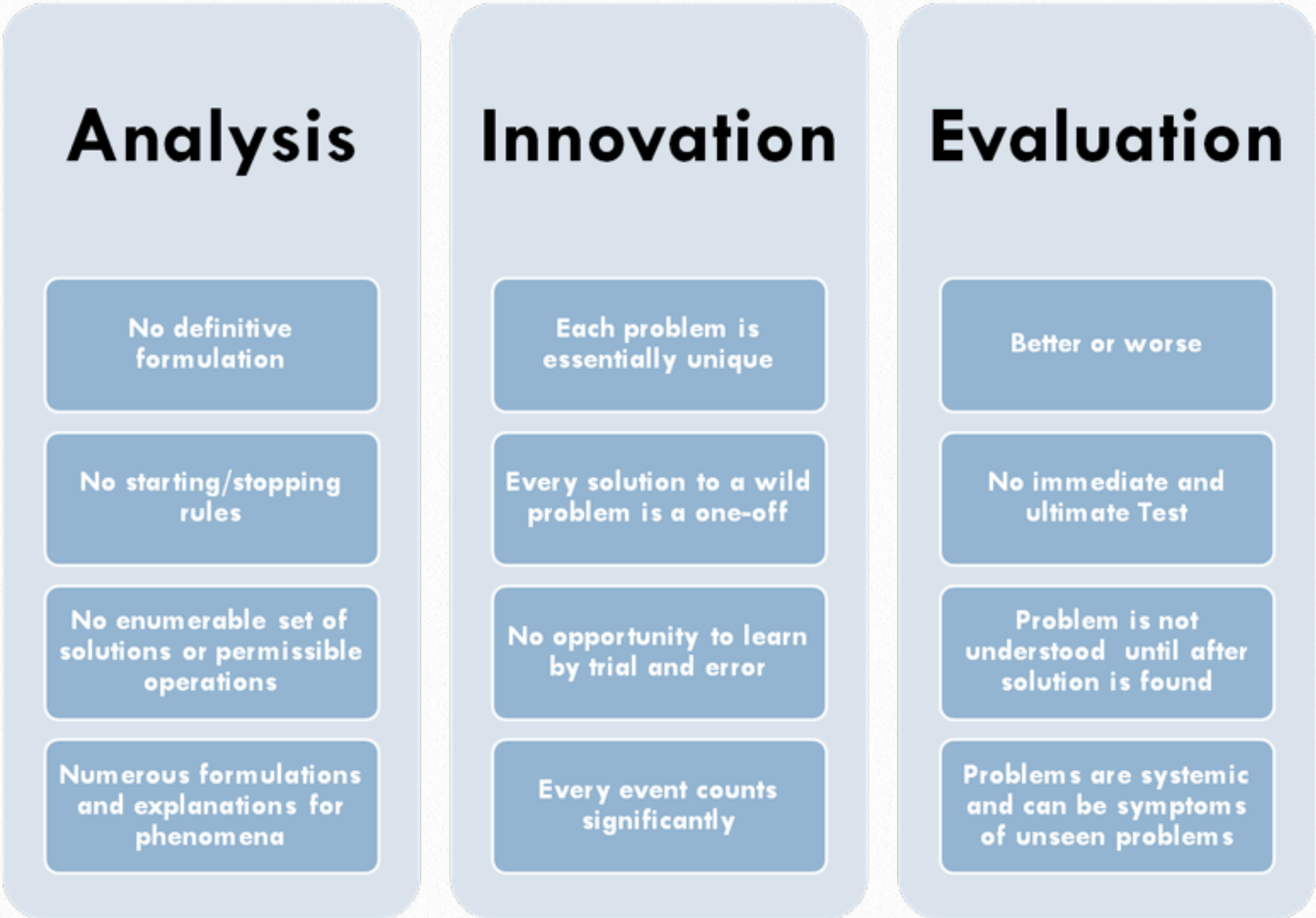
In this way, we define 'art' not as a collection of abstract symbols, but as a socially situated process of discovery that motivates and contextualizes the development of other kinds of thinking, including problem solving, and the contestation of symbolic and social norms (supported by Gopnik, 2010). This is evident in the communities of the Abstract Expressionists in New York, the Dadaists in France, and the artist-led workshops of the Renaissance, where groups of individuals assembled to launch coordinated and collaborative attacks on the state of Representation in art from critical, contradictory, and craft perspectives. These historically-situated communities, often expressed as sub-altern or counter-cultures (Hebdige, 1979), reject the status quo in the 6-Ps within their professional domain. Creative communities thus create an arena wherein individuals may present countervailing views of philosophy regarding practice; further, the support of these communities allow practitioners to propose an Avant Garde in opposition to the 'kitsch' of their contemporary forms (Greenberg, 1923). Bakhtin (Vice, 1997) further describes the 'central discoveries' of the Avant Garde, including Polyphony (the creation of the possibility of a dialogic relationship between minds and ideas), representation (the depiction of the idea in human terms), and the recognition of the importance of dialogs between minds as a key factor in the development of thought.

In the epigraphs for this section, Holland et al. (1998) note the importance of the Avant Garde and its role in expanding beyond what is currently known to be possible within a domain. Thus, the true power of revolutionary artistic creativity (such as we find in virtuosic professionals in architecture, law, and the sciences) in the context of professional practice can thus be seen as the individual's participation in these like-minded alternative communities of practice (as in the Bauhaus in architecture). It is in these spaces, and enabled by the social support of the community, that expertise grows beyond routine practice into creative expression. The growth of these communities of creativity also provide the context for the development of Design Thinking and the conditions for the long-term development of cross-domain, adaptive expertise within the context of the larger social world.

3.3 Putting Metacognition to Work: Design Thinking and Adaptive Expertise

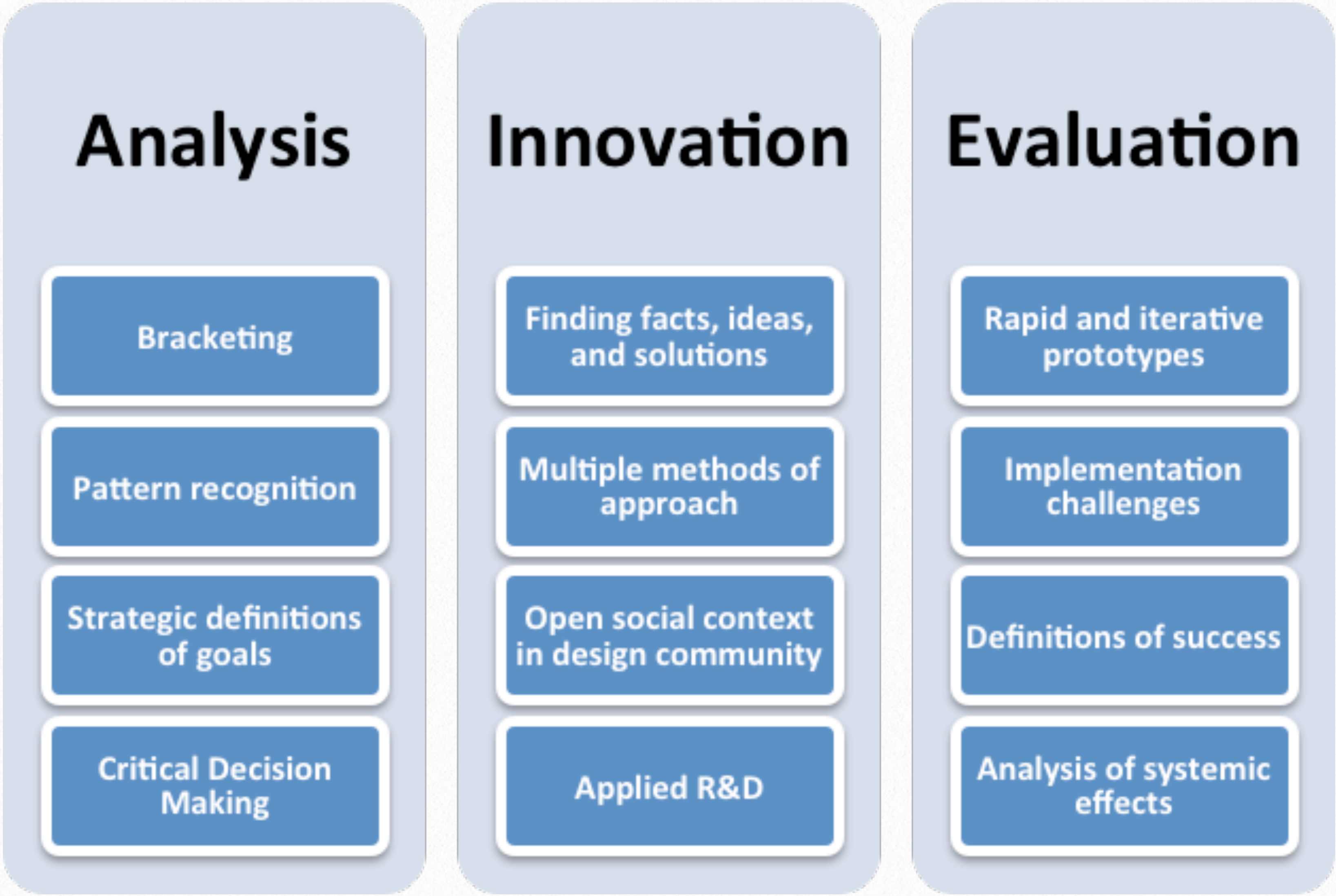
The Mind at Work by Mike Rose (2005) discusses at length the adaptive cognitive and behavioral techniques that experts apply in their day-to-day work (what we have termed 'little-c creativity'). While Rose focuses on the underappreciated expertise of working-class individuals (e.g. waitresses), he joins Lave and Wenger (1991) in extrapolating lessons from relatively well-defined workplaces (e.g. tailors and waitresses). Studies like these are of exceptional value, as they clearly describe the context of the cognitive and social elements of expertise. However, they do not clearly examine how expert groups change and grow in response to wild, ill-defined systemic problems.

Lave and Wenger describe the enculturation process of experts (wherein 'newcomers become old-timers') that exist in professional communities, but do not clearly discuss the individual's own adaptive process in a grey, messy world. However, Nelson and Stolterman's The Design Way (2003) makes progress on a middle road. In it, Nelson describes the ways that experts interact with the problems in their environment, and captures some of the ways that the application of theory (and an imagination of 'how things might be') influences responses to wild problems. In The Design Way and Cross (2001), the authors posit that one of the defining characteristics of expertise-in-action stems from the ability to control variables, bracket complexity, and advance the controlled evolution of problem states. That is, expert professionals design strategies, artifacts, social systems, and environments that enable the solution of wild problems in a given performance environment.



The figure above reconfigures the wild problem definition into a form that most instructional designers (a form of learning professional) will recognize. Educational Technology's core organizing design heuristic is the 'ADDIE' model of instructional design. It is a recursive, non-linear process that involves analysis, design, development, implementation, and evaluation. The figure is based on this model, but combines the design, development, and implementation phases into a single block called 'innovation.' While innovation is an ill-defined term in the literature, the creation of new tools, techniques, and structures is clearly a part of any solution to a wild problem, and usually occurs during these phases. Equally, expert knowledge is required to analyze and evaluate the boundaries of projects.

In understanding where and how the specific traits of wild problems influence the design process, we may be able to design learning and expert communities that respond to the complex and difficult circumstances that present themselves in the wild.



The figure above illustrates how experts respond to the challenges posed by wild problems. These descriptions of expert design solutions are primarily drawn from two sources: Scott Berkun's The Myths of Innovation (2007) and Nelson and Stolterman. Berkun's book clarifies some of the misconceptions about the nature of innovation in expert and non-expert settings, and provides an actionable set of anti-definitions. That is, Berkun tells us what innovation is not so that we may understand how it functions in a complicated context. Nelson's book, though full of platitudes, gives us an excellent insight into the kinds of behaviors that form expert designers' skill sets.

While it is unrealistic to expect to teach professionals all of the design skills that they will need to decisively manipulate their environment via classroom teaching, it may be beneficial to make explicit the skills that are necessary to confront wild problems. This way, 'newcomers' can focus on these strategies and integrate them into their thought processes as they become 'old timers.' The synthetic construction of these communities is difficult to design and engineer, but design expertise provides opportunities to improve the efficacy of professionals (as designers) at the appropriate point in their development (similar to Riel and Polin's theory of learning community development, 2004).

Beyond the role of design thinking in professions, Wenger (1998) identifies four key ways that the deliberate design of practices, products, and institutions within communities mediates ideas of meaning, time, space, and power (p.231). This is especially true at the level of the professions, as these communities are in a constant state of balancing deliberate change and the consequences of those changes. The resultant model of 'design for learning' includes four key tensions that will help us further understand the role of design in the context-based learning that occurs in professions:

1. **Participation/Reification:** Wenger claims that designs for practice always implies a tension amongst the environmental presence of the right tools, people, and knowledge and the ability of the individual participants to reify their expertise using those artifacts and agents. Designs for learning guide the professions' thinking about the need for the instantiation of expertise and performance in particular places, times, and ways.

2. **Designed/Emergent:** Wenger further claims that practices arise in response to designs, as a delta between the real and the imagined or ideal. It is the tension between the enactment and resolution of designs in a practice space, and the cascading emergence of needs in response to the implementation of the design. This tension shapes professional learning communities in real ways as members test new modes of practice.

3. **Local/Global:** Wenger locates the tension between internal and external community assessments of learning, participation, and legitimacy in the relationship between the local and the global. As he notes, "no community can fully design the learning of another…[and] no community may fully design its own learning" (p.234). In this way, professions (as local communities) have designed and built elaborate structures to encase their knowledge, but will need the help from the larger world to continue improving the learning of its participant.

4. **Identification/Negotiability:** Designs represent perspectives, and those perspectives may be meaningful (or not) and shared (or not) by participants in the community of professionals. Designs in the professions also serve as bids for power, and are similar to the boundary-forming objects described by Abbott (1988).

As guardians of the public trust, of knowledge domains, and of power-distribution systems, any system of education for professional learners must seriously address and develop the design thinking skills examined here. That is, at the individual/cognitive understanding of the role of design thinking in bracketing complexity (as in Rittel and Weber), as a means of achieving deliberate change in an uncertain and emerging world (Nelson), and as a fundamental process of professional life (Wenger, 1998). It is to that 'life' that we now turn.

4.0
Situated Theories-of-Action

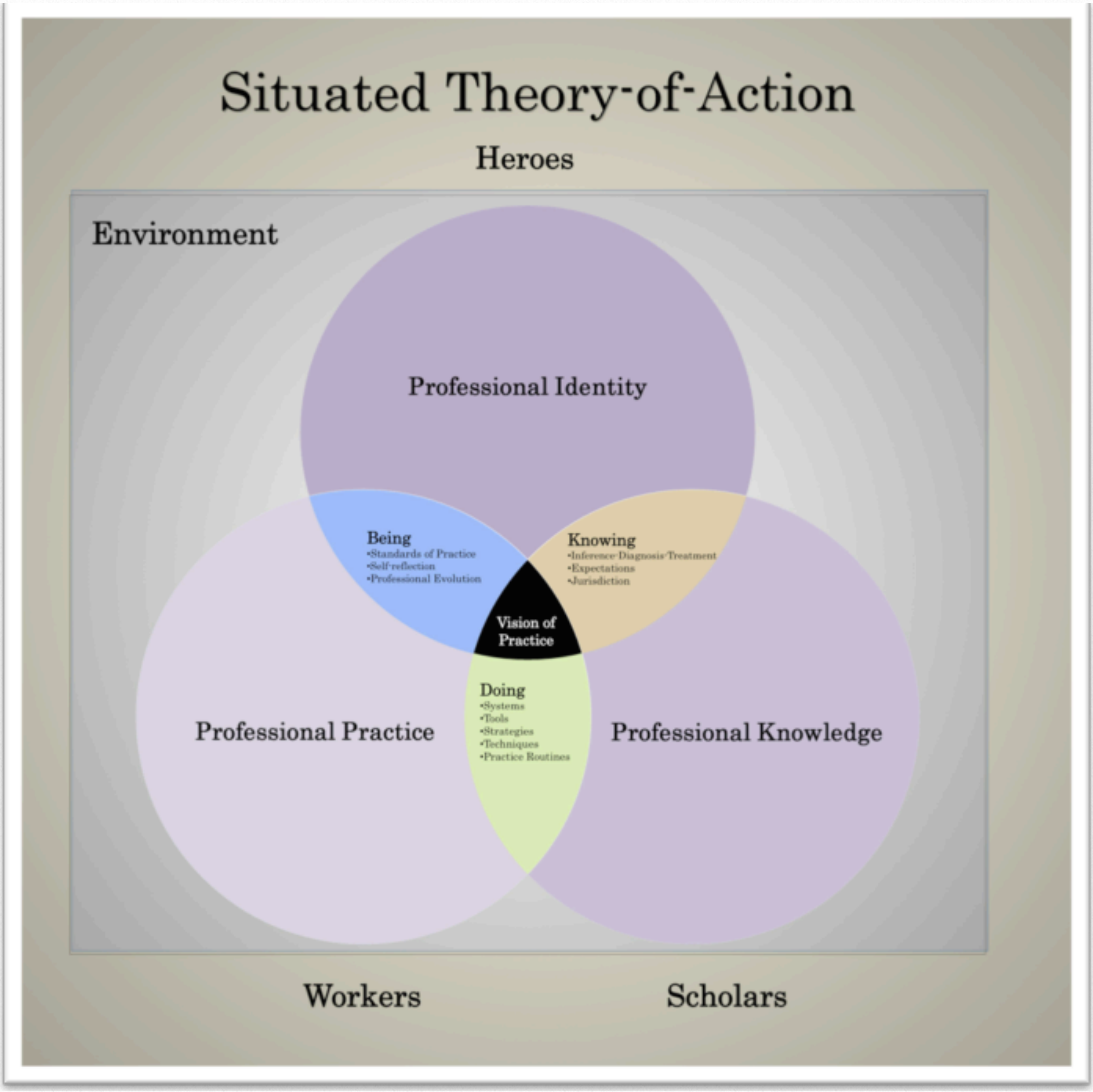


Figure 4 – The Professional Situated Theory-of-Action Framework

4.0 The Situation of Knowledge Within Professional Theories-of-Action

Being a professional is a way of being in the world, and that way of being involves the balancing of agency, choice, and risk (Lampert, 1986; Breakwell, 2007; Holland, Lachiotte, Skinner, Cain, 1998). Thus, this section of the construct will attempt to outline a situative perspective on the development of expertise that unites the socially-oriented components of the individual's available operations and knowledge into a framework called a Theory of Action. A Theory of Action (Argyris, 1997) describes the macro-product of a teacher's knowledge, identity, and practice (Darling-Hammond and Bransford, 2005), the boundary areas and interactions between these components, and the operation of these areas at the moral level of the community. The use of a Theory of Action model of situated expertise can also help us to understand how expert professionals calibrate their efforts based on their strengths and weaknesses relative to the demands of the performance and social environment. To illustrate the importance of these community-level values, we shall examine four zones on this construct map: 1) Professional Identity-Knowledge-Practice, 2) the Prime Locus of Vision of Practice, 3) the Reification Loci, and 4) the Moral Level. Each of these segments can help us to understand the relationship of the individual professional's internal psychological processes and social-psychological pressures in ways that can help us to enrich and strengthen professional education and development activities.

