Instructional Design Roadmap: Principles to Maximize Learning across Developmental Stages

Jennifer J. Vogel-Walcutt, Karol G. Ross
Cognitive Performance Group
Orlando, Florida
jennifer@cognitiveperformancegroup.com,
karol@cognitiveperformancegroup.com

Jennifer K. Phillips
Cognitive Performance Group
Orlando, Florida
jenni@cognitiveperormancegroup.com

ABSTRACT

Effective training programs consider a range of factors to determine the types, timing, and content of interventions for trainees. However, the distinct characteristics of individuals' knowledge and capabilities as a function of their level of proficiency can be among the most difficult factors to identify and address. Instructional interventions would benefit from a scientifically-derived framework matching stages of practitioner proficiency to the most powerful instructional strategies given learner characteristics. In response to this need, our paper presents an adaptive training framework for system developers. The framework incorporates best practices from the learning sciences and demonstrates application of a developmental model to design low-cost, high-impact training tools. Specifically, we identified instructional design strategies that promote trainee attentional focus, create necessary schema in long term memory, and filter incoming information efficiently to maximize training impact. We integrated these general principles with a mastery model defining the knowledge, skills, and behaviors of Marine instructors as they develop across five distinct stages of practitioner proficiency, from novice to expert. The resulting structure served as a roadmap and guide for selecting stage-appropriate instructional strategies, design elements, content focus, delivery methods, and learning assessments throughout the development of a training program for Marine instructors. Finally, we organized the stage-specific guidance into a broadly-applicable, easy-to-use framework for training developers. The design principles are scientifically sound, generalizable across domains and audiences, and combined, create efficient, high-impact solutions.

ABOUT THE AUTHORS

Jennifer Vogel-Walcutt is a Senior Scientist at the Cognitive Performance Group with over 15 years of experience in research and development for training and education. Dr. Vogel-Walcutt's recent interests focus primarily on developing instructional techniques to improve the effectiveness and efficiency of training military personnel. Projects in development currently focus on the application of these techniques to develop specific skills such as perception, metacognition, and decision making. Dr. Vogel-Walcutt has acted as PI or co-PI on several large, federally funded, education and military grants.

Karol G. Ross is the Chief Scientist for Cognitive Performance Group where she conducts applied research using qualitative and quantitative methods to develop performance models, training, and assessments in military environments. Her prior research includes a project to refine a general five-stage model of cognitive skills acquisition to support training development. She applied this model to the development of a tactical thinking model and a Tactical Thinking Behaviorally Anchored Rating Scale for the US Army. Dr. Ross has conducted research to develop a performance model and assessment tool for cognitive skills related to counter-IED performance. She has developed models of performance for and supported development of a training product for the Joint, Interagency, Intergovernmental, and Multinational operating environment. Dr. Ross recently served as the PI for an ONR research effort to develop a mastery model and an assessment battery to support USMC infantry squad leader development. She is currently the PI for the Master Instructor Development program (MInD) for ONR in support of the USMC which includes development of a mastery model and instructor assessment battery.

Jennifer K. Phillips is the Chief Operating Officer and a Senior Scientist at the Cognitive Performance Group. Her research interests include skill acquisition, cognitive performance improvement, and the nature of expertise. Ms. Phillips applies cognitive task analysis and related techniques to model performance across the levels of proficiency, designs learning solutions including decision-centered training scenarios and facilitation techniques, and develops metrics for cognition and decision

making. She is currently supporting the Marine Corps' Small Unit Decision Making initiatives and instructor professional development efforts, and recently served as program leader for an effort to develop a Decision Training Toolkit for Marines and Soldiers.

Instructional Design Roadmap: Principles to Maximize Learning across Developmental Stages

Jennifer J. Vogel-Walcutt, Karol G. Ross
Cognitive Performance Group
Orlando, Florida
jennifer@cognitiveperformancegroup.com,
karol@cognitiveperformancegroup.com

Jennifer K. Phillips
Cognitive Performance Group
Orlando, Florida
jenni@cognitiveperormancegroup.com

INTRODUCTION

The demand for instructor expertise has increased due to operational demands. The modern operational environment requires operators at all levels to function in a more decentralized manner and apply knowledge and skills fluidly and adaptively across dynamically changing environments. Instruction to prepare them for these cognitive demands must go far beyond the traditional lecture-based methods and hands-on applications that supported previous generations of Warfighters. Rather, advanced instructional techniques that support deep understanding, promote flexible application of knowledge, and build critical thinking skills are necessary. Instruction must be highly interactive and engage learners in guided discovery and knowledge application, case studies, and problem contexts. Exercises and practical applications must support knowledge application in context, facilitate discussion regarding workable and ineffective solutions, and incorporate high levels of coaching and feedback. To develop these advanced instructional skills, especially in a compressed time period, new instructors require a substantial amount of instruction and support, practice and feedback, and guidance for continuous development.

Each formal school in the Marines has a unique method of preparing instructors for these challenges, but none have sufficient time and resources to formally provide instructors with sustainment or enrichment training to ensure continued development during their tenure. Military instructors often do not have the time or support necessary to achieve mastery or even ensure continued professional development during their tenure as instructors. Most instructors have been teaching less than three years and experience only one instructional assignment in their careers. Educators who have chosen careers in teaching prepare and certify for the role over a period of years, while military instructors' preparation for the duty is severely compressed. Teaching skill must develop to adequate levels in the early months of the typical three-year billet and continue to grow and progress after initial formal training to maximize the individual's ability.

The Marine Corps Training and Education Command (TECOM) and many of the formal schools across the Corps recognize the need to provide better support for instructor development. An Instructor Professional Development (IPD) initiative has been pursued by TECOM to examine the problem space and further professionalize the instructor cadre throughout the Marine Corps. Independent of the TECOM parent command, individual formal schools have designed and implemented new instructor development programs and certification processes with the goal of producing higher-quality instructors. With few exceptions, the Marine Corps training and education community acknowledges a gap in both time and tools available to properly develop instructors. The community continues to examine methods to improve instructor development processes and practices that are affordable, sustainable, and grounded in a good understanding of effective training practices and instructor needs.

Given the current instructor needs and operational demands, the community is poised to support the creation and transition of efficient processes aimed at enriching instructor development. For example, the Office of Naval Research, in close collaboration with TECOM, has supported research that resulted in a generalizable Instructor Mastery Model (IMM) specific to Marine Corps instructors (Ross, Phillips, & Lineberger, 2015). The IMM defines ten key performance areas (KPAs) for Marine instructors and delineates the path to mastery by characterizing individuals across a model of five stages of development—novice, advanced beginner, competent, proficient, and expert—as originally described by Dreyfus and Dreyfus (1986) and expanded by Ross, Phillips, & Cohn (2009). Specific performance indicators are associated with each KPA and stage of development. In comparison with other civilian instructor competency models, the IMM considers the unique requirements associated with Marine Corps formal

schools. For example, the instructor duty goes far beyond the classroom, to developing and mentoring Marines personally as well as professionally, and building future leaders and potentially, future co-workers who will serve side by side in a unit. The model has been accepted by the Marine Corps and integrated into formal documentation to guide instructor development. The next step in increasing the efficiency of progressing individuals through these stages is to identify key instructional strategies that correspond to each stage of development and articulate how best to rapidly instantiate them into training programs.

FRAMEWORK

Significant evidence supports the notion that infusing instructional elements into computer based learning programs can substantially accelerate the learning process (Vogel-Walcutt, Carper, Bowers, Nicholson, 2010). However, as individuals increase their knowledge base and experience, instructional supports are recommended to fade in accordance with increased levels of mastery in an effort to reduce redundancy (Renkl & Atkinson, 2007). Essentially, in a learner-centered approach to education, instructional design should be based on human cognitive architecture and the ways in which efficient schema development and organization are achieved and to do so, instructional guidance must be adjusted as mastery levels increase (Walsh, Moss, Johnson, Holder, & Madura, 2002). What is less clear is how to implement these findings in applied learning programs that promote accelerated learning while balancing the need for resource efficiency. More specifically, as deep comprehension, or understanding, of the material is the ultimate goal, aiding learners to develop their own schema during the learning process can be particularly beneficial (Loyens & Gijbels, 2008). Consequently, this paper aims to describe a framework that utilizes instructional elements in a variety of ways to accelerate learning, focused predominately on the ultimate goal of enhancing knowledge application skills.