4.1 Core Strengths: Professional Identity-Knowledge-Practice

As we have already seen in this paper, it is possible to describe an expert professional's orientation towards shared group knowledge and practice from a cognitive and metacognitive perspective. However, the situative view of these phenomena focuses on the social validity of these qualities as they are enacted in the performance environment, and adds the concept of Identity to the mix. Holland et al. note the importance of Identity-in-society to the stories we tell others about ourselves, but also the stories we tell ourselves about ourselves:

People tell others who they are, but even more important, they tell themselves and then try to act as though they are who they say they are. These self-understandings, especially those with strong emotional resonance for the teller, are what we refer to as identities.
-Holland et al, 1998, p.3

In this way, a professional's Identity-Knowledge-Practice are not only defined by how professionals view and understand themselves, but also by how others agents interpret them and respond; this is similar to the metacognitive structure of Role-Taking, but from a socially co-constructed perspective. As such, the constant negotiation of identity, knowledge, and practice in fields are the subject of significant inter- and intra-professional competition and gatekeeping (Abbott, 1988; Friedson, 2001). Thus, these constructs can be understood as existing in a reactive state, prone to fluctuations and changes as the social and environmental conditions of the profession and performance environment change. Further, they are the ultimate strengths of the profession that any legitimate peripheral participant may draw from to accomplish their goals and tasks.

4.2 Areas of Reification: Being, Knowing, and Doing

In continuing the analysis of the Theory of Action model of professional education, we will briefly examine the boundary areas that form at the interloci of the diagram (Figure 2, below). These areas form from the intersection of two constructs, and correspond to the components of a teacher's theory of action that outside observers can access. Unlike their parent regions, these areas come into existence when a practitioner draws from their body of professional strength to advance their goals. These areas are named in parallel with Herrenkohl and Mertl's (2010) view of knowledge as a process of learning to 'Be, Know, and Do," and they contain several qualities that are flexible and open to contestation by individual professional education programs.

- **Being**, as the intersection of Identity and Practice, contains the practices of community reflection and a strong belief in standards of practice, as well as a drive for continued evolution in the context of their environment. Equally, it contains the confidence in practice that is a part of being an expert professional, and the assurance of quality performance and client-service within the community-established parameters.

- **Knowing**, as the intersection of Knowledge and Identity, includes domain-specific content knowledge, as well as belief that the professional should possess the power and jurisdiction to infer about the condition, diagnose, and treat their clients (Abbott, 1988). Further, it contains the individuals' socially situated understanding of how to apply their knowledge in given

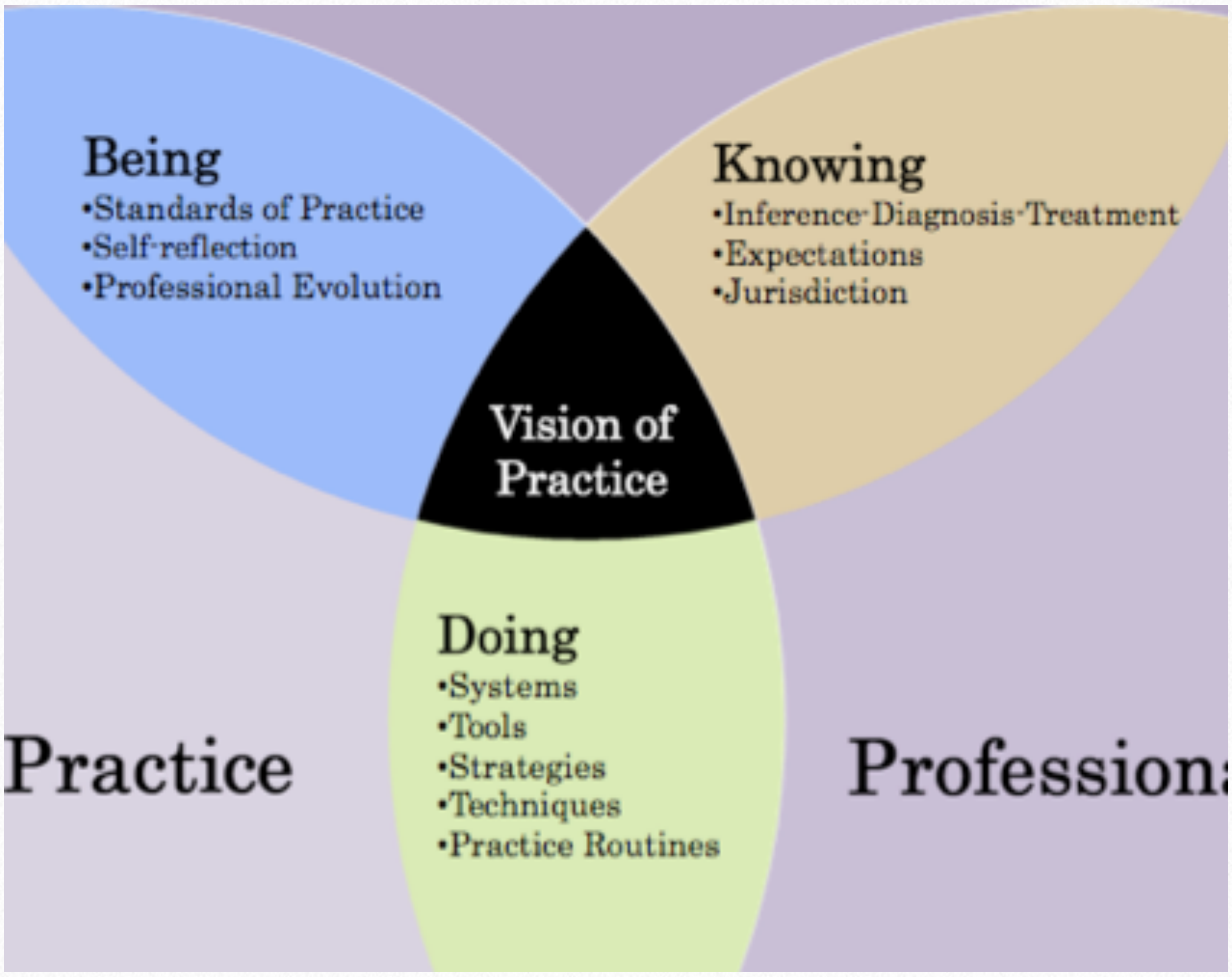


Figure 5 – Details of the Interloci: Being, Knowing, and Doing

environments, as facilitated by their socially rendered identity (as a doctor, as a lawyer, etc.).

• **Doing**, as the intersection of Practice and Knowledge, contains craft and pedagogical content knowledge, as well as the command of routines, systems, and techniques of the profession. That is, it is an understanding of how to apply knowledge in communally appropriate ways and at judicious times. It also contains the social activities necessary to promote the routinization of practices that codify and advance the knowledge of the field.

4.3 Heroes, Scholars, Workers: A Moral Framework for Situated Professional Theories of Action

The concept of a 'moral' framework as proposed here does not imply a specific morality. Rather, the 'level of morality' places the following constructs at the highest levels of individual and group achievements. They are the community-oriented aspirations created by the people in the professions, and the psychological role of these archetypal figures may have substantive effects

• **The Hero and Professional Identity:** To understand and value one's work as a calling (a necessity for professionalism, according to Shulman, 1997), a discipline requires profession-wide heroes that can serve as representations of ideal performance. Certain fields have successfully enshrined some members (e.g. Thurgood Marshall, Jonas Salk, and Frank Lloyd Wright, and Florence Nightingale), while other disciplines fail to advance discipline-wide paragons (e.g. education and engineering). The presence or lack of visible, symbolic heroes may have an impact on individual professional's performance in real ways, especially as regards ethics and longevity.

• **The Scholar and Professional Knowledge**: The Scholar archetype represents the professional's obligation to advance and propagate their version of the field's thinking, to write a new historiography for their time and place. The Scholar zone indicates that professional must have the ability to evaluate and understand trends in the larger field so that they can shape their own intellectual relationship to their practice over time. This is required so that they may continue to develop and use the language and cognitive tools necessary to decompose and analyze their own practices for communication to other members.

• **The Worker and Professional Practice:** The development of a strong identification as a Worker or practitioner may also be essential for the longevity of practice necessary to develop advanced forms of expertise in professional practice. People who engage in practice with others in a strong professional community and develop a practitioner identity (e.g. Grossman et al., 2009; Lave, 1996; Lave and Wenger, 1991; Levine, 2010; Zeichner, 2009) are more likely to maintain the social relationships they form there, and thus persist in their practice for an extended period. The approximation and enactment of the Worker archetype could also be seen as a mediating factor in the uptake of the lessons learned from the Hero and Scholar zones. Without a strong sense of commitment to their professional activities and their community, individuals will not be able to articulate their personal goals and aspirations.

4.4 The Prime-Locus: Vision of Practice

Central to the development of a strong Theory of Action is an individually internalized construct that unites the components into an ordered whole. This Vision of Practice relates the individual professional's cognitive and metacognitive processes to the possible available actions and activities in the social world. At this level of the ecological space, the individual places themselves in relationship to all of the various forces that exist in that performance environment. That is, the individual views their own Identity-Practice-Knowledge as existing to support certain kinds of professional activities and in opposition to others. In this way, it creates an opportunity for the expert professional to lead and guide other members of their community towards new visions of practice that are grounded in the individual and social goals of the community.

This vision allows the professional to marshal their existing cognitive and metacognitive attributes in service of a purpose. Further, it allows them to align that purpose with the core strengths of their profession (Identity-Knowledge-Practice), with the profession's areas of reification (Being-Knowing-Doing), and finally, with the Moral level of the community (Heroes-Scholars-Workers).

5.0 Conclusion

As we have seen, expert professionals balance a number of cognitive, social, and environmental variables at the same time, and evolve a complex network of cognitive, metacognitive, and social activities to learn and grow. We will close this definition of the ecological perspective of professional expertise with a look towards the next two questions, and their role in operationalizing the constructs described in this paper. In this case, operationalization will require two additional systems. First, a means of mapping these constructs onto real-life circumstances in a rigorous and flexible fashion that provides the ability to capitalize on opportunities for performance improvement. Second, we will need a rigorous system of research methods to perform the analysis necessary to identify opportunities for technological augmentation in practice.

For this reason, Question 2 will help focus on potential strategies for using technology to augment learning given the increasing complexity of domain knowledge, divisions of labor, and interdisciplinary collaboration in professional disciplines. Learning Scientists and instructional designers now have the opportunity to use these Big-T Technologies (or systems of interlocking learning processes, tools, and opportunities enable by digital technologies) to generate new perspectives on orchestrating and augmenting professionals' performance. Thus, Question 2 will look at three potential models of Technological system design that will support professionals at the cognitive, metacognitive, and situative levels.

Question 3 will then explore a multi-method design-based research system that be used to monitor and improve the learning Technology systems advocated in Question 2. This process will fold together five methodologies into a team-based methods system that provides a multi-layer view of the professional, their knowledge, and their performance environment. It is this Design-based Swiss Army Knife that will help to see changes in the professional's behavior and opportunities for continued improvement. Success in these endeavors will ideally yield a means of making people more successful in their work and thus better servants of the public good.

Bibliography

Abbot, A. (1988). The System of Professions. Chicago: University of Chicago Press.

Anderson, J.R. (1983). The architecture of cognition. Cambridge, MA: Harvard University Press.

Annetta, L. A., Minogue, J., Holmes, S. Y., & Cheng, M.-T. (2009). Investigating the impact of video games on high school students' engagement and learning about genetics. Computers & Education, 53(1), 74-85. Elsevier Ltd.

Argyris, C. (1997). Learning and Teaching: A Theory of Action Perspective. Journal of Management Education, 21(1), 9-26.

Argyris, C., Putnam, R., Smith, D.M. (1965). Action Science. Jossey-Bass: San Francisco.

Argyris, C., and Schon, D. (1974). Theory in Practice: Increasing professional effectiveness. Jossey-Bass: San Francisco.

Ball, D.L., and Bass, H. (2000). Interweaving content and pedagogy in teaching and learning to teach: Knowing and using mathematics. In J. Boaler (Ed.), Multiple perspectives on the teaching and learning of mathematics (pp. 83-104). Westport, CT: Ablex.

Barab, S. A, & Roth, W.M. (2006). Curriculum-based ecosystems: Supporting knowing from an ecological perspective. Educational Researcher, 35(5), 3-13.

Barr, M. (2011). Predictions: A universal principle in the operation of the human brain. In M. Bar (Ed.), Predictions in the brain, (pp. 1-5). New York: Oxford University Press.

Beattie, G. (2004). Visible thought: The new psychology of body language. New York: Routledge.

Berkun, S. (2007). The Myths of Innovation. Sebastopol, CA: O'Reilley Media, Inc.

Biddle, B.J. (1987). Recent developments in role theory. Annual Review of Sociology, 12, 67-92.

Bourdieu, Pierre. 1977. Outline of a Theory of Practice. Cambridge University Press.

Brann, E.T.H. (1991). The world of the Imagination: Sum and substance. Savage, MD: Rowman & Littlefield Publishers.

Bransford, J.B., & Schwartz, D.L. (2007). It tales expertise to make expertise: Some thoughts about why and how and reflections on the themes in chapters 15-18 In K. A. Ericsson (Ed.), The development of professional expertise, (pp.432-448). Cambridge: Cambridge University Press.

Breakwell, G.M. (2007). The Psychology of Risk. New York: Cambridge University Press.

Briñol, P. and DeMarree, K.G. (2012). Social metacognition: thinking about thinking in social psychology. In P. Briñol and K.G. DeMarree, Social Metacognition, (pp. 1-20). New York: Psychology Press.

Bronfenbrenner, U. (1979). The ecology of human development. Cambridge, MA: Harvard University Press.

Byrne, R.M.J. (2005). The Rational Imagination: How People Create Alternatives to Reality. Cambridge, MA: MIT Press.

Chi, M.T.H., & Koeske, R. (1983). Network representation of a child's dinosaur knowledge. Developmental Psychology, 19, 29-39.

Christensen, C.M., Baumann, H., Ruggles, R., & Sadtler, T.M. (2006). "Disruptive Innovation for Social Change" Harvard Business Review, December 2006.

Clark, R. C. (2008a). Building Expertise. San Francisco: Pfeiffer.

Clark, R.C. (2008b). Developing technical training. San Francisco: Pfeiffer.

Clark, R.C., & Lyons, C. (2004). Graphics for Learning. San Francisco: Pfeiffer.

Clark, R.C., & Mayer, R. (2008). E-Learning and the Science of Instruction. San Francisco: Pfeiffer.

Collins, A., & Halverson, R. (2009). Rethinking Education in the Age of Technology. New York: Teachers College Press.

Corsini D.A. (1971). Memory: Interaction of stimulus and organismic factors. Human Development 14(1),, 101-121.

Crawford, M.B. (2010). Shop class as soul craft. An inquiry into the value of work. New York: Penguin.

Cross, N. (2001). Designerly ways of knowing: Design discipline versus design science. Design Studies 17(3) 49-55

Csíkszentmihályi, M. (2008). Flow: The psychology of optimal experience. New York: Harper Perennial Modern Classics.

Damasio, A. (1994). Descartes's error: Emotion, reason, and the human brain. New York: Putnam.

Darling-Hammond, L., & Bransford, J. (2005). Preparing Teachers for a Changing World. San Francisco: Jossey-Bass.

De Groot, A. D. (1965). Thought and Choice in Chess. Paris: Mouton & Co.

Doering, A., Veletsianos, G., Scharber, C., Miller, C. (2009). Using the technological, pedagogical, and content knowledge framework to design online learning environments and professional development. Journal of Educational Computing, 43(1), 319-346.

Dreyfus, H. L., & Dreyfus, S. E. (1986). Mind over machine: The power of human intuition and expertise in the era of the computer. New York: Free Press.

Duvignaud, J. (1971). The sociology of art. London: Paladin

Durepos, G.A.T., Mills, A.J. (2012). Anti-history: Theorizing the past, history, and historiography in management and organization studies. New York: Information Age Publishing.

Ericsson K.A. (2007). Enhancing the development of professional performance: Implications from the study of deliberate practice. In K. A. Ericsson (Ed.), The development of professional expertise, (pp.405-427). Cambridge: Cambridge University Press.

Engestrom, Y. (2003). The New Generation of Expertise: Seven Theses. In Helen Rainbird, Allison Fuller, and Anne Munro, Workplace Learning in Context. New York: Routledge.

Fogg, B.J. (2003) Persuasive technology: Using computers to change what we think and do. New York: Morgan Kaufmann Publishers.

Forgas, J.P. (2008). The role of affect in attitudes and attitude change. In W.D. Cran and R. Prislin (Eds.), Attitudes and Attitude Change. New York: Psychology Press.

Freidson, E. (2001). Professionalism: The Third Logic, on the practice of knowledge. Chicago: University of Chicago Press.

Gabriel, S., & Young, A. (2011) Being a vampire without being bitten: The narrative collective-assimilation hypothesis. Psychological Science, 22(8), 990-994.

Gallagher, Shaun. 2005. How the Body Shapes the Mind. Oxford: Oxford University Press.

Gardner, H. (2004). Frames of Mind: The theory of multiple intelligences. New York: Basic Books.

Gibson, J.J. (1997). The ecological approach to visual perception. Boston: Houghton Mifflin.

Gladwell, M. (2007). Blink. New York: Back Bay Books.

Glenberg, A.M. (1997). What memory is for. Behavioral and Brain Sciences, 20, 1-55.

Glockner, A., & Witteman, C. (2010). Foundations for tracing intuition: models, findings, and categorizations. In A. Gockner and C. Witteman (Eds.) Foundations for Tracing Intuition, (pp. 1-23). New York: Psychology Press.

Gobbo, C., & Chi, M.T.H., (1986). How knowledge is structured and used by expert and novice children. Cognitive Development, 1, 221-237.

Goffman, Erving (1959). The Presentation of Self In Everyday Life. New York: Doubleday.

Gopnik, A. (2010). Van Gogh's Ear. The New Yorker, January 4, 2010. Accessed online on August 10, 2012. http://www.newyorker.com/reporting/2010/01/04/100104fa_fact_gopnik?currentPage=all

Greeno, J.G. (1998). The situativity of knowling, learning, and research. American Psychologist, 53(1), 5-26

Grossman, P., Compton, C., Igra, D., & Williamson, P. W. (2009). Teaching Practice: A Cross-Professional Perspective. Teachers College Record, 111(9), 2055-2100.

Hacker, D.J. (1998). Metacogition: Definitions and empirical foundations. In D.J. Hacker, J. Dunklosky, & A.C. Graesser (Eds.), Metacognition in Educational Theory and Practice, (pp.1-23). Mahwah, NJ: Lawrence Erlbaum Associates.

Harmon-Jones, E. (2002). A cognitive dissonance theory perspective on persuasion. In J. Dillard and M. Pfau, The Persuasion Handbook (pp. 99-116). Thousand Oaks, CA: SAGE.

Hebdige, R. (1979). Subculture: The meaning of style. New York: New Accents

Herrenkohl, L.R., & Mertl, V. (2010). How Students Come to Be, Know, and Do: A Case for a Broad View of Learning. Cambridge University Press.

Hilgers, Mathieu. 2009. Habitus, Freedom and Reflexivity 'Theory and Psychology' Vol. 19 (6), pp. 728-755

Holland, D., Lachiotte, Jr., W., Skinner, D., Cain, C. (1998). Identity and agency in cultural worlds. Cambridge, MA: Harvard University Press.

Horstman, T., & Kerr, S. (2011). An analysis of design strategies for creating educational experiences in virtual environments. In M. S. Khine, & I. M. Saleh, New Science of Learning: Cognition, Computers, and Collaboration in Education (pp. 183-206). New York: Springer.

Hutchins, E. (1996). Cognition in the Wild. Cambridge, MA: MIT Press.

Hurlburt, Russell (2009). "Iteratively Apprehending Pristine Experience.".Journal of Consciousness Studies 16: 156–188.

Johnson, M., (1987) .The Body in the Mind. Chicago: University of Chicago Press.

Johnson, M.K. (2007) Memory systems: A cognitive construct for analysis and synthesis. In Roediger, H., Dudai, Y., Fitzpatrick, S. (Eds.), Science of memory: Concepts, p.353-357. New York: Oxford University Press.

Kalyuga, S. (2007) Expertise reversal effect and its implications for learner-tailored instruction. Educational Psychology Review 19(4), 509 - 539.

Kalyuga, S., Chandler, P., Sweller, J. (1998). Levels of expertise and instructional design. Human Factors, 40(1), 1-17.

Keil, F.C., Lockhart, K.L, Keil, D.C., Keil, D.R., Keil, M.F. (2005). “Looking for Mr. Smarty Pants: Intelligence and expertise in the Simpsons. “ In Alan Brown, and Chris Logan, The psychology of the Simpsons, (pp. 173-186). Dallas, TX: BenBella Books.

Krull, D.S. (2001). "On Partitioning the Fundamental Attribution Error: Dispositionalism and the Correspondence Bias". Cognitive Social Psychology: the Princeton Symposium on the Legacy and Future of Social Cognition New York: Lawrence Erlbaum Associates.

Lakoff, G., & Johnson , M.(, 1999). Philosophy in the Flesh. New York: Basic Books.

Lakoff, G. & Johnson, M.(1980) Metaphors We Live By. Chicago: University of Chicago Press.

Lampert, M. (1985). How Do Teachers Manage to Teach? Perspectives on Problems in Practice. Harvard Educational Review, 55(2), 178-194.

Lave, J. (1996). Teaching as learning, in practice. Mind, Culture and, Activity, 3(3), 149-164.

Lave, J., & Wenger, E. (1991). Situated Learning: Legitimate Peripheral Participation. New York: Cambridge University Press.

Lazarus, Richard S. (1982). Thoughts on the relations between emotion and cognition. American Psychologist, 37(9), 1019-1024

Leahy, W., & Sweller, J. (2008). "The Imagination Effect Increases with an Increased Intrinsic Cognitive Load". Applied Cognitive Psychology 22: 275.

Leahy, W., & Sweller, J. (2005). Interactions among the imagination, expertise reversal, and element interactivity effect. The Journal of Experimental Psychology: Applied 11(4), 266-276.

LeDoux, J. (2002) The Synaptic Self: How Our Brains Become Who We Are, New York: Viking Penguin

Lepore, J. (2009). Not so fast. New Yorker, October 12. Retrieved from http://www.newyorker.com/arts/critics/atlarge/2009/10/12/091012crat_atlarge_lepore

Levine, T. (2010). Tools for the Study and Design of Collaborative Teacher Learning: The Affordances of Different Conceptions of Teacher Community and Activity Theory. Teacher Education Quarterly, 37(1), 109-130.

Liberman, N., Trope, Y., Rim, S. (2011) Prediction: A construal-level theory perspective. In M. Bar, Predictions in the brain (pp. 144-158). New York: Oxford University Press.

Maslow, Abraham (1954). Motivation and Personality. New York: Harper.

Matsumoto, D., Frank, M.G., Hwang, H.S. (Eds.) (2013). Nonverbal communication: science and applications. Los Angeles: SAGE.

Mattarella-Micke, A., Mateo, J., Kozak, M. N., Foster, K., & Beilock, S. L. (2011). Choke or thrive? The relation between salivary cortisol and math performance depends on individual differences in working memory and math-anxiety. Emotion, 11(4), 1000-5.

Meltzoff A.N., Decety J. (2003). "What imitation tells us about social cognition: A rapprochement between developmental psychology and cognitive neuroscience". The Philosophical Transactions of the Royal Society, London 358: 491–500.

Mieg, H. A. (2009). Two factors of expertise? Excellence and professionalism of environmental experts. High Ability Studies, 20(1), 91-115.

Moulyn, A.C. (1991). Mind-Body: A pluralistic interpretation of Mind-Body interaction under the guidelines of Time, Space, and Movment. New York: Greenwood Press.

National Research Council. (2000). How People Learn: Brain, Mind, Experience, and School. Washington, D.C.: National Academy Press.

Nelson, H. G., & Stolterman, E. (2003). The Design Way: Intentional Change in an Unpredictable World. Englewood Cliffs, NJ, USA: Educational Technology Publications.

Niedenthal, P. & Halberstadt, J. (2000). Grounding categories in emotional response. In J.P. Forgas (Ed.), Feeling and Thinking: The role of affect in social cognition (pp. 357-368). New York: Cambridge University Press.

Perlmutter, M. (1988). Research on memory: Past, present, future. In F.E. Weinert & M. Perlmutter (Eds.), Memory development: Universal changes and Individual differences (pp. 353-380). Hillsdale, NJ: Lawrence Erlbaum Associates.

Petroski, H. (1992) The evolution of useful things. New York: Knopf.

Pfau, M., Tusing, K.J., Koerner, A.F., Lee, W.P., Godbold, L.C., Penaloza, L.J., Yang, V.S., and Hong, Y. (1997). Enriching the inoculation construct: The role of critical components in the process of resistance. Human Communication Research, 24, 187-215.

Riel, M. & Polin, L. (2004) Learning Communities: Common Ground and Critical Differences in Designing Technical Support. In Barab, S. A., Kling, R., & Gray, J. (Eds.). Designing for Virtual Communities in the Service of Learning. Cambridge, MA: Cambridge University Press.

Ritchey, Tom; "Wicked Problems: Structuring Social Messes with Morphological Analysis," Swedish Morphological Society, last revised 7 November 2007.

Rittel, H., & Webber, M. (1973). Dilemmas in a General Theory of Planning. In Policy Sciences, Volume 4 (pp. 155-169). Amsterdam: Elsevier Scientific Publishing Company, Inc.

Rose, M. (1999). “Our Hands Will Know”: The development of tactile diagnostic skill – teaching, learning, and situated cognition in a physical therapy program. Anthropolgy & Education Quarterly 30(2) 133-160.

Rose, M. (2005). The Mind at Work: Valuing the Intelligence of the American Worker. New York: Penguin Books.

Sabbagh, M., Bowman, L.C., Evraire, L., Ito, J. (2009). Neurodevelopmental correlates of theory of mind in pre-school children. Child Development, 80(4), 1147-1162.

Schon, D. (1983). The Reflective Practitioner: How Professionals Think in Action. New York: Basic Books.

Schoenfeld, A. H. (1992). Learning to think mathematically: Problem solving, metacognition, and sensemaking in mathematics. In D. Grouws (Ed.), Handbook for Research on Mathematics Teaching and Learning (pp. 334-370). New York: MacMillan.

Scott, C. L.; Harris, R. J.; & Rothe, A. R. (2001). "Embodied cognition through improvisation improves memory for a dramatic monologue". Discourse Processes 31 (3): 293–305.),

Shulman, L. (1986). Those who understand: Knowledge growth in teaching. Educational Researcher, 15, 4-14

Shulman, L. S. (1998). Theory, Practice, and the Education of Professionals. Elementary School Journal, 98(5), 511-526.

Shwarte, L., (2009). Intuition and Imagination. In B. Huppauf and C. Wulf (Eds.), Dynamics and Performativity of Imagination: The image between the visible and invisible. New York, Routledge

Son, L.K., Kornell, N., Finn, B., Cantlon, J.F. (2012). Metacognition and the social animal. In P. Brinol and K.G. DeMarree (Eds.), Social Metacognition, (pp. 159-178). New York: Psychology Press.

Stanovich, Keith E.; Richard F. West (1983). "On Priming by a Sentence Context". Journal of Experimental Psychology, 112 (1).

Surprenant, A.M. & Neath, I. (2009). Principles of Memory. New York: Psychology Press.

Szabo, E.A., and Pfau, M. (2002). Nuances in inoculation: Theory and applications. In

J. Dillard and M. Pfau, The Persuasion Handbook (pp. 233-258). Thousand Oaks, CA: SAGE.

Tarricone, P. (2011). The taxonomy of metacognition. New York: Psychology Press.

Taylor, D. W. (1998). Aviation Maintenance Training Curriculum Evaluation: A Case Study. (Unpublished doctoral dissertation). University of Washington, Seattle, USA.

Thompson, L., and Cohen, T. (2012). Metacognition in Teams and Organizations. In P. Brinol and K. DeMarree, Social Metacognition (pp. 283-299). New York, Psychology Press.

Torrens, D., Thompson, V.A., and Cramer, K.M., (1999). Individual differences and the belief-bias effect: Mental models, logical necessity, and abstract reasoning. Thinking and Reasoning, 5, 1-28

Van Dillen, L. F., Heslenfeld, D. J., & Koole, S. L. (2009). Tuning down the emotional brain: an fMRI study of the effects of cognitive load on the processing of affective images. NeuroImage, 45(4), 1212-19.

Vice, S. (1997). Introducing Bakhtin. New York: Palgrave.

Vygotsky, L., & Kozulin (1986). Thought and Language. Cambridge, MA: MIT Press.

Vygotsky, L., Cole, M., John-Steiner, V., Scribner, S., & Souberman, E. (1978). Mind in Society: The Development of Higher Psychological Processes. Cambridge, MA: Harvard University Press.

Watzke, H. (Oct. 19, 2010). The brain in your gut. [Video File] Retrieved from: http://www.ted.com/talks/heribert_watzke_the_brain_in_your_gut.html

Wagman, M. (1998). Cognitive Science and the Mind-Body Problem. London: Praeger.

Wenger, E. (1987). Artificial Intelligence and Tutoring Systems. Los Altos, CA: Morgan Kaufmann Publishers.

Wenger, E. (1998). Communities of Practice. Cambridge, MA: Cmabridge Press.

Wenger, E., McDermott, R., & Snyder, W. M. (2002). Cultivating Communities of Practice: A Guide to Managing Knowledge. Boston: Harvard Business School Press.

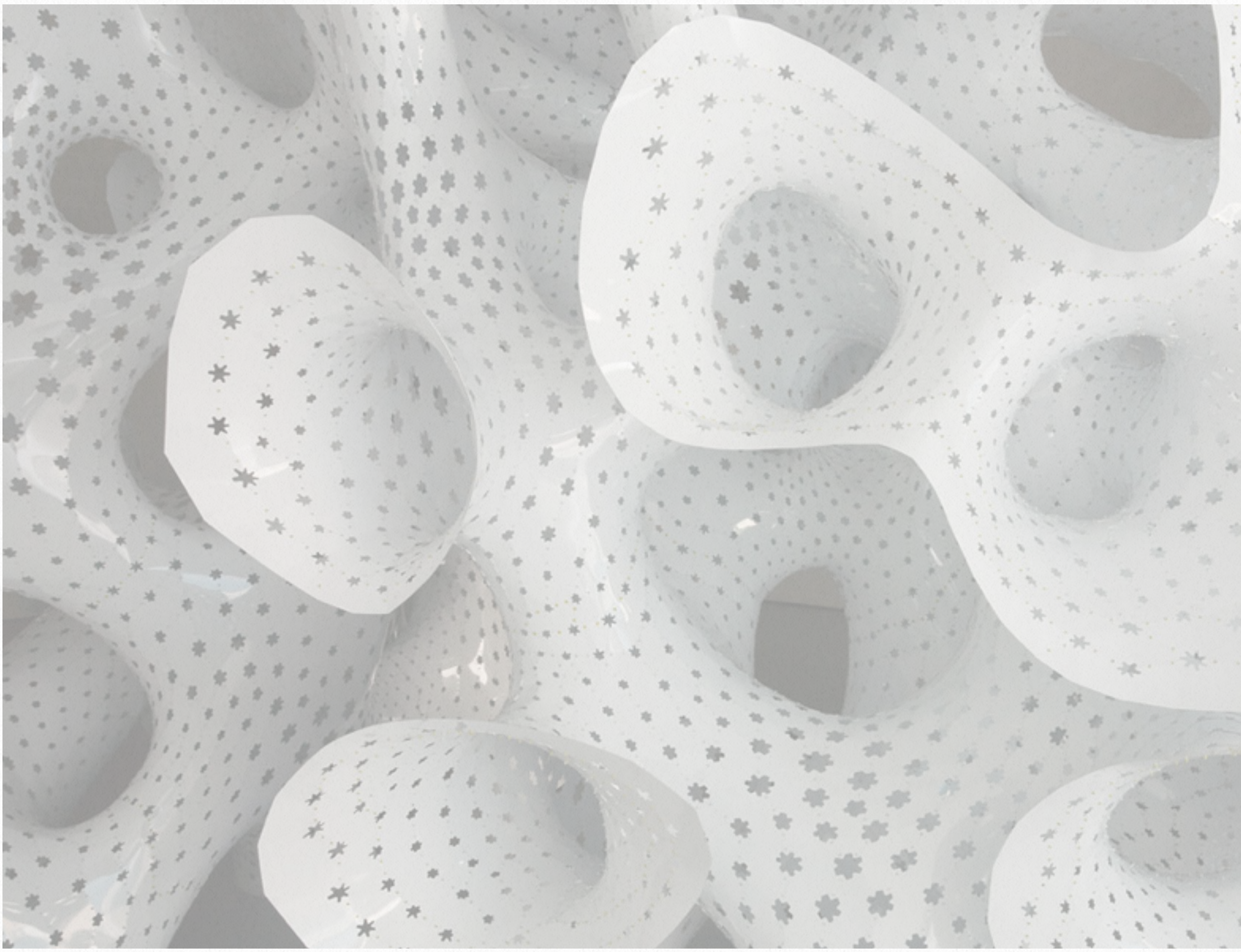
Weissman, D. (2003). Lost Souls: The Philosophic Origins of a Cultural Dilemma. Albany, NY: State Universities of New York Press.