Accordingly, several defining principles have been noted to drive the selection process of instructional elements. First, it has been well supported that learners at different stages of mastery acquire and assimilate information differently (Dreyfus and Dreyfus, 1986). Therefore, strategies employed at each stage should aim to reduce information lost during instruction, increase comprehension, and most importantly, aid learners in developing their own schema organization. In order to reduce information loss, several strategies have been identified that support knowledge acquisition (e.g., advance organizers, sequencing of information, and scaffolding) (Mayer, 2003). For improved comprehension, or better organized schema, strategies such as targeted feedback, metacognitive prompting, worked examples, and problem based learning strategies (Capon & Kuhn, 2004; Derry et al., 2006; Darabi, Nelson, & Palanki, 2007) have demonstrated significant impact.

LEVELS OF MASTERY

Mastery levels are broken down into five stages: novice, advanced beginner, competent, proficient, and expert (Benner, 1984). General, domain agnostic, descriptions of these stages are briefly provided below.

Novice

Due to their lack of experience, novices depend on rules and knowledge learned in textbooks and classroom instruction to guide their behavior. Therefore, their behavior exhibits a tendency to view situations without taking context into consideration, often leading to misinterpretations. They are also easily overwhelmed when confronted with multiple stimuli (McElroy et al., 1991) and can therefore miss important environmental or behavioral cues.

Advanced Beginner

Advanced beginners tend to make decisions analytically and do not feel a sense of belonging due to their lack of understanding of the given situation (Dreyfus & Dreyfus, 1986). Their repertoire is limited and they favor a few techniques. They can independently assess meaningful aspects of the context, but often fail to understand the meaning of the whole situation or how to leverage or respond to what they are seeing. When new information is uncovered, they stick to the original plan and are generally unable to adjust. Combined, these characteristics result in an individual who struggles to stay focused, often missing important cues, and misinterpreting the ones he or she does notice.

Competent

Competent individuals view situations deliberately and analytically, performing tasks in an efficient and organized manner. They know how to anticipate future problems, as long as a situation is similar to a previous experience. They still focus on individual features rather than problems as a whole (Houldsworth et al., 1997), making it difficult to view tasks in terms of their relationship to existing plans of action. They are more focused on their plans than the situational elements that arise. Planning and preparation to think through contingencies prior to entering the classroom in order to manage the learning environment are important for the competent learner. Assessing effectiveness of instruction, deepening facilitation skills to help students apply new knowledge, and customizing instruction are key growth areas to fully perform at this stage.

Proficient

Individuals at the proficient level think holistically, operating fluidly and seamlessly, using an "integrated rapid response" approach. They can perceive meaningful patterns in large, complex sets of data (Klein, 1998) and can detect problems and anomalies faster than less skilled individuals. The achievement of the Proficient stage allows the performer to understand the situation as a whole, but there may still be hesitation on how to act on the meaning. Practice with difficult and varied situations, realizing the consequences of their actions through reflection and discussion, and coaching others can help the Proficient performer move to the Expert stage.

Expert

Experts' actions are often automatic, making it difficult for them to articulate their rationale in decision making. Due to the breadth of their experience and knowledge, they have a wide range of routines and tactics readily available (Klein, 1998), typically increasing their probability of success. These individuals are seamless and efficient in their actions. They are commonly seen as leaders, whether by action only or also possessing typical leadership qualities. They make their jobs appear easy, even in complex, novel situations. Experts continue to learn through practice with complex, novel situations in both real-life performance and simulated events followed by reflection and/or peer discussion, to extend their ability to identify situational patterns and action scripts and through coaching others.

KEY STRATEGIES

In order for the framework to maximize efficiency and effectiveness, several key strategies that are generalizable and easy to instantiate, regardless of content, need to be identified and incorporated into the replicable framework. Eight such strategies are described below and organized by expertise level (see table 1). The descriptions are grouped by how the strategies impact learning. Specifically, advance organizers, sequencing, and problem based learning strategies help individuals receive information in a way that optimizes how it is filed and organized in long term memory. Scaffolding and feedback work together to help students stay focused on the correct material and to aid them in progressing to the next level. Metacognitive prompting and worked examples aim to focus individual's attention on the most important factors in the lesson and to reflect on which elements of the learning process are working and which ones need adjustment. Finally, multiple iterations of practice opportunities for applying knowledge helps learners clarify and refine schema in long term memory, increasing their ability to analyze and respond to future novel situations.