Wlodkowski, R.J. (2008). Enhancing adult motivation to learn: A comprehensive guide for teaching all adults. San Francisco: Jossey-Bass.

Zeichner, K. (2009). Rethinking the Connections Between Campus Courses and Field Experiences in College- and University-Based Teacher Education. Journal of Teacher Education, 61(1-2), 89-99.

4

Form Finding: Thematic Experiments in Instructional Design



Form Finding: Thematic Experiments in Instructional Design

Exam Question 2:

Can the cognitive-situative framework help us to envision new learning technologies that coordinate cognitive and socially situated learning activities?

0.0 Rethinking Technology in the Age of Learning

Our time is a time for crossing barriers, for erasing old categories – for probing around. When two seemingly disparate elements are imaginatively poised, put in apposition in new and unique ways, startling discoveries often result.

Marshall McLuhan and Quentin Fiore,

The Medium is the Massage: An Inventory of Effects, 1967

In this paper, we will continue to expand the Ecological Theory-of-Action model through a series of instructional design models. We will use the concepts and construct definitions from the previous section to imagine a technologically-mediated instructional design system that could help to bring professional cognition and situated knowledge into a generative relationship. As such, we will examine three potential synthetic models of instructional design that can help practitioners, researchers, and interventionists to strategically plan systems that cultivate professionals' abilities in the context of their practice.

These systems, along with emerging digital tools, provide a new vision for technology that allows us to reduce the traditional distance between learning and practice. This goal comes from Rethinking Education in the Age of Technology by Collins and Halverson (2008). In the book, the authors explore of the risks and benefits of technology in the education of learners across the life span. They describe a future wherein the integration of technology into learning spaces provides learners with control over the processes, resources, and development of their learning. Thus, technologies provide us with flexible opportunities to help learners achieve their fullest potential (as in Dewey's idea of personal intellectual liberation). The needs for the development technologies to support learning in practice within the professions come from three major sources. First, Schon (1983) and Shulman (1986) argue that professional education must break down the divides between the domain knowledge of the field and its manifestations in the practice environment to continue growing. However, advances in technology have made it possible to develop tools to bridge that gap. The ubiquitous nature of the mobile Internet now allows individuals to access information to support their thinking at any time, thus blurring the boundaries between learning and performance environments. The consequences of this blur are ongoing and poorly understood.

Second, new trends in research (NRC, 2000) indicate that there are substantial opportunities for learning in the complex ecologies that exist in informal learning environments. That is, we can now begin to envision learning environments where teacher, learner, performance, and assessment, exist in a seamlessly integrated whole. In these environments, learners and 'more knowledgeable others' (including humans and computer systems; Wenger, 1987; Vygotsky, 1975) interact to perform complex whole tasks in the context of a sheltered enactment in appropriately naturalistic circumstances (Grossman, et al., 2009; also, the 'fading' principle in Clark and Meyer, 2008). This vision has particular importance to professionals, who practice in uncertain and contingent conditions, as it removes the barriers between formal and informal learning experiences. However, the research on informal learning is still young, and the core perspectives are in contention.

Third, the revolutionary thinking of Marshall McLuhan (1965), William Catton (1980), and Ray Kurtzweil (2000) have allowed us to understand the key roles of media and technology in the augmentation of the individual's capacity for learning and thinking. As McLuhan (2008) and Vygotsky (1975) note, human systems of meaning have substantial power to shape our understanding of the possibilities inherent in our world, as a matter of form and as a matter of substance. And just as mechanical technology augments the capacities of our bodies to do work (Catton, 1980; he calls the human-machine system "Homo Colossus"), digital and communications technologies may augment professionals' abilities to take deliberate action in the world. Unlike mechanical technology, digital technology operates in the spaces between the world of the mind and the world of the body.

It is in this space that Kurzweil finds a goal for the future: The development of augmentative digital technologies that enhance the power of the individual's mind in its envi-

Ecological Level	Reagent 1	Reagent 2	Resultant System
Cognitive	Expertise Continuum Dreyfus and Dreyfus, 1988	Learning Architectures Clark, 2008	Cognitive Development Novak, 2011
Metacognitive	A-O-F Framework Porter, 2007	Legacy Challenge Cycle Schwartz et al., 1999	Metacognitive Support Novak, 2012
Situative	Moments of Need Gottfredson and Mosher, 2010	Temporal-Spatial Technologies Novak, 2011	PISE Novak, 2012

Figure 1 – Table of Reagents and Products

ronment. These three revolutionary concepts are expressed in current thought in the area of New Literacies (Gee, 2010; Knobel & Lankshear, 2007), where meaning-making, personal engagement with content and knowledge, and representations of ideas are placed in the foreground of practices. Research in this area is ongoing, as new technologies emerge into the professional ecosystem (e.g. the early adoption of Blackberry devices and Smart-phones). However, we may look beyond the limitations of specific technologies to find places where Technology (as a larger phenomena of human augmentation) may support the evolution of thinking and action. Thus, we may posit models of learning technology design that support the integration of evolving consumer technologies.

This paper will explore three instructional design patterns that allow for the integration of judiciously designed learning technologies to support the development of professional expertise, as it is instantiated in the performance environment. This will proceed using the three major constructs of professional expertise developed in the previous paper (cognitive, metacognitive, and situative) as organizing tools for the design principles. Each design model is addressed by a synthesis of two reagents (Figure 1) that will help to address the needs at the specific level of the ecosystem where an opportunity has emerged.

At the cognitive level, we will see how Dreyfus and Dreyfus' (1988) continuum model of expert performance fuses with Clark's model of learning architectures (2008) to produce a systematic method of advancing cognition in performance environments. At the metacognitive level, Porter's (2008) Activity-Object-Features model of design for Web 2.0 spaces fuses with Schwartz, Lin, Brophy, and Bransford's (1999) Legacy Challenge Learning Cycle to provide a means for developing the metacognitive skills described in Question 1. Finally, at the Situative level, we will see how Gottfredson and Mosher's (2010) Moments of Need framework combines with opportunities provided by Temporal-Spatial technologies to produce the Physical-Intellectual-Social-Emotional (PISE) model of professional development. These models represent only a few of the infinite possibilities for supporting learning in the context of professional practice through technology (e.g. Jefsioutine and Kinght, 2007; Benyon, 2007), but they represent a new of envisioning the future of augmented learning design for professional audiences.

1.0 A Design for an Instructional System that Develops Cognitive Expertise

As we saw in part one of this trilogy of essays, there are a number of theoretical paradigms (NRC, 2000; De Groot, 1965; Lave and Wenger, 1991) that attempt to explain the evolutionary process of learners as they move from novice to expert in a given knowledge domain. In this segment, we will add an additional way: Dreyfus and Dreyfus' continuum model of expertise (1986). This model offers a useful five-stage description of the novice-to-expert continuum that can help us understand the qualities of behavior and thought that underlie professionals' cognition as it evolves over time. This continuum describes the distinctions between various levels of expertise in terms of the decision-making process used by the individual as he or she moves towards mastery. We use this phase model to develop a systematic technique for the development of the cognitive aspects of professional expertise examined in the previous essay.

According to Dreyfus and Dreyfus, this model of skill acquisition begins with a first stage wherein the novice works to gain a broad understanding of the skill mostly through formal instruction. During and after formal instruction, the novice practices the skill based on the rules that they have learned. This practice is directly shaped by the prior knowledge that the learner brings with them to the learning process. With additional practice, the novice ascends to the stage of advanced beginner. Here, the novice begins to supplement their limited understanding of the problem by generating a series of situational rules for behavior as they encounter iterations of the problem or situation. This is the stage where the-learner begins to understand the interaction between rules and context, and an understanding of when context dictates that rules be over-ridden.

The competent performer has a more sophisticated understanding of the situational rules found in a domain. This sense of understanding can be overwhelming because the individual is often unable to objectively discern which problem elements are important. Competent performers cope by using one of two strategies. They may become inactive and are unable to choose any plan at all, or they may proceed by rig-

Figure 2 - A Summary of the Dreyfus and Dreyfus (1986) model of expert development

idly adopting a plan and sticking to it without regard for changing circumstances. The proficient performer has significant experience in the application of domain knowledge to the real world. These experiences can be described as encounters with the problem in instantiations or cases (Spiro, Feltovich, Jacobson, and Coulson, 1992), after which the individual stores the case in memory. Each case retains the major features of the problem, including the eventual solution and is organized as a narrative in long term memory. Those who are proficient engage in problem solving on two levels (Schon, 1983). First, at an intuitive level, they infer potential solutions via pattern recognition, grasping the salient features in the problem space and comparing these features to previous cases. Then, depending on the complexity of the problem, the proficient performer may consciously consider a number of courses of action and speculate on potential outcomes before selecting what s/he considers to be the most successful strategy (Taylor, 1998).

The expert performer's behavior differs from the proficient performer in both the depth and breadth of experience in the knowledge domain. Expert problem solving behavior is often characterized by a mature and practiced understanding of the knowledge domain. However, such know-how is often highly individual, idiosyncratic, and intuitive in nature. Experts also describe entering a state of 'Flow,' or sustained deliberate practice (Csikszentmihalyi, 1990), where their experiences, thinking, and the environment all combine into a satisfying experience that results in the right behavior or solution for the situation. In these situations, experts may be unaware of how they arrive at the chosen behavior or solution (De Groot, 1965; Pylyshyn, 1984).

The Dreyfus and Dreyfus' continuum model helps to render the development of expertise in environments as a linear series of phases that unfold over time. However, unlike previ-

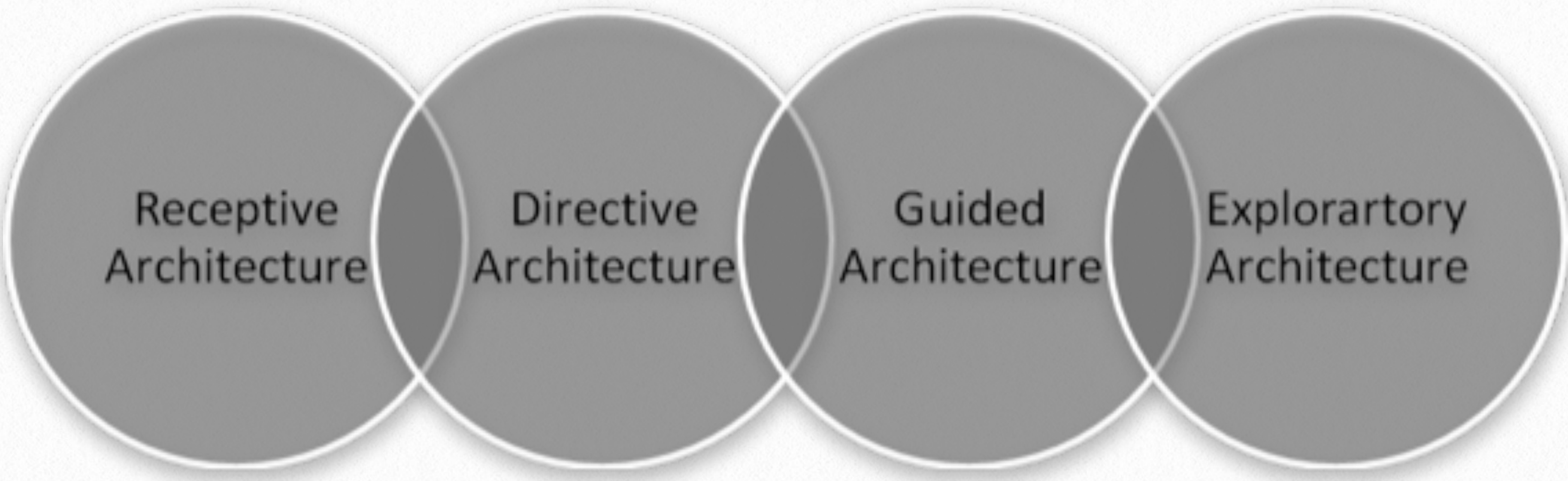


Figure 3 - Clark's Four Architectures, visualized as interlocking strategies.

ous models, it is descriptive. It tells us how and when experts learn to think and act, but little of the ways of cultivating this knowledge. To balance this deficit, the author looked for a mode of instructional design that could help to illuminate the opportunities for action across these phases. This led the author to Ruth Clark's Four Architectures for Learning. This constructivist mode of instructional design, when synchronized with Dreyfus and Dreyfus' continuum model, provides a guide for a systematic design for developing cognitive expertise.

Clark (2008) acknowledges that the construction of new knowledge can occur in a number of different instructional environments and through a diverse array of teaching methods. Her book, Building Expertise, characterizes constructivist learning in terms of four general architectures that have unique properties and are useful for reaching particular kinds of goals. First, in the Receptive Architecture, teachers deliver content to students in a format that does not include many opportunities for direct engagement. This is what we would normally term 'didacticism,' or classroom teaching. Second, Directive Architectures are based on instructive models of learning that follow specific steps. We would normally identify this as a feature of Instructional Systems Design, but it also has roots in the Behaviorist educational methods that emerged from the work of B.F. Skinner in the 1950s and 1960s.

While these first two architectures are familiar, the final two are much more rarely seen in the world of adult training. Third, Clark describes the Guided Discovery Architecture. This mode helps learners build their mental models through inductive learning and through the observation of the results of their choices and actions. Guided Discovery offers learners the opportunity to experiment, test alternative solutions, make mistakes, and experience the consequences of those mistakes in a low-risk, confidence building environment. This leads to a much richer, integrated learning experience that learners can transfer more easily to their daily environment.

Fourth and finally, Clark describes the Exploratory (or 'open-ended') Architecture. This is the most quintessentially constructivist architecture, as it gives the learner a large amount of control over the goals, parameters, methods, and outcomes of their learning experience. In this architecture, learners use their existing knowledge and interests to propel their exploration of new ideas and information. This method builds schema very quickly, as learners must develop their mental models in order to find new information, integrate it with their current knowledge, and acquire new skills that make the completion of their 'project' possible. This model is very rarely seen in work environments for two main reasons. First, it is very difficult to assess in conventional terms. There are no 'right' or 'wrong' answers to an Exploratory question; even the more generous terms 'optimal' and 'sub-optimal' do not quite fit the spirit of exploration. Second, Exploratory Architectures require substantial investments in terms of time, resources, and existing expertise (Bransford and Schwartz, 2009) to yield the greatest improvements in learner performance. However, these investments in time and effort can transform learners from competent performers into extraordinarily creative and innovative thinkers.

When selecting one of Clark's architectures for a learning event, learning designers should consider what Vygotsky's Zone of Proximal Development (ZPD). According to Vygotsky (1975), students sometimes arrive at the cusp of competence but cannot complete their task without a push from an external source (like a teacher or, in constructivist thought, a facilitator). These Zones appear as students build their mental schema, and facilitators must give students that final push into competence at a task at the exact moment that it is necessary. This push can come in the form of a facilitator recommending resources, providing overt scaffolding, or using other facilitation or teaching techniques.

Learning designers should seek to determine how much scaffolding is needed for each learner in each learning event in their program. These decisions should then guide the selection of the combination of Clark's architectures that provides adequate support for learners as they move through stages of development and Zones of Proximal Development. This would mean the development of an instructional program keeps students within their ZPD throughout their growth from novice to expert. For example, novices require more overt scaffolding, so consider using the Receptive or Directive models for early development. As the learner develops expertise, he or she will require more opportunities for practice, and so require more subtle scaffolding to guide their self-motivated learning.