Advance organizers (AOs) promote knowledge acquisition and assimilation of information by creating a structure for filtering and filing incoming information (Ausubel, 1960). AOs are most commonly presented in the form of an outline, audio or video multimedia presentation, or a narrative (Hanley, Herron, & Cole, 1995) and act to introduce material at the beginning of the learning process. Used in these manners, AOs have proven to significantly improve depth of comprehension and recall. For example, learning software might provide prompts to encourage or remind students what steps to take, graphical organizers or other notations to help students plan and monitor their problem solving, or representations that help learners track the steps they have taken in the problem-solving process. In all these cases, the software provides additional assistance beyond what a simpler, more basic tool would have provided, in order to allow learners to accomplish tasks beyond their capabilities. **Sequencing** information according to the mastery level of the learner can help students manage cognitive overload and therefore reduce task shedding, or lost information (Corbalan, Kester, & van Merrienboer, 2006). Consequently, it is necessary to individualize learning

pathways, adjusting task difficulty from simple to complex and declarative to deep comprehension, as learners increase in mastery. Further, orienting learners' knowledge to real life experiences or applications can aid in the process of filing and organizing information in long term memory and ultimately improve knowledge retrieval and application (Kester, Lehnen, vanGerven, & Kirschner, 2006). More specifically, instructional elements that focus on **problem based learning** have been supported in the literature for improving not only the ability to understand information but also in improving one's ability to apply that information to a novel situation (Hmelo-Silver, et al., 2007). Supporting learners in self-reflection activities and self-directed inquiry can help encourage learners to be active participants in their own learning experience.

Scaffolding involves simultaneously increasing instructional complexity while decreasing supportive learning strategies (Puntambekar & Hubscher, 2005; Vygotsky, 1978). Allowing individuals to acquire an amount of information appropriate for their level of mastery enables them to file and organize the information without task-shedding. It also aids in the assimilation of knowledge and development of problem-solving skills (Reiser, 2004). By also removing extraneous or already-learned information, learners are further aided in efficiency by maintaining a clear focus on the necessary learning material (Collins, 1996). Scaffolding may be in the form of tips, best practices, worked examples, interactive activities and resources that would support the learner in improving competency. **Feedback** can be provided in a variety of ways to learners in order to help facilitate the accurate filing of information in long term memory (Butler & Winne, 1995). From a general perspective, feedback that is direct, clear, and immediate is most helpful to individuals at the novice level because they have not yet developed a highly complex nor organized schema structure to be able to accurately filter and file incoming information. Novices tend to be rule-bound and looking for the right answer rather than attuning their performance to contextual cues. Feedback that helps the novice recognize contextual cues can accelerate their understanding of the meaning of new information and begin to build skill in flexible application of knowledge. Conversely, individuals higher in mastery level are typically better supported by delayed, comprehensive, thought-provoking feedback because individuals at this level need to first experience the full scenario and understand the events as a composite before they can utilize global feedback in a useful manner (Shute, 2008). If feedback is provided too frequently to individuals at this level, there is a significant risk of disrupting educational flow and reducing efficiency (Vogel-Walcutt, Fiore, Bowers, & Nicholson, 2009).

Metacognition involves being active in one's learning process by reflecting on his or her personal learning experience to determine what is understood, what needs to be better understood, and how to obtain that information (Schraw, 1998). To support this skill, several studies have investigated the use of **metacognitive prompting** techniques aimed at cueing individuals to conduct this process during their learning experience. Results suggest that individuals at all levels of learning can benefit significantly from these reflective exercises and that the act of self-reflection alone, as opposed to additionally grading the accuracy of an individual's personal review, has the greatest impact on the learning process (Cuevas, Fiore, Bowers, & Salas, 2004). **Worked examples** involve demonstrating the pathway to achieving an answer to a problem or completing a task correctly so that learners can learn the correct way initially, rather than figuring it out for themselves (Darabi, Nelson, & Palanki, 2007). By showing the correct answer at the onset, cognitive load is reduced and learning is more efficient in novices (van Gog, Paas, & van Merrienboer, 2008). However, demonstrating "the correct way" or "the schoolhouse solution" in this manner before the learner has an opportunity to interact with the material can have the effect of impeding the formation of schema derived from interacting with the performance context. Examples of "correct performance" can override the learner's emerging schema and sometimes examples and this process have to be unlearned for the learner to perform at higher levels (Spiro, Feltovich, Jacobson, & Coulson, 1992). Therefore, worked examples should be used carefully. As learners progress up the mastery continuum, deep comprehension and application to real-world problems makes the worked example less useful, and reflection on knowledge and performance and feedback are the more important elements. By the competent stage, the learner is able to focus more on organizing and clarifying information in order to effectively apply it (Darabi, Nelson, & Palanki, 2007). Practice in context with reflection and feedback become the more important activities.

Finally, **multiple iterations across contexts** support the construction of schema by the user and the ability to flexibly apply that knowledge across a range of situations. For example, Cognitive Flexibility Theory (CFT; Spiro, Feltovich, Jacobson, & Coulson, 1992; Hoffman et al., 2014) focuses on the nature of learning in complex and ill-structured domains. With CFT, "the learner encounters multiple scenarios for the purpose of restructuring knowledge, as one learns adaptive responses to radically changing situational demands" (Spiro & Jehng, 1990, p. 165). Emphasis is placed on: (1) providing learners with the opportunity to develop their own knowledge representations; (2) providing learners with information in order to properly learn how knowledge is represented in different contexts, and (3) helping learners transfer knowledge and skills beyond the initial learning situation by providing multiple, diverse case

examples and scenarios for practice. This approach goes beyond the simple concept of multiple repetitions of specific sets of skills and addresses the need for learners preparing for highly cognitive performance to practice knowledge application repeatedly *and* across varying contexts to build schema to support the flexible application of knowledge and integrated skills in real-world settings. Accordingly, the generalizable framework provided in this paper (see table 1) aims to provide stage-specific, varied methods and multiple experiences through the training cycle to mastery.

Table 1. Event Sequences by Expertise Level

Mastery	AO	Lesson	Practice	FB	S	MP	MG/Test
Novice	Yes	Yes (focused on basics)	Yes (clear with pauses and explanations)	Yes (Immediate, Clear)	Yes (clear with pauses and explanations)	Yes	Yes (basics)
Advanced Beginner	Yes	Yes (focused on concepts)	Yes (nuanced with few explanations)	Yes (Immediate, conceptual)	Yes (nuanced with few explanations)	Yes	Yes (conceptual)
Intermediate	Yes	Available (focused on concepts)	Available (nuanced, no explanations)	Yes (delayed, conceptual)	Available (nuanced, no explanations)	Yes	Yes (application)
Proficient	Yes	No	No	Yes (delayed, applied)	No	Yes	Yes (problem-oriented)
Expert	Yes	No	No	Yes (delayed, pattern-focused across situations)	No	Yes	Yes (multiple to find patterns)

*Note: Advance Organizer (AO), Feedback (FB), Scaffolding (S), Metacognitive Prompting (MP), Mini Game (MG)

EVENT SEQUENCES

Working downward on the columns of table 1, **AOs** are used for novices in order to provide a basic pre-structure for incoming information. As individuals progress through mastery, the support needed for organization fades and AOs disappear from instruction. Worked examples are initially used to clarify the path to success for problem completion. However, as students better understand the problem sets and develop their own methods for solving them, the specificity of the examples reduces and eventually they become largely unnecessary. **Lessons** for novices focus primarily on declarative, factual information and change to conceptual as the learners master the basic material. Eventually, students at the highest levels require more discussion-based learning than lecture-based methods. They need to share rather than receive new information. **Practice** involves providing trainees the opportunity to apply their knowledge in a variety of settings. This allows the brain to clarify the similarities and differences between schema in LTM. In doing so, individuals can better organize and distinguish incoming information leading to a more efficient filtering process and more accurate self-developed understanding of the key concepts. **Feedback** begins as immediate and clear to ensure novices stay focused on the correct information and file it accurately into LTM. As individuals progress, the feedback needs to wait until the end of the learning (delayed feedback) to allow individuals the opportunity to assimilate the full experience at the conceptual level. Feedback for experts focuses mostly on encouraging self-reflection and consideration of alternate solutions or generalizable lessons for alternate situations. **Scaffolding** is initially provided to support and guide individuals along the learning pathway. As their schema organization and experience increase however, learners are able to self-navigate and find the answers or help they need as they need it. Too much intervention at the later stages can impede, rather than aid, progress. **Metacognitive prompting** has been shown to be useful to learners at all levels. However, at the earliest stages of mastery, students need to focus on basic structure development in long-term memory (LTM). As they progress, conceptual refinement

is the goal and consequently, the focus and complexity of the prompts increases. **Mini-games and tests** also increase from basic declarative questioning to scenario-based problem solving that may have more than one solution.