Based on the models and theories described by Clark (2008) and Dreyfus and Dreyfus (1986), the diagram (Fig. 8) summarizes a potential expertise development system that fuses elements of Instructional Systems Design and features of Constructivist teaching into a new kind of instructional system.

As we have seen earlier, novice performers (row 1) must acquire new skills and knowledge about their domain. This 'front-loading' can be accomplished through traditional training methods, including classroom and online training. When learners have become aware of the basic skills of their domain, they might graduate to the status of advanced beginner (row 2). At this point, carefully constructed worked examples can provide learners with a scaffold for transferring their in-class knowledge (acquired as a novice) to their job environment. As the worker becomes more comfortable with their new tasks and knowledge, they enter competence phase (row 3). Here, a system of performance support and intelligent tutoring tools will help learners deal with the more complex elements of their domain, especially the vagaries that come with more advanced performance in ill-structured domains.

As learners continue towards the proficiency phase (row 4), they will integrate more and more domain knowledge from their environment into their existing schema. It is at this point that most learners stop progressing, as they have exhausted the challenges and opportunities for growth in their daily lives. However, an organization can continue to improve their workers beyond competence through the use of problem-based learning and simulations. These techniques can help cultivate the kinds of creative, deep thinking that

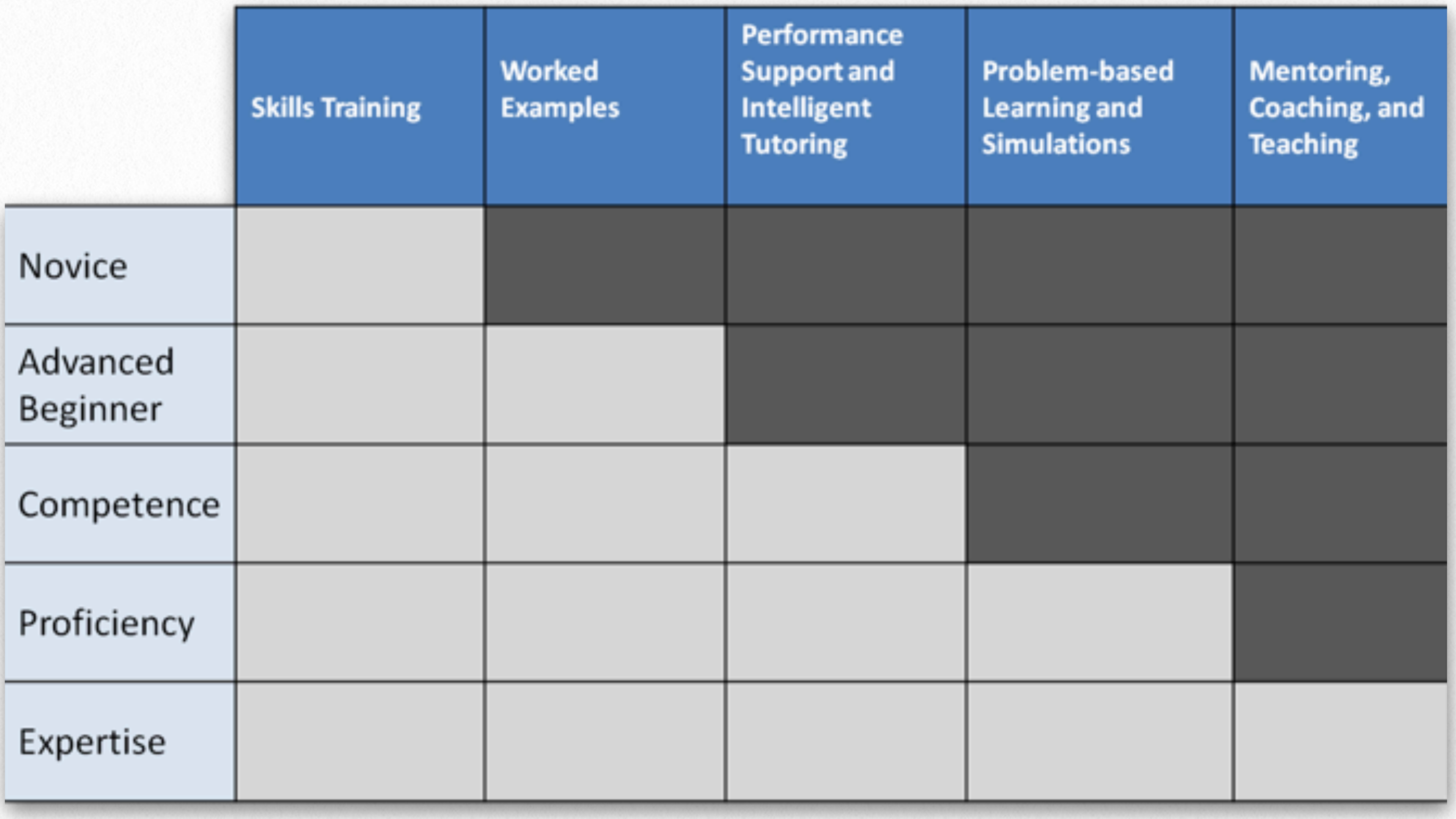


Figure 4 - Light grey squares indicate that a type of learning experience (column) is appropriate for a learner's level of expertise (row). Dark grey squares indicate that a learning experience is not appropriate for that level. For example, square [1,1] indicates that novices should receive training, but square [1,2] indicates that novices should not engage with worked examples until they have an adequate grasp of the basic procedures and vocabulary.

drives innovative problem solving. As proficient learners develop their skills through problems and simulations, they should also be given the opportunity to mentor and teach their own students. Teaching and mentoring are as essential to the development of expertise for the mentor as for the mentee, and they provide an opportunity for the expert to contribute to the health of the overall community.

2.0
Metacognitive Learning Cycles for Constructing Knowledge

Figure 5 – The Metacognitive Construct

The author believes that it is inefficient to use the cognitive-level system design to teach metacognitive skills, as metacognition processes may develop more quickly when embedded in the richness of the performance environment. In searching an appropriate system for the development of the eleven metacognitive skills described in the previous paper, we will attempt to hybridize two more design processes. The success of this fusion could provide instructional designers with new ways of developing technologically-mediated performance support systems for metacognition. This extends existing ideas of performance support (Rossett and Schafer, 2007; Gottfredson and Mosher, 2010) that support the mapping of the world of cognition onto the professionals' world of performance. Thus, we will examine how these two models can integrate to support the metacogni-

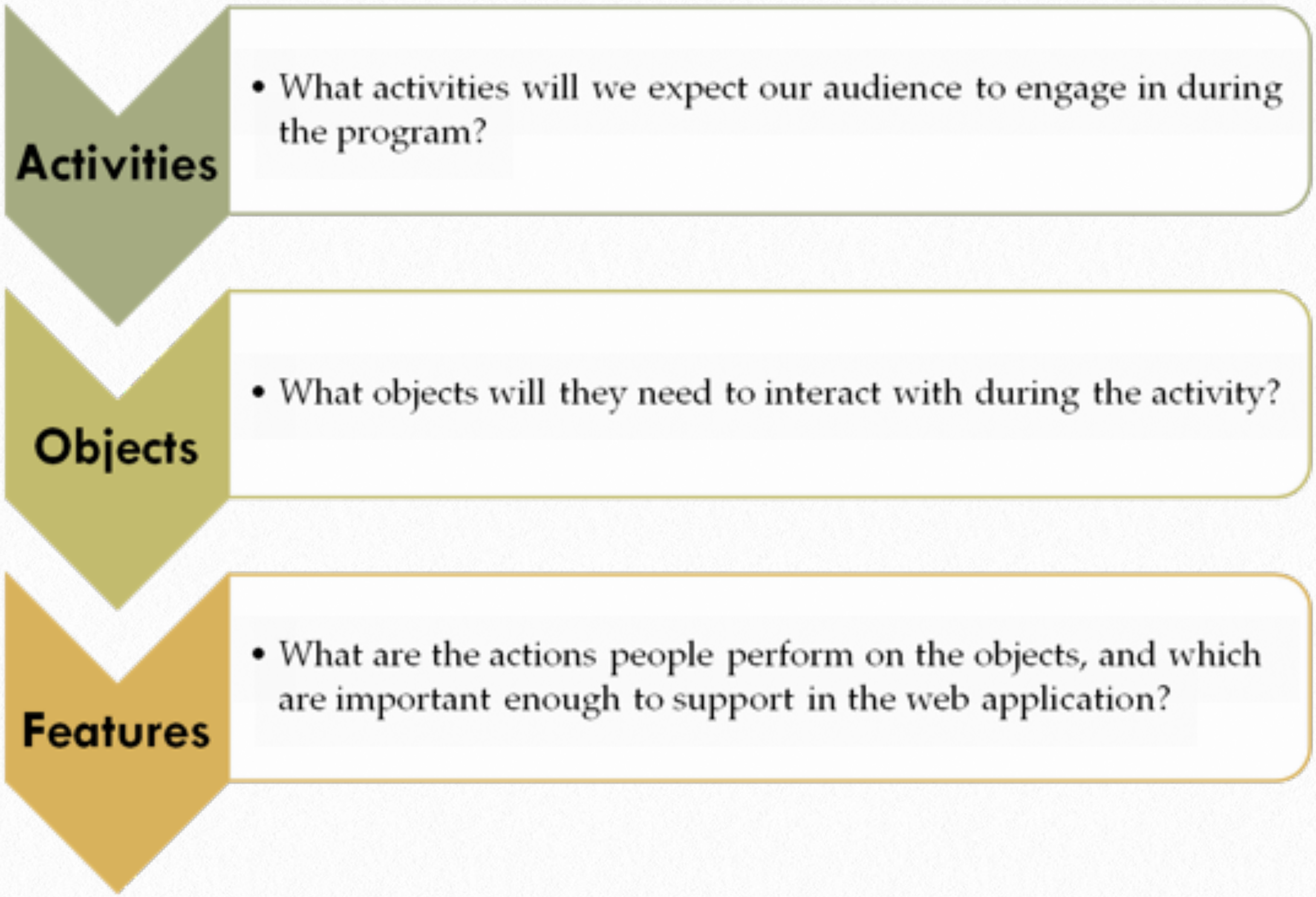


Figure 6 – The Activities-Objects-Features (A-O-F) Model

tive features discussed in the last question.

The first comes from Porter (2008) calls the 'Activities-Objects-Features' model of development of Web 2.0 services and technologies. In surveying successful social media companies, Porter discovered that the standout services came from sites that focused on supporting a single activity rather than suite of features. When companies focused their efforts on a particular activity (e.g. shopping, sharing photos, online journaling) and created a platform to specifically support that activity, people reported a greater degree of satisfaction with the site. Further, the focus on a core activity leads to tools that support users and their thinking at the moment of reification of that activity.

The graphic above summarizes the core questions of each part of the A-O-F model. After identifying the particular activity, the designer should identify the kinds of virtual objects (e.g. content modules, images, videos, audio) that the user will interact with during the activity. The identification of objects in turn allows designers to consider the necessary fea-

Figure 7 - The Legacy Challenge Cycle

tures (or possible actions and interactions) of the system. If the designers have accurately described the parameters of the activity, then the features should seamlessly support learners as they perform in their environment.

While Porter's model helps us to envision the design of the technological platform and its interacting components, it does not provide tell us about the procedural relationship between these objects. Our second reagent in this project, the Legacy Challenge Cycle (Schwartz, Lin, Brophy, and Bransford, 1999; features are also described in Merrill, 2002; Clark and Meyer, 2008), provides a clearer picture of the process that unites the Activities-Objects-Features into a metacognitively oriented learning experience. In these cycles, learners are introduced to authentic situations and challenges that are explored through iterative cycles of writing, resource integration, revision, small group sharing, and reporting to the larger group (Fig. 7). This exploratory learning system provides opportunities for learners to identify their preconceptions, examine evidence from experts, and reflect on their thinking in private and public ways.

However, we may note that the Legacy Challenge Cycle formulation emphasizes self-reflective metacognitive processes. While self-reflection is the keystone of metacognition and involved in all of the other processes, it is only one of many potential metacognitive activities that professionals engage in during their performance. The author is now in a position to ask, “What would the AOF-LCC hybrid look like if it were calibrated towards other kinds of metacognitive activities?” This work is still in progress, but the author can envision three potential digital platforms that support metacognition in the following ways:

- A learning cycle embedded in a virtual platform that helps professionals understand and improve their practice through successive role-taking activities and theories of mind.

- A digital strategy-selection support system that helps learners to track and evaluate the effects of past choices on changes by proceeding through several rounds of deliberation and analysis.

- A tool that trains professionals to control and monitor their emotions and bodies during their performance through various self-regulatory techniques and Flow-enhancements.

The convergence of the AOF and LCC models may allow instructional designers to develop technologically-mediated learning platforms that augment and guide the metacognitive learning practices of professionals as they perform real-world tasks. Augmentation of this ability in the context of a learning cycle may help to promote the development and transfer of those skills into other domains within the performance environment.

3.0
Learning Events and Structures in the Situated Professional Realm

Finally, we close the examination of models with an exploration of instructional design models that serve the situative level of the ecology. The synthesis between models in this segment will allow us to consider technologies that cultivate professionals' theories-of-action in the context of their work environment. This is an essential goal, as professionals must learn to think about the place of their performance in the larger community of practice. But where do the opportunities for situative alignment occur, and how can we capitalize on them?

In response to these questions, Gottfredson and Mosher (2011) identify five 'Moments of Need' within performance ecosystems. These five moments are opportunities for change, and performance technologists must manage these events carefully to ensure harmonious work. These include Moments of:

• **New**, when learners require entirely new skills and knowledge within a domain as a response to changes in their ecosystem. The acquisition of new skills and knowledge is essential to the long-term growth of the professional's model of the domain and ability to manipulate the variables.

• **More**, when learners expand their knowledge within a domain, or acquire knowledge from other tribes and groups within their system. This occurs regularly in the professions, as expected levels of shared knowledge rise over time and require continued professional development.

• **Apply**, when learners need to act on their knowledge, including activities like planning, remembering, and adaptation that constitute their role within the ecosystem. This also includes the application of ostensibly theoretical knowledge to an environment, or the application of one domain's thinking to another domain's problem.

• **Solve**, when learners address problems (expected or otherwise) as they emerge in their segment of the ecosystem. This is related to the demands of routine and wicked problems, as well as their emergence from other activities in the ecosystem.

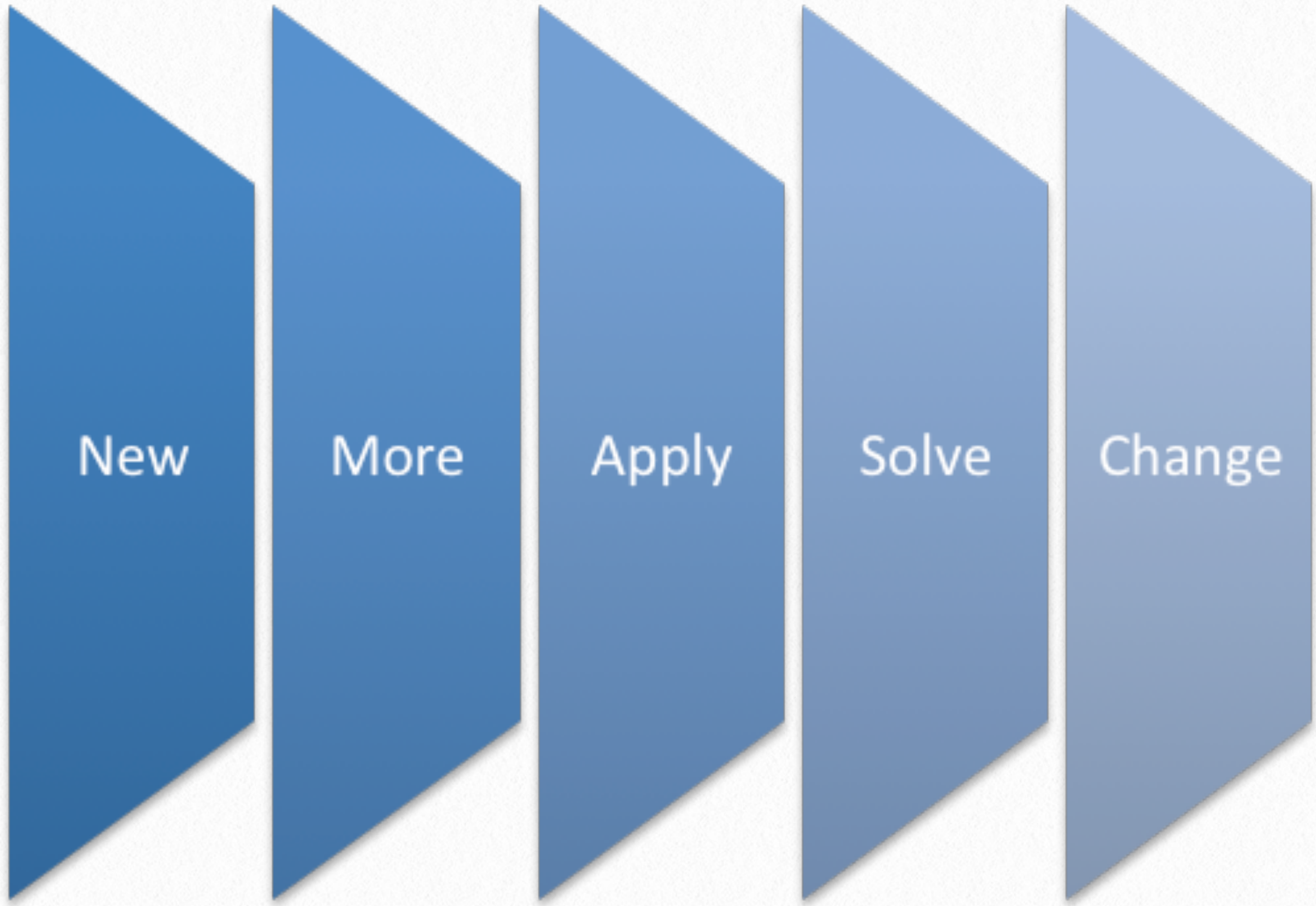


Figure 8 – The Moments of Need Framework

• **Change**, when learners must alter their performance to match a changing environmental characteristic or new demands. This is especially challenging when that performance is deeply ingrained or require knowledge from a new domain, and can require substantial effort to alter.

Using moments of need as a framework for understanding the kinds of challenges that workers face could allow training organizations to respond proactively to the development of instructional systems instead of waiting for problems to emerge. The development of 'intelligence' from the analysis of existing data about professionals' performance can help researchers understand and predict the changes that are occurring within their world.

While Gottfredson and Mosher tell us when we can expect these moments, they do not tell use how to develop technologies to support learners in those moments. The following model (Fig. 9) describes the interrelations of a set of instructional technology interventions that could provide the technological scaffolding to support the development of professionals across the environment:

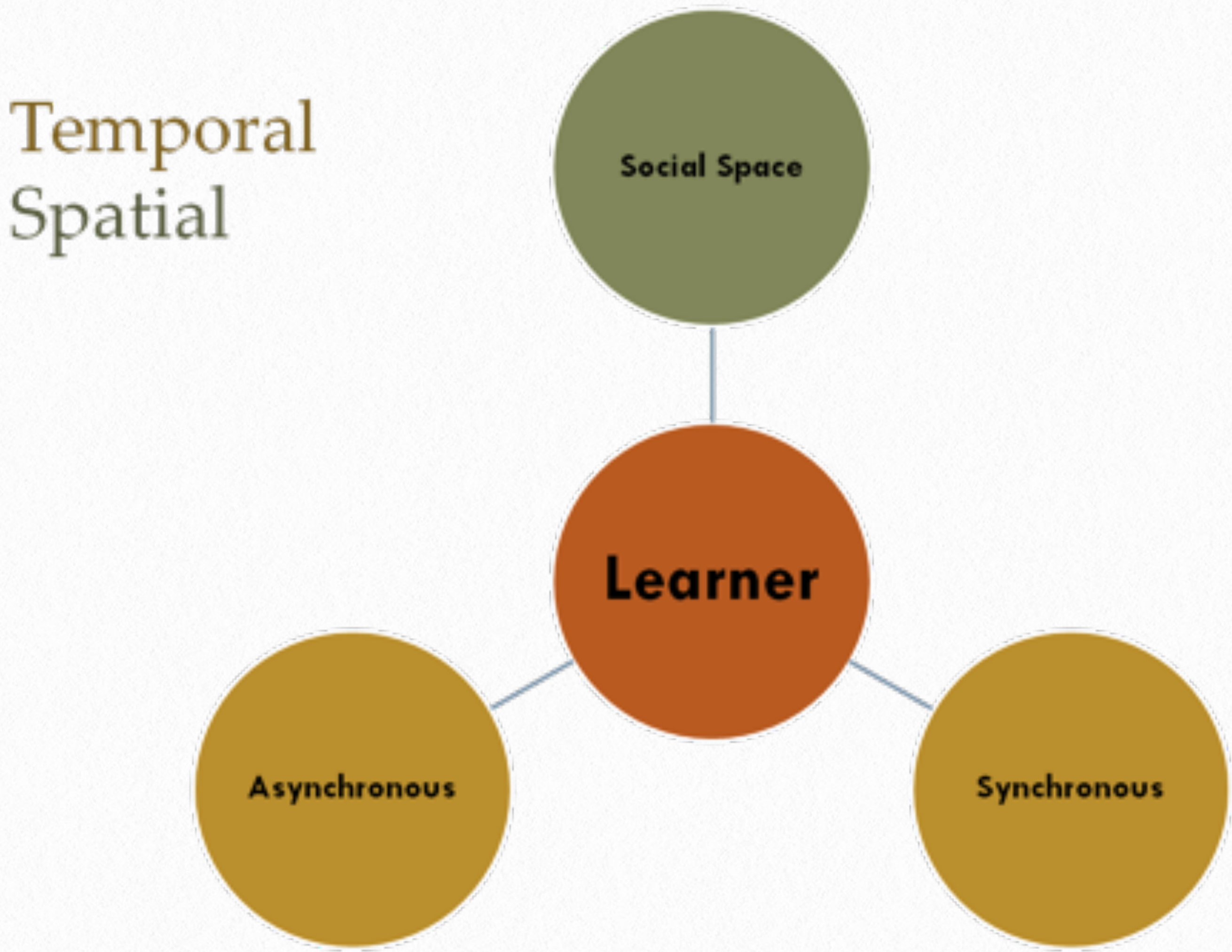


Figure 9 – The Temporo-Spatial Model

The yellow spheres, Asynchronous and Synchronous, describe temporal technologies that support time-based activities, both time-shifted and real-time. Synchronous tools, such as Adobe Connect or BlackBoard Elluminate, provide teachers with opportunities to interface for live meetings, discussions, enactments, and webcam-based peer reviews of their teaching practices. Asynchronous learning activities, like message boards and discussion forums, provide novice teachers with spaces to ask long-term questions of practice and strategy, as well as non-essential enrichment activities.

The green sphere represents a 'spatial' tool that encapsulates social activities simultaneously in real-time and time-shifted ways. These technologies include social networking tools, social bookmarking, blogs, custom wikis, collaborative workspaces like GoogleDocs, and context-sensitive mobile technologies (Shen, Wang, Gao, Novak, and Tang, 2009; Novak, Wang, and Callaghan, 2012). Specific technologies aside, this model helps us to understand the virtual 'places' and occasions when the user interacts with a given technology. Taken together, the

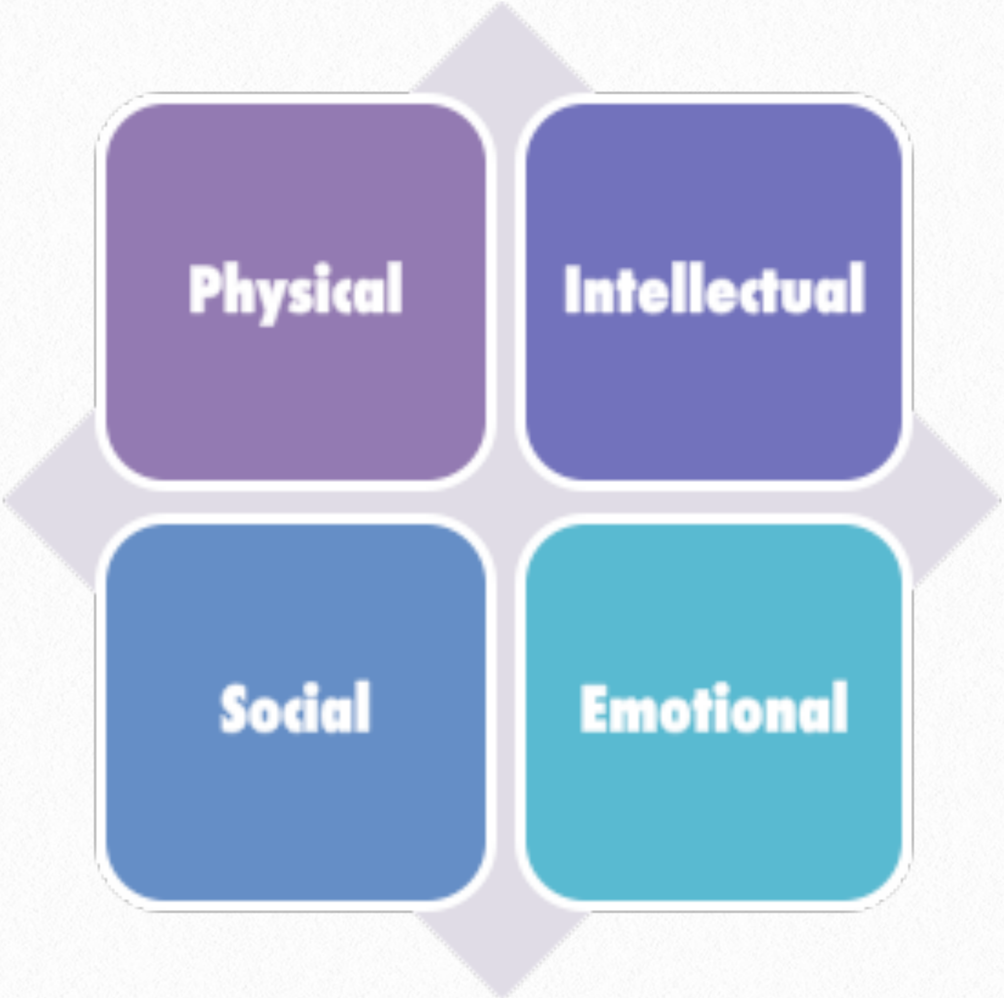


Figure 10 – The Physical-Intellectual-Social-Emotional Model of Situated

Moments of Need Framework and the Temporo-Spatial framework can help instructional designers envision ways of supporting professionals in their changing world.

Thus, it is at the convergence of Moments of Need in the professional environment and Temporal-Spatial Opportunities in the learner's technology environment that we find a model for designing learning experiences in the situative realm. The professional's theory of action may be augmented by focusing on the times and places where physical, intellectual, social, and emotional experiences are necessary to the moral development and vision of the professional. In this hybrid-model, instructional designers should consider how these four experience influence how the professional must know, be, and do. Thus, the intersection of MoN and TSO yields the Physical, Intellectual, Social, and Emotional (PISE) that can support learners through different technological environments as they arrive at particular moments of reification.

At the outset, instructional designers should consider the role of the physical body in the context of the performance ecology, and how the person's inhabitation of spaces and locations influences their ability to perform their role. Next, they should consider the ideas and ways of knowing that are important within the professional's domain and environment. Then, designers should consider how the social environment informs the needs of learner at the Moments of Need identified during the analysis. Finally, the proposed learning materials should connect with the learners at an emotional level so that they might remember how they felt during the experience. With continued development, the PISE model may allow instructional designers to create performance support technologies that promote the long-term growth of the professional in their situative context by cultivating the whole person. The PISE process would ideally cultivate the individual's ability to be, know, and do, and advance them to the ideal moral positions of Hero-Scholar-Worker by turning them into the professional that they envision themselves. It is in cultivating the whole person that we advance the professional into the position of expert.

4.0 Conclusion

In this question, we have examined three modes of instructional design that focus on the learner instead of the designer. This learner-centeredness challenges traditional instructional design methods (e.g. the ADDIE model) by proposing the adoption of strategies that focus on learning as opposed to instructing. In this way, we may consider these models the author's first forays beyond instructional design and into the realm of the Learning Sciences. This new evolution of Educational Technology has the potential to advance professional development by focusing on the human-environment interactions that occur in the context of practice. In the next question, we will examine the necessary research methodologies that will make this possible.

Bibliography

Barnett, B.G. (1995). "Developing reflection and expertise: can mentors make the difference?" Journal of Educational Administration, 33 (5), 45-59.

Benyon, D. (2007) Information architecture and navigation design for websites. In P. Zaphris and S. Kurniawan (Eds.), Human Computer Interaction Research in Web Design and Evaluation, (pp.165-184). Hershey, PA: IGI Global.

Bransford, J.D., and Schwartz, D.L. (2009). It takes expertise to make expertise: Some thoughts about why and how. In K.A. Ericsson (Ed.), Development of Professional Expertise (432-448). New York: Cambridge University Press.

Carbonell, J.R. (1970). AI in CAI: Artificial intelligence approach to computer assisted instruction. IEEE Transoctions on Man-Machine Systems, 11, 190-202.

Carroll, J.M. (2000). Making use: Scenario-based design of human-computer interactions. Cambridge, MA: MIT Press.

Catton, W. (1980). Overshoot: The ecological roots of revolutionary change.

Clark, R. C. (2008). Building Expertise. San Francisco: Pfeiffer.

Clark, R.C., & Mayer, R. (2008). E-Learning and the Science of Instruction. San Francisco: Pfeiffer:

Clark, R.C., Nguyen, F., Sweller, J. (2006). Efficiency in learning:evidence-based guidelines to manage cognitive load. San Francisco: Pfeiffer.

Collins, A., & Halverson, R. (2009). Rethinking Education in the Age of Technology. New York: Teachers College Press.

Csíkszentmihályi, M. (1990). Flow: The psychology of optimal experience. New York: Harper Perennial Modern Classics.

De Groot, A. D. (1965). Thought and Choice in Chess. Paris: Mouton & Co.

Dreyfus, H. L., & Dreyfus, S. E. (1986). Mind over machine: The power of human intuition and expertise in the era of the computer. New York: Free Press.

Ericsson, K. A. (2009). Development of Professional Expertise. New York: Cambridge University Press.

Gee, J. (2010). New digital media and learning as an emerging area and “worked examples” as one way forward. Cambridge, MA: MIT Press.

Gottfredson, C., & Mosher, B. (2011). Innovative performance support. New York: McGraw Hill.

Grossman, P., Compton, C., Igra, D., & Williamson, P. W. (2009). Teaching Practice: A Cross-Professional Perspective. Teachers College Record, 111(9), 2055-2100.

Hatano, G., Inagaki, K. (1986). Two courses of expertise. In H. Stevenson, H. Azuma, & K. Hakuta (eds.), Child Development and Education in Japan (p.262-272). New York: Freeman.

Jefsioutine, M., and Knight, J. (2007) Design methods for experience design. In P. Zaphris and S. Kurniawan (Eds.), Human Computer Interaction Research in Web Design and Evaluation, (pp.130-147). Hershey, PA: IGI Global.

Knobel, M., and Lankshear, C. (Eds.) (2007). A new literacies sampler. New York: Peter Lang.

Kurzweil, R. (2000). The age of spiritual machines. New York: Penguin.

Lave, J., & Wenger, E. (1991). Situated Learning: Legitimate Peripheral Participation. New York: Cambridge University Press.

Lou, Y., Abrami, P.C., d'Apollonia, S. (2001). Small group and individual learning with technology: A meta-analysis. Review of Educational Research, 71(3), 449-521.

McLuhan, M. (2008). Understanding media: The extensions of man. Cambridge, MA: MIT Press.

McLuhan, M., and Fiore, Q. (1967). The medium is the massage: An inventory of effects. New York: Bantam Books.

Merrill, M. D. (2002). First principles of instruction. Educational Technology Research and Development, 50(3), 43-59.

Moreno, R., Mayer, R.E. (2005). Role of guidance, reflection, and interactivity in an agent-based multimedia game. Journal of Educational Psychology, 97(1), 117-128.

National Research Council. (2000). How People Learn: Brain, Mind, Experience, and School. Washington, D.C.: National Academy Press.

Nguyen, F. (2006). What you already know does matter: Expertise and electronic performance support systems. Performance Improvement, 45(4), 9-12.

Novak, D., Wang, M., & Callaghan, V. (2012). Looking In, Looking Out: A Discussion of the Educational Affordances of Current Mobile Augmented Reality Technologies. In J. Jia (ed.), Educational Stages and Interactive Learning: From Kindergarten to Workplace Training. Hershey, PA: IGI Global.

Shen, R. M., Wang, M. J., Gao, W. P., Novak, D., & Tang, L. (2009). Mobile Learning in a Large Blended Computer Science Classroom: System Function, Pedagogies, and Their Impact on Learning. IEEE Transactions on Education, 52(4), 538-546.

Pylyshyn, Z.W. (1984). Computation and cognition: Towards a foundation for cognitive science. Cambridge, MA: MIT Press

Porter, J. (2008). Designing for the social web. San Francisco: New Riders Press.

Riel, M. & Polin, L. (2004) Learning Communities: Common Ground and Critical Differences in Designing Technical Support. In Barab, S. A., Kling, R., & Gray, J. (Eds.). Designing for Virtual Communities in the Service of Learning. Cambridge, MA: Cambridge University Press.

Rossett, A., and Gautier-Downes, S. (1991). The handbook of job aids. San Francisco: Pfeiffer.

Rossett, A., & Marino, G. (2005). If Coaching is Good , then E-Coaching is< Training and Development, 45(11), 46-49.