EXAMPLE PROGRESSION

The golden path per trainee is conceptualized as the best sequencing and presentation of the learning materials for each individual. If a learner has no proficiency and the system has no data on which to make recommendations, a generic scope and sequence of training material would be recommended based on expert input into the most critical key performance areas, subcategories, and threads relevant to the target learning material. However, as the user interacts with different learning materials within the program, the system would adjust based on their performance by providing additional support and resources when they are failing, and eliminating materials they may no longer need when desired proficiency is demonstrated. The type of materials and presentation format would be based on the 8 general principles described in table 1. It is anticipated that the golden path for each user would constantly be adjusted as new data are added to the system. For instance, if a new class assessment was completed, the system would adjust based on demonstrated proficiencies or identified gaps in performance. In most cases, these changes would be tweaks such as recommending an additional resource material item, but could result in re-sequencing of modules to be completed. The supervisor or user could adjust the golden path for the user at any time by changing learning priorities. Ultimately, the goal is that infusion of the 8 instructional interventions happens on the backend, with the supervisor and users only seeing lists of modules in priority order and the learning material optimally presented based on the user's unique needs and mastery level. As a consequence, efficient deep learning is expected.

SUMMARY

By using a pre-developed and replicable framework for assigning instructional strategies, the efficiency of program development and generalizability across content increases substantially while maintaining and even increasing effectiveness. It is recommended that these a priori strategies provide an organizational structure and clarify for developers a method and sequence, as well as rationale, for infusing efficiency strategies. Particular to the Marine Corps, a replicable solution across content areas can also optimize resource allocation for development and delivery of instructional content while aiming to reduce the time to train and reach proficiency.

ACKNOWLEDGEMENTS

REFERENCES

Ausubel, D.P. (1960). The use of advance organizers in the learning and retention of meaningful verbal learning. *Journal of Educational Psychology, 51,* 267-72.

Benner, P. (1984). From novice to expert: Excellence and power in clinical nursing practice. Menlo Park, CA: Addison-Wesley Publishing Company Nursing Division.

Butler, D.L. and Winne, P.H. (1995). Feedback and self-regulated learning: A theoretical synthesis. *Review of Educational Research, 65*(3), 245-281.

Capon, N. & Kuhn, D. (2004). What's so good about problem-based learning? *Cognition and Instruction,* 22(1), 61-79.

Collins, L.M. (1996). Is reliability obsolete? A commentary on "are simple gain scores obsolete?" *Applied Psychological Measurement, 20*(3), 289-92.

Corbalan, G., Kester, L. & van Merrienboer, J.J.G. (2006). Towards a personalized task selection model with shared instructional control. *Instructional Science, 34*(5), 399-422.

Cuevas, H. M., Fiore, S. M., Bowers, C. A., & Salas, E. (2004). Fostering constructive cognitive and metacognitive activity in computer-based complex task training environments. Computers in Human Behavior, 20, 225-241.

Darabi, A.A., Nelson, D.W., Palanki, S. (2007). Acquisition of troubleshooting skills in a computer simulation: Worked example vs. Conventional problem solving instructional strategies. *Computer in human behavior, 23*, 1809-1819.

Derry, S. J., Hmelo-Silver, C. E., Nagarajan, A., Chernobilsky, E., & Beitzel, B. (2006). Cognitive transfer revisited: Can we exploit new media to solve old problems on a large scale? *Journal of Educational Computing Research,* 35, 145–162.

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

Hanley, J.E.B., Herron, C. & Cole, S.P. (1995). Using video as an advance organizer to a written passage in the FLES classroom. *Modern Language Journal, 79,* 57-66.

Hmelo-Silver, C.E., Duncan, R.G., & Chinn, C.A. (2007). Scaffolding and achievement in problem-based and inquiry learning: A response to Kirschner, Sweller, and Clark (2006). *Educational Psychologist,* 42(2), 99–107.

Hoffman, R. R., Ward, P., Feltovich, P. J., DiBello, L., Fiore, S. M., & Andrews, D. H. (2014). Accelerated expertise: Training for high proficiency in a complex world. Psychology Press.

Houldsworth, B., O'Brien, J., Butler, J., & Edwards, J. (1997). Learning in the restructured workplace: A case study. Ed and Train., 39(6), 211-218.

Kester, L., Lehnen, C., vanGerven, P.W.M. & Kirschner, P.A. (2006). Just-in-time, schematic supportive information presentation during cognitive skill acquisition. *Computers in Human Behavior, 22*(1), 93-112.

Kirschner, P.A., Sweller, J., & Clark, R.E. (2006). Why minimal guidance during instruction does not work: An analysis of the failure of constructivist, discovery, problem-based, experiential, and inquiry-based teaching. *Educational psychologist, 41(2)*, 75-86.

Klein, G. (1998). *Sources of power: How people make decisions*. Cambridge, MA: MIT Press.

Loyens, S. M. M. & Gijbels, D. (2008). Understanding the effects of constructivist learning environments: Introducing a multi-directional approach. *Instructional Science,* 36:351-357.

Mayer, R.E. (2003). The promise of multimedia learning: using the same instructional design methods across different media. *Learning and Instruction, 13,* 125-139.

Puntambekar, S. & Hubscher, R. (2005). Tools for scaffolding students in a complete learning environment: what have we gained and what have we missed? *Educational Psychologist, 40*(1), 1.

Reiser, B. J. (2004). Scaffolding complex learning: The mechanisms of structuring and problematizing student work. *Journal of the Learning Sciences,* 13, 273–304.

Renkl, A. & Atkinson, R.K. (2007). Interactive learning environments: Contemporary issues and trends. An introduction to the special issue. *Educ Psychol Rev,* 19, 235-238.

Phillips, J., Ross, K., & Cohn, J. (2009). Creating tactical expertise using simulations: Guidance for scenario developers and instructors. In D. Schmorrow, J. Cohn, and D. Nicholson (Eds.), *The PSI Handbook of Virtual Environments for Training and Education, Volume 1* (pp. 148-164). Westport, Connecticut: Praeger Security International.

Ross, K.G., Phillips, J.K., & Lineberger, R.E. (2015). *Marine Corps Instructor Mastery Model* (Technical Report prepared under Contract N000014-C-0106 for the Office of Naval Research and the USMC Training and Education Command). Orlando, FL: Cognitive Perf. Grp.

Schraw, G. (1998). Promoting general metacognitive awareness. *Instructional Science, 26*(1-2), 113-125.

Shute, V.J. (2008). Focus on formative feedback. *Review of Educational Research, 78*(1), 153-89.

Spiro, R. J., Feltovich, P. J., Jacobson, M. J., & Coulson, R. L. (1992). Cognitive flexibility, constructivism, and hypertext: Random access instruction for advanced knowledge acquisition in ill-structured domains. In T. Duffy & D. Jonassen (Eds.), Constructivism and the technology of instruction: A conversation (pp. 121-128). Mahwah, NJ: Lawrence Erlbaum & Associates.

Spiro, R. J., & Jehng, J. (1990). Cognitive flexibility and hypertext: Theory and technology for the non-linear and multidimensional traversal of complex subject matter. In D. Nix & R. J. Spiro (Eds.), Cognition, education, and multimedia (pp. 163-205). Mahwah, NJ: Lawrence Erlbaum & Associates Inc.

van Gog, T., Paas, F., & van Merrienboer, J.J.G. (2008). Effects of studying sequences of process-oriented and product-oriented worked examples on troubleshooting transfer efficiency. *Learning and instruction, 18(3)*, 211-222.

Vogel-Walcutt, J.J., Fiore, S., Bowers, C., & Nicholson, D. (2009). Embedding metacognitive prompts during SBT to improve knowledge acquisition. Paper presented at the 53rd annual meeting of the Human Factors and Ergonomic Society, October 19-23, San Antonio, TX.

Vogel-Walcutt, J.J., Marino Carper, T., Bowers, C., & Nicholson, D. (2010). Utilizing Learners' Internal States to Drive Feedback Decisions: A Preliminary Investigation. *Journal of educational computing research*.

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

Walsh, M. B., Moss, C. M., Johnson, B. G., Holder, D. A., & Madura, J. D. (2002). Quantitative impact of a cognitive modeling intelligent tutoring system on student performance in balancing chemical equations. *The Chemical Educator*, *7*(6), 379-383.