Rossett, A., and Shafer, L. (2006). Job aids and performance support. San Francisco: Pfeiffer.

Schmidt, H.E., Moust, J.H.C. (2000). Factors affecting small-group tutorial learning: A review of research. In D.H. Evensen & C.E. Hmelo (Eds.), Problem-based learning. Mahwah, NJ: Lawrence Erlbaum.

Schon, D. (1983). The Reflective Practitioner: How Professionals Think in Action. New York: Basic Books.

Schwartz, D.L., Lin, X., Brophy, S., Bransford, J.D. (1999) Toward the Development of Flexibly Adaptive Instructional Designs. In Charles Riegeluth (ed.), Instructional-Design Theories and Models: A New Paradigm of Instructional Theory, Volume 2. New York: Lawrence Erlbaum.

Short, P.M., Rinehart, J.S. (1993). Reflection as a means of developing expertise. Educational Administration Quarterly, 29(4), 501-521.

Shulman, L. (1986). Those who understand: Knowledge growth in teaching. Educational Researcher, 15, 4-14

Spiro, R.J., Feltovich, P.J., Jacobson, M.J., & Coulson, R.I. (1992) Cognitive flexibility, constructivism, and hypertext: Random access instruction for advanced knowledge acquisition in ill-structured domains. In T. M. Duffy & D. H. Jonassen (Eds.) Constructivism and the Technology of Instruction. 121-128. Hillsdale, NJ: Lawrence Earlbaum & Associates.

Taylor, D. W. (1998). Aviation Maintenance Training Curriculum Evaluation: A Case Study. (Unpublished doctoral dissertation). University of Washington, Seattle, USA.

Van Eck, R. (2006). Digital game-based learning. Educause Review, 41(2), 17-30.

Van Merrienboer, & J.J.G., Boot, E.W. (2009). Research on past and current training in professional domains: The emerging need for a paradigm shift. In K.A. Ericsson (Ed.), Development of Professional Expertise (131-156). New York: Cambridge University Press.

Vygotsky, L., Cole, M., John-Steiner, V., Scribner, S., & Souberman, E. (1978). Mind in Society: The Development of Higher Psychological Processes. Cambridge, MA: Harvard University Press.

Wenger, E. (1987). Artificial Intelligence and Tutoring Systems. Los Altos, CA: Morgan Kaufmann Publishers.

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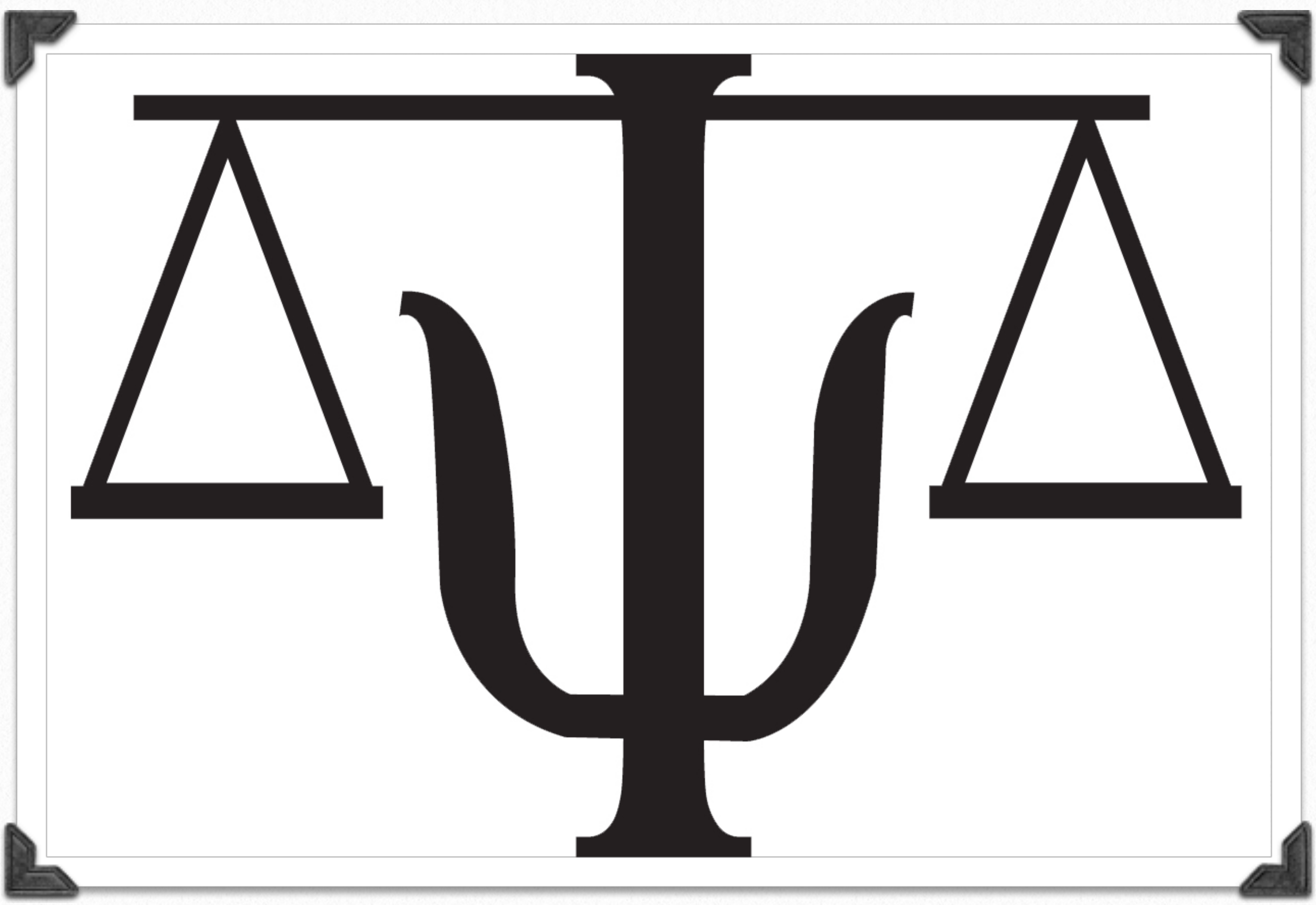
A Richer Picture



A Richer Picture: Design-based Methods of Inquiry

Question 3: Methods

Can the synthesis of several existing qualitative methodologies enable us to analyze data in ways that tell us about learners and their performance ecosystems?

A Richer Picture

In Question 1, we developed a series of constructs that define professional expertise as it exists at cognitive, metacognitive, and situative levels of the performance ecosystem. In Question 2, we took some time to examine potential strategies for integrating augmentative technologies into the ecosystem at each of these levels. Now, we turn to methodology, or the ways of knowing about how to select appropriate technologies given particular learning goals at particular levels and times in the professional ecology. This paper will draw from the philosophies and methodologies associated with the Learning Sciences in order to develop a team-based, systematic approach to implementing new learning technologies in professional performance ecologies.

Research on methodologies as they relate to the use of technology has traditionally come from the Human-Centered Design Engineering and Educational Technology spaces. However, this paper will offer the idea that the Learning Sciences may provide significant new contributions to research on the development of technologies for learning in the context of complex professional practice environments. This assertion comes from the author's observation of three major trends in research methodologies in the field at the moment. The first comes from the evolving discourse on the role of experimental design as it relates to the complexity of ecological research. That is, learning occurs simultaneously at all levels of the individual's experience; isolating one characteristic for study by experimental control has yielded dubious results when generalized to larger populations outside of the controlled setting. In this way, research in the Learning Sciences should build from experimental results drawn from across the field, and emphasize the integration and implementation of these results.

Second, Dr. Elizabeth Sanders of the University of Washington has astutely critiqued mixed-methods research for failing to provide quality results in either the quantitative or qualitative realm. That is, in attempting to serve two separate modes of thought (positivist and post-positivist), researchers fail to serve either. While Dr. Sanders is correct, research related to professional ecosystem research still requires the adoption of multiple qualitative and quantitative measures to dig deeply into the phenomena.

However, the means of addressing this critique and creating a robust, scientific means of mapping goals to opportunities comes from two sources. First, trends towards Action Research (Argyris, 1968) have opened up significant new avenues for research that involve the development of research projects that address realistic contexts. That is, if research in the Learning Sciences occurs in the real world, it should also exist to transform that world (DBR Collective, 2003). Equally, meta-studies on research across disciplines show that the number of team-based research projects has steadily increased over the decades (Price, 1986). One plausible explanation for this issue is the emergence of Big Science and Big Data, or the multi-faceted analysis of data from hundreds of sources in different disciplines in the service of a study. Thus, Learning Sciences' need for mixed-methods could be met through the adoption of methodologies that are purposefully team-based, and that capitalize on the recombination of unique skill sets from a variety of loci of research expertise.

Finally, research on the use of technology to augment professional performance and expertise in the learning sciences should privilege the trend towards Action Research, and its' descendent Design-based Research (DBR). Collins (1992) and Brown (1992) formulated the methodological philosophy to study the complex interrelationships of design, research, and practice that occur during the creation of technology enhanced environments (Wang & Hannafin, 2005). Subsequent generations of Design-based Research theory have generated a new means of approaching the implementation of technologies in learning and performance environments that is learner-centered, context-responsive, and valuable to theory and practice (DBR Collective, 2003; Penuel, Fishman, Chang, 2011). Thus, DBR is ideal for research in the application of technology to education

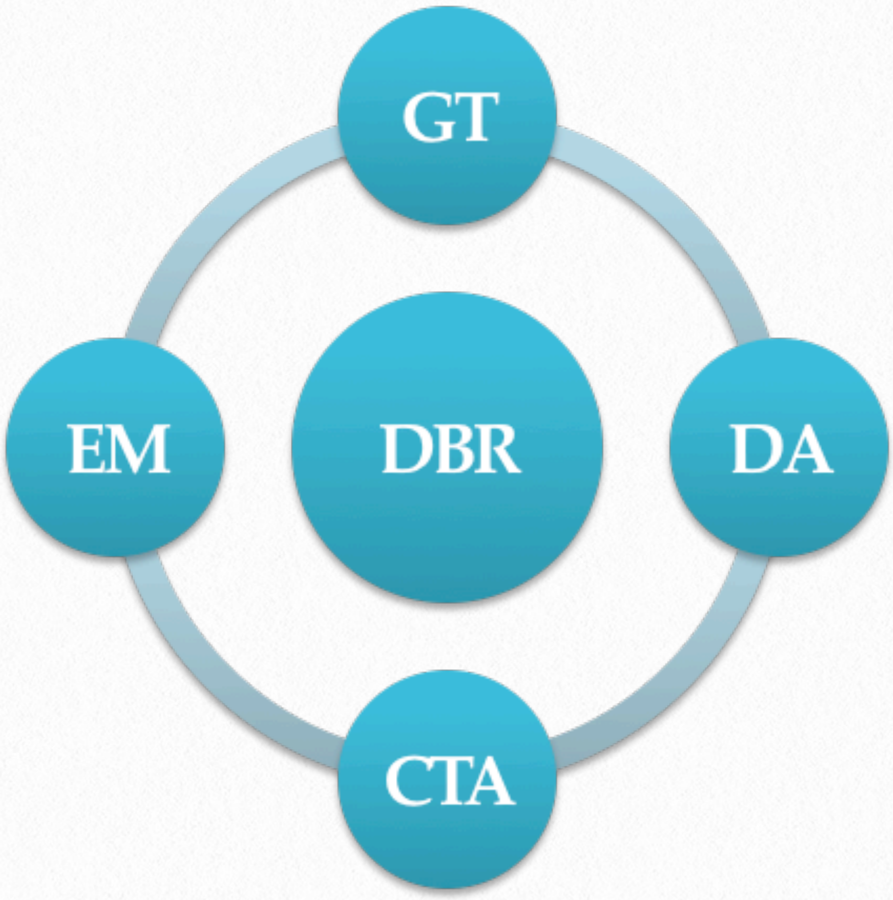


Figure 1 – Design-based Research is supported through Grounded Theory, Discourse Analysis, Cognitive Task Analysis, and Ethnomethodological strategies

because it allows for a sufficiently flexible, rigorous, and complex approach to the relationships of designs, interventions, and research.

This flexibility is key for researching the ways that changes in Technological systems can induce changes in behavior, and vice versa. Further, DBR's ability to treat research as an ongoing, co-constructed, and valuable asset to both researcher and practitioner means that it provides value directly to the client as well as to their professional community. In this way, DBR could provide the necessary operations for the advanced study of the capacities of technologies to support professionals' learning in the context of their practice by unifying a variety of tools.

Knowing in Complexity: A Multi-Method System for Researching the Support of Expertise Through Technology

Based on these trends, the author will offer a potential model of DBR that integrates several kinds of methodologies into a philosophically cohesive and rigorous whole that can adapt to the needs and goals of teams of researchers. To ac-

Method and Sources	Purpose	Summary
Design-based Research **(Brown, 1992; Collins, 1992; DBR Collective, 2003)**	**Action Generates Thought**	DBR provides an understanding of the population, project context, and researcher-client goals. DBR aligns the other methods towards a common purpose.
Grounded Theory (Glaser and Strauss, 1967; Glesne, 2011)	**Thoughts Take Form**	GT provides a means for understanding how professionals understand their roles, their work, and themselves.
Discourse Analysis Tools (Gee, 2010a; Gee, 2010b)	**Forms Become Order**	DA tools provide a means of understanding how people use language to express emotional and identity-oriented components of their vision of practice.
Cognitive Task Analysis (Hoffman and Militello, 2009)	**Order Becomes Process**	CTA provides a way to map and delineate the specific cognitive, metacognitive, and procedural component of a professional's activity in their context.
Ethnomethodology (Garfinkle, 1967; Koschmann, Stahl, & Zemel, 2007)	**Process Becomes Action**	EM, as a method, helps to understand how processes become part of a professional's theory of action, and how this takes shape as socially-situated means of activity that is recognizable to all of the actors in the community of practice.

Table 1 – The DBR System

complish this task, we will examine the interrelationships between Grounded Theory, Discourse Analysis, Cognitive Task Analysis, Ethnomethodology, and DBR (Figure 1).

These five methodologies, when oriented towards a central problem, can help researchers and clients to understand the professional performance environment in richer ways. This section of the paper will proceed through the logic of this model, with an emphasis on the integration of these methods into a cohesive whole. It is through this process that we may trace the relationships between thought and action as the professional reifies and enacts them in their environment. This is summarized in Table 1.

Design-based Research: Action Generates Thought

In working out the logic of this particular instance of the model, DBR's unique position as both a means of research and the impetus for action makes it an ideal candidate to serve as a controller module for this research system. That is, researchers that specialize in four other methodologies may relate their findings in deliberate ways through this initial plan of action. The circuit created by these tools can help to ensure that the researchers and clients select the optimal forms and placements of technology within the ecosystem by virtue of its capacity for the rich representation of the thought of candidates. This could lead to better tools for sensing and capitalizing on opportunities for the implementation of technologies that address specific aspects of professionals' performance at various levels of the ecosystem (as described in Forsman, 2007).

DBR's strongly learner-centered stance serves to codify the co-constructed goals and needs of the researchers and clients, and help them form a vision for providing value at the practical and theoretical levels. This explicit relationship between the researcher, client, and developer is not a sign of weakness in this methodology, but rather the source of its strength (Barab, Thomas, Dodge, Squire, and Newell, 2004). To safeguard this strength (and the rigor that attends and supports it), Wang and Hannafin (2005) describe DBR studies as having five key properties. In their formulation, DBR studies are:

• Pragmatic, or the extent of the improvements in practice for the clients as weighed against the costs and intrusiveness of the research.

• Grounded, or the acknowledgement that research and design occur in real-world environments, but are equally grounded in theoretical literature and philosophical goals. Thus, literature and existing research becomes a source of data that may be used in decision-making and the triangulation of findings.

• Interactive, Iterative, Flexible, or the understanding that participants and researchers must work together to define the problem as it emerges, and progress through several cycles of experimentation to arrive at better solutions.

• Integrative, or the continuing integration of mixed-methods as a means to maintain rigor as the problem emerges and changes. Equally, researchers should construct sample sets that contain a variety of representations of participant performance and knowledge.

• Contextual, or the denial of traditionally positivist and population-general principles of research, that allow for the creation, implementation, and evolution of population-specific changes to processes.

From these initial principles, it is possible to see how this method of research may help to codify the usually messy technology development and implementation processes that are employed by instructional designers and developers that support professionals in the field. Through this process, one could imagine a system wherein organizations use their various data streams to systematically record and understand the changes and needs-for-change that occur in their professional populations. Further, DBR can help those organizations to systematically chart their strategic efforts over time, and to use technologies to address the specific needs of their learner. This is especially important as professional teaching and learning support structures move towards a globally-distributed model. To achieve the best possible results, this author argues that researchers should align their skills and knowledge to the particular demands of the population, problems, and outcomes of their clients. Thus, the decisions and lessons-learned from the DBR project should come from a variety of methods that buttress one another (Wang and Hannafin, 2005). In the above model (one of many possible formulations), this process begins with Grounded Theory.

Grounded Theory: Thoughts Take Form

In this example of the research cycle, we begin with Grounded Theory (GT), as formulated by Glaser and Strauss (1967). This method was developed as an explicitly post-facto development of themes that initially seems to conflict with DBR's adoption of a priori learning theories in the initial development phases. However, GT allows researchers to examine the expressions of behavior as they occur in naturalistic settings, and to derive theories about actors based on the systematic analysis of expressions of those behaviors. In this context, Grounded Theory allows researchers to observe the formation of thoughts and mental models through a holistic view of the activities of professionals. The method's role is thus formulated as the study of "Thoughts Taking Form" in the context of activities and communications.

In particular, Glaser's idea that "All is Data" allows for the use of multiple methods of analysis to understand the meaning of professionals' interactions with their environment. This perspective allows theory to emerge from the artifacts, discussions, trends, and solutions that were produced in a particular socio-historical context. In many ways, the cycles of investigation and theory development that occur in Grounded Theory are ideal for the study of participants' uses of technology in authentic contexts. Technological tools are deeply bound to local actors, social structures, and resources (Engstrom, 2003), and Grounded Theory's technique of thematic analysis (Glesne, 2011) can help to identify recurring trends in interactions and tool use that might be indicative of a previously unseen behavior or need.

The use of the Grounded Theory approach to data analysis also serves three larger purposes in this system. First, Grounded Theory may provide a valuable framework for the analysis of learners' behavior as they interact with the digital and non-digital technologies in their environment. The close analysis of artifacts produced by professionals, as well as close observations of the effects of media on their products, can help to determine future uses for the technology.

Second, Grounded Theory's generative approach to the development of research questions can help to maintain an open stance towards alternative and conflicting explanations of phenomenon, especially as the phenomena are traced across the ecology. This is important, as the various 'slices' of the professional ecosystem in this mixed-methods system may contain different motivations, roles, and ways of thinking that must be resolved through the data.

Finally, Grounded Theory's compatibility with constant case comparison strategies and single-case research designs (Kazdin, 1982; Yin, 2008) will enable preliminary theories to grow to encompass a variety of settings and actors. The development of professionals' expertise and technology use occur in a variety of venues (formal and informal), across several media (visual, audial, and textual), and may be collected in different ways. Thus, Grounded Theory may form a unified base of themes for comparison across the methodologies.

Discourse Analysis Tools: Forms Become Order

In tandem with GT analysis, James Gee's Discourse Analysis Tools (2010a; 2010b) allow researchers to further understand the meaning of these actions and thoughts as they are related in the minds of expert professionals. Gee developed 27 DA tools to help guide researchers through the specific kinds of meaning and order that are expressed through language. These methods and tools provide researchers with key 'modules' that they may implement to understand and dissect the ways that 'Forms Become Order" in the languages used by communities of practice. These tools are also essential to excavating expert professionals' 'knowledge-in-practice' (Wenger, 1998), as language tools (Vygotsky, 1975) are essential mediators in the use of technology in many professional disciplines. These tools may also help to clarify how communications technologies and software mediate the nature of communications in the course of professionals' learning.

The 27 tools included in Gee's DA toolkit are theoretically 'hot-swappable,' meaning that one tool could replace another when applied to the same samples of communications and interactions. In this way, they form a set of interlocking lenses that can help to provide higher-resolution images of interactions within communities of practice. Given the large number of tools, however, researchers should endeavor to select tools that inform their research questions in logical and rational ways.

In projecting forward to future studies of actual communications in performance environments, the overall DBR project for enhancing professionals' learning through technology might benefit from the use of Gee's tools to help unravel how professionals know, do, and live in their communities of practice. One conceivable model might align these tools in the following fashion using Herrenkohl and Mertl's Knowing/Doing/Being framework (2010) to select the questions that best-suit their goals.

Knowing

• Tool 3: The Making Strange Tool. Since most instructional designers inhabit spaces at the periphery of the professional communities of practice that they serve, the Making Strange Tool is a natural starting point for the study of their adoption and adaptation of technology. With this tool, researchers may closely examine the underlying assumptions and knowledge that professionals use to communicate their purposes to others. By probing these 'taken-for-granted' discussions, instructional designers may further understand what is known and not known by the speakers. This is useful in constructing systems to support professional ways of knowing.

Doing

• Tool 15: The Activities Building Tool. In this tool, Gee provides a lens for examining how communications facilitate, build, or enact ideas and knowledge within the context of the larger community. Further, it presses researchers to examine how social norms, cultures, and institutions create boundaries that bracket out or allow certain kinds of interactions, and how these phenomena coalesce from individual goals and actions into long-term practices.

• Tool 7: The Doing and Not Just Saying Tool. This concept is related to Ethnomethodology's "contingently achieved accomplishment" (discussed later), in that it examines what the individual professional wishes to achieve through their interactions with others in the world. Gee notes that this tool deals with actions, whereas Tool 15 (above) deals with practices as they exist and build over time.

Being

• Tool 16: The Identities Building Tool. This tool asks researchers to examine what kinds of socially recognizable identities are enacted by professionals and clients in their environments, and the efforts of those actors to communicate those identities to others. This tool may also be used to understand the positionality of the speaker and their audience, and how participants see themselves in relationship to one another and centers of authority.

The researcher should have leverage to select the discourse tools that they deem necessary for the project's context and interests; the closer the alignment of the Tool with the ends of the project, the more effective the outcome.

Cognitive Task Analysis: Order Becomes Process

Instructional designers do have one tool in their kit that can help capture and describe expertise in a way that makes it more easily transmissible. Cognitive Task Analysis (CTA), as a methodology, is historically tied to the study of experts. In the larger history of the study of expertise (professional and routine), CTA forms a methodological bridge between the unique knowledge of experts and the unique needs of novices in their performance environments. While the method has particular limitations, instructional designers have successfully used this technique to decompose the various cognitive components of expertise, and recompose it in teachable terms. Along with this technique comes a danger that CTA decomposition and recomposition loses the subtle emotional, associative, and pattern-recognition skills that define expertise. This loss reduces the utility of CTA if expertise is viewed as individualized and unique. Still, CTAs fulfill a valuable role in this research process by serving as a means of developing course, job, and task outlines for experts to use in collaborative environments.

In proposing the use of CTA as a method of expertise capture and analysis, we would hope to advocate its use as an analytic as well as a descriptive tool, in line with the expectations described by Annett (2000). To dispel confusion, we will adopt the formulation of CTA provided by Hoffman and Militello's Perspectives on Cognitive Task Analysis (2009):

CTA is a methodology for the empirical study of workplaces and work patterns, resulting in: (a) descriptions of cognitive processes and phenomena accompanying goal-directed work, (b) explanations of work activity in terms of the cognitive phenomena and processes, and (c) application of the results to the betterment of work and the quality of working life by creating better work spaces, better supporting artifacts (i.e., technologies), and by creating work methods that enhance human satisfaction and pleasure, that amplify human intrinsic motivation, and that accelerate the achievement of proficiency. (p.59)

This definition of CTA differentiates the technique from past iterations of 'job-analysis' and 'task-analysis' through the inclusion of 'cognitive phenomena and processes.' It also establishes the common ground of CTA with instructional design by asserting the importance of ,the application of the results to the betterment of work and the quality of working life as well as 'accelerating the achievement of proficiency.'

From a technique standpoint, Hoffman and Militello offer the PARI (Precursor, Action, Result, Interpretation) model of analyzing expert behavior. This model was created to capture the cognitive processes of computer system troubleshooters, and asks the experts to work in pairs as they think aloud while solving test problems. As they work, the experts represent their knowledge by drawing pictures, timelines, diagrams, and maps that serve to prompt further questions from the researcher and expert. This method creates a richer view of their expertise than the more behaviorist job analysis techniques.

CTA techniques can also provide instructional designers with flexible modes of expertise analysis. In Seamster, Redding, Cannon, Ryder, and Purcell (1993), a team of instructional designers employed CTA techniques to develop a new Federal Aviation Administration (FAA) curriculum for air traffic controllers (ATCs, a type of high-performing professional). The team used a systematic CTA to analyze the specific knowledge and cognitive skills possessed by master ATCs that allow them to circumvent the limitations of normal human information processing.'(p.280) The article describes three phases of cognitive analysis: Paired Problem Solving, Mental Model and Task Decomposition, and Strategy Analysis. The authors used the information from these studies to develop a map of the cognitive hierarchy of the air traffic controllers' mental models. In concluding, the authors describe the training program that resulted from the CTA:

The training program based on the results from these cognitive analyses organizes instructional objectives around key characteristics of the expert mental model and strategies. This does not mean that students are taught to structure their knowledge and skills around a fixed expert model. The resulting training program is organized into blocks, with the instruction in each block tailored so that small chunks of related knowledge and skills are taught together. The instruction is immediately followed by simulation-based practice. (p.281)

The flexibility of this design process and its ability to integrate realistic expert knowledge in cognitively organized chunks provides a valuable model for instructional designers who need to produce or sharpen expertise as well as technical and behavioral proficiency.

Cognitive Task Analysis methodologies (in all of their various flavors and forms) provide a means for direct and accurate representations of an individual professional's mental model of their domain. Thus, CTAs provide a crucial way of measuring and understanding how people align their cognitive and metacognitive processes perform their job. Further, CTAs provide a way to understand how and why professionals take actions at crucial junctions in their environment. However, researchers should apply one more significant methodology to the data to understand how these socially-embedded processes transform from cognitive processes into action.

Ethnomethodology (EM): Process Becomes Action

In the Design-based Research system, Ethnomethodology (Garfinkel, 1965) serves as a check on the alignment of the design experiment with the needs and expectations of the end user professional. The guiding policies of the philosophy may help to maintain the alignment of the technological intervention in ways that prevent wasted effort and maximize the value of the intervention in achieving change. It may also act as a check for the learner-centeredness and parsimony of the solution. Thus, EM provides the epistemological principles necessary for transforming the grounded theories developed through GT, DA, and CTA into actionable plans.

Koschmann, Stahl, and Zemel (2007) provide a succinct analysis of the implications of Ethnomethodology for Design-based Research by analyzing Garfinkel's five EM policies. In understanding how these policies shape the role of the researcher in relation to the role of the participant, we may use them to contemplate how technologies can fit into the existing social fabric of an environment in ways that augment the participants thinking in the moment.

Policy 1: Indifference

According to Garfinkel, Ethnomethodology requires that the researcher maintain a stance that is free of value judgments about the observed events, as well as an understanding that any event may serve as evidence for the proposed phenomena. That is, in Ethnomethodology, one transaction is as good as another, even if it goes counter to the societally described norms of the researcher. Koschmann et al. submit that this policy stands in opposition to many kinds of experimental research, and that this opposition is essential to advancing the methodologies of design-based research systems. Unlike statistically-based experimental methodologies, Ethnomethodology is unconcerned with the statistical frequency of an event. Rather, it is deeply concerned with the relationship of the events to the experience of the individual. In this way, Ethnomethodology's indifference allows researchers in design-based experiments to honor the perspectives, needs, and norms of the participants.

Policy 2: Contingently Achieved Accomplishment

Garfinkel concept of contingently achieved accomplishment plays an important role in buttressing some of the assumptions about knowledge that exist in this research process. This is because Grounded Theory, Discourse Analysis, and Ethnomethodology share a belief that meaning is negotiated between parties in complex, contextually appropriate ways. Koschmann et al. note that the activities of instruction occur in much this way, with teachers and learners interpreting and negotiating meaning in a chronological stream of activity in the environment. They note that this places the analyst in the position of interpreting how these communities of practice create ‘instruction’ in a moment-to-moment way using systems of meaning to create and bind the environment.

Policy 3: Relevance

As with Grounded Theory methods, Garfinkel’s policy of Relevance proposes that researchers bracket out their pre-existing theories of participant behavior at the outset of the study. Researchers must allow the participants to interpret what is important about their situation in the moment; the role of the researcher is only to understand how the participants make these connections (Koschmann et al., 2007). This policy is key in ensuring that the introduction of technological systems through DBR actually produces interventions that help the participant to grow in their work. The practices that Garfinkel advocates to serve this policy may also serve to prevent the design of technological interventions for injudicious reasons (e.g. Forsman, 2007).

Policy 4: Accountability

With this policy, Ethnomethodology establishes the assumption that the observed actors are doing something competently for reasons that have some sort of ‘rational’ root in the individual’s mind. That is, people may do seemingly inexplicable things for what they perceive as perfectly reasonable reasons. As with Relevance, Accountability places the onus on the researcher to understand the connections between the action and rationale without judgment. Thus, the word ‘accountability’ implies both the responsibility of an actor to account for breaches in their own sensemaking behaviors to others, and also the idea that the roots of the behavior are an illustration of some activity (e.g. sharing, demanding, etc.) that is meaningful to the actors. For this reason, Ethnomethodological Accountability is important in the DBR system as well, because it ensures that the existing knowledge and ways of Knowing-Being-Doing are honored as they are reshaped by the implementation of the technology.

Policy 5: Indexicality

With the policy of Indexicality, Garfinkel links the meanings expressed by actors to the context of the expression. That is, the speaker uses their theory of mind to make assumptions about the knowledge and interests of listeners to make their project understood. In this way, utterances are indexed (or hyperlocated) to a multiplicity of meanings that are shared and interpreted (or not) by other actors. Thus, meaning and circumstance cannot be separated. This property ensures that the generalizations to action that must occur in the proposed Design-based Research cycle allow the professional learners to manage the complexity of the shifting meanings and practices of others.

By following the policies of Ethnomethodology, the proposed actions that result from the Design-based Research system will remain situated firmly in the realistic needs of the individuals. It is in the translation from Process into Action that these policies are the most important to the overall research method system, and the most crucial for providing true support to professionals in the context of their practice.

Conclusion

In the course of these exams, we have seen the definition of an ecological model of Professional Expertise, how technology might support the development of people across the model, and finally, how we might design technological systems to deliberately find and tailor these technologies to the context. While the development of this theory is ongoing, preliminary results suggest that it is possible to use the definitions, tools, and methods described here to produce more creative, rewarding, and productive means of cultivating professional expertise than are currently in the marketplace of ideas.

Bibliography

Barab, S. A., Thomas, M. K., Dodge, T., Squire, K., & Newell, M. (2004). Critical design ethnography: Designing for change. Education, 35(2), 254-268.

Brown, A. (1992). Design experiments: Theoretical and methodological challenges in creating complex interventions in classroom settings. Journal of the Learning Sciences, 2 141-178.

Collins, A. (1992). Toward a design science of education. New York: Center for Technology in Education.

Design-Based Research Collective (2003). Design-based research: An emerging paradigm for educational inquiry. Educational Researcher, 32(1), 5-8.

Engestrom, Y. (2003). The new generation of expertise: Seven theses. In Helen Rainbird, Allison Fuller, and Anne Munro, Workplace Learning in Context. New York: Routledge.

Forsman, C. (2007). From behavior to design: Answering the questions of Who and What to build human-centered products and information systems. In P. Zaphris and S. Kurniawan (Eds.), Human Computer Interaction Research in Web Design and Evaluation, (pp.108-129). Hershey, PA: IGI Global.

Garfinkel, H. (1967). Studies in ethnomethodology. Englewood Cliffs, NJ: Prentice-Halls.

Gee, J.P. (2010a). An introduction to Discourse Analysis: Theory and method. New York: Routledge.

Gee, J.P. (2010b) How to do Discourse Analysis: A toolkit. New York: Routledge.

Glaser, B.G., and Strauss, A.L. (1967). The discovery of Grounded Theory: Strategies for qualitative research. Chicago: Aldine.

Glesne, C. (2011). Becoming qualitative researchers: An introduction. New York: Pearson.

Herrenkohl, L.R., & Mertl, V. (2010). How Students Come to Be, Know, and Do: A Case for a Broad View of Learning. Cambridge University Press.

Hoffman, R. R., & Militello, L. G. (2009). Perspectives on Cognitive Task Analysis. New York: Psychology Press.

Kazdin, A.E. (1982). Single-case research design. Oxford: Oxford University Press.

Koschmann, T., Stahl, G., Zemel, A. (2007). The Video Analysts' Manifesto. In R. Goldman, R. Pea, B. Barron, and S.J. Derry (Eds.), Video Research in the Learning Sciences. Mahwah, New Jersey: Lawrence Erlbaum Associates (pp. 133-143).

Penuel, W. R., Fishman, B. J., & Cheng, B. (2011). Developing the area of design-based implementation research. Menlo Park, CA: SRI International.

Price, D. J. S. (1986). Collaboration in an Invisible College. In Little science, big science...and beyond (pp. 119-134). New York: Columbia University Press.

Seamster, T. L., Redding, R. E., Cannon, J. R., Ryder, J. M., & Purcell, J. A. (1993).

Cognitive Task Analysis of Expertise in Air Traffic Control. The International Journal of Aviation Psychology, 3(4), 257-283.

Wang, F., & Hannafin, M. (2005). Design-based research and technology enhanced learning environments. Educational Technology Research & Design, 53(4), 5-23

Yin, R.K. (2008). Case study research: Design and methods. Thousand Oaks, CA: SAGE.