Cognitive Flexibility Theory and its Application to Learning Resources

Jiaming Cheng & Tiffany A. Koszalka
Syracuse University – RIDLR project

Abstract

Cognitive Flexibility Theory (CFT) suggests that deep learning requires learners to engage with new content from multiple perspectives and in flexible ways of thinking. Research on CFT-informed learning environments suggests that flexible thinking during learning activities supports the development of higher order thinking skills (e.g. problem solving) and prompts positive changes in the learner's affective domain. Thus, incorporating CFT principles into learning resources should prompt learners to engage deeply with instructional content. This paper provides an overview of theoretical, research, and practice CFT principles, summarizing points for learning resources design.

Definition of Cognitive Flexibility

Psychologists (Spensley & Taylor, 1999) claimed that cognitive flexibility is a higher-order cognitive function that develops as children mature. Cognitive flexibility in the psychology literature (Moore & Malinowski, 2008; Dennis & Vander Wal, 2010) was referred to as a domain-general ability. By possessing this ability, a person is able to adapt cognitive processing strategies to deal with new, unexpected and changing conditions. Scholars in other fields adapted this definition in their own contexts. For example, Krems (1995), who studied complex problem solving, views cognitive flexibility as an "ability to adjust his or her problem solving as task demands are modified" (p. 202). Communication scholars refer to cognitive flexibility as a component of communication related to a person's awareness of the alternatives in a given situation, willingness to be flexible, and the self-efficacy of being flexible (Martin & Rubin, 1995).

Even though the new, unexpected and changing condition mentioned in Krems (1995) and communication scholars' (Martin & Rubin, 1995) studies were different perspectives of cognitive flexibility, the core component is the same – adjusting oneself to cope with new situations. Their studies on cognitive flexibility focused on the underlying cognitive processes in the human brain, such as awareness, attention, and goals.

Discussion of cognitive flexibility here focuses on the theoretical and practice work of Spiro et al., (1988), which prescribes instructional design guidelines for advanced learning in ill-structured domains. This work, from educational psychology and cognitive sciences perspectives, suggested cognitive flexibility was an attempt to improve learning failures in advanced learning scenarios focused on ill-structured domains (Spiro et al., 1987; Spiro et al., 1988). In these perspectives, CFT speaks to the nature of adjusting thinking or behavior to adapt to different situations or contexts.

CFT proposes that learners develop a better understanding of the complexity of content by engaging with multiple representations of the same information in different contexts. The theory suggests that seeing multiple representations of the same content or phenomenon helps learners develop mental scaffolding necessary for considering new applications of the knowledge in their knowledge in new situations. Cognitive Flexibility Theory is thus contextualized as an instructional prescription to help students achieve more deep learning in authentic ill-structured contexts, to be able to think about this new knowledge flexibly, and to be able to apply this new knowledge to novel situations (Spiro et al., 1992). *Flexible* is used to describe knowledge representation in human minds, which provides insights into principles for creating learning resources that may better support or prompt learners to develop the capacity to understand content from multiple perspectives. "A central claim of cognitive flexibility theory is that revisiting the same material at different times, in rearranged contexts, for different purposes, and from different perspectives is essential for attaining the goals of advanced knowledge acquisition (mastery of complexity in understanding and preparation for transfer)" (Spiro et al., 1995, p. 93-94).

Cognitive Flexibility Theory: Advanced Learning and Ill-Structured Domains

CFT hinges on the definition of advanced learning and ill-structured domain. Advanced knowledge acquisition is relative to introductory level learning. In advanced levels, "the learner must attain a deeper understanding of content material, reason with it, and apply it flexibly in diverse contexts" (Spiro et al., 1988, p. 4). This suggests that learners develop a more comprehensive, or deep, understanding of new content and are able to think about 'it' (new content), problem-solve with 'it,' apply 'it' to multiple contexts, thus advanced knowledge is constructed about this content within the learner's cognitive structures.

There are several deficiencies in approaches to instruction that are defined as supporting advanced knowledge acquisition, such as oversimplification of complex concepts and overreliance on a single mental representation (Spiro et al., 1988). These deficiencies often stemmed from educators' assumptions that the instructional methods for introductory level knowledge and advanced knowledge were the same.

Deficiencies in advanced learning techniques are especially noticeable in ill-structured domains where content is complex and there are multiple solutions to a single problem. Well-structured domains lend themselves to problems that can be defined based on specific tenets and solved through the application of an algorithm, generally resulting in a single correct answer (King & Kitchner, 1994). Ill-structuredness is defined as "there cannot be any recourse to homogeneity, to any single course of action across instances, whether it involves a single guiding principle, a single organizational scheme, or a single prototype case" (Spiro et al., 1987, p. 9). In other words, ill-structured domains and problems are complex, are best analyzed from multiple perspectives, and lend themselves to multiple perspectives or solutions. Therefore, flexible knowledge representation is needed to overcome deficiencies of advanced learning acquisition in ill-structured domains. Learning environments designed to supports multiple knowledge representations help learners restructure their knowledge spontaneously, apply the knowledge beyond the initial situation, and adapt knowledge into the new, unexpected, and/or changing situations (Spiro & Jehng, 1990).

The *criss-crossed landscape* (Wittgenstein, 1953, as quoted in Spiro et al., 1987) is used to explain the mechanisms of CFT. Complex concept/knowledge domains are compared a landscape using sites in the landscape as a metaphor for cases used for instruction. A landscape has different features, but none of the sites with a same features, would be exactly same. Knowing all of the features in a landscape is not equal to knowing the actual landscape. The best way to know a landscape is to visit it from different directions. Therefore, an instructional system too, should present different dimensions (features) with various cases (sites), to achieve "the twin goals of highlighting multifacetedness and establishing multiple connections" (Spiro et al., 1987, p.10).

One example of a learning environment based on CFT is Knowledge Acquisition in Nonlinear Environment (KANE). KANE aimed at improving students' advanced understanding of the film *Citizen Kane*, which had "a complex and subtle structure" (Spiro & Jehng, 1990, p. 173). In KANE, the film was re-edited to get scenes showing a same theme together, for example students can see "five scenes in a row, taken from various places in the film, that illustrate different varieties or 'flavors' of the 'Wealth Corrupts' theme" (Spiro et al., 1995, p. 98). Therefore, students have the chance of learning the complex concepts from multiple perspectives rather than an oversimplified definition and a set of over regularized principles.

KANE also offered an option of listening to expert commentary on the meaning of a theme after students viewed the scenes. The commentary provided supplementary guidance of the concept's meanings-in-use, which might not be covered by an abstract definition. Spiro stressed that this situation-sensitive meaning of the concept was different from a dictionary definition which offered different meaning of a word and the similarities across cases. In KANE an instance of use which was situation-sensitive was expressed. Another function of expert commentary was to cross-reference other instances of the conceptual structure and to other conceptual themes. Students would learn the concept theme with an isolated case, and also other conceptual structures which could be used to analyzed the case. Other empirical studies have been conducted by researchers to improve the problem of advance learning in ill-structured domain by applying CFT to design and development learning environments.

Brief Literature Review

Cognitive Flexibility Theory (CFT) is presented in three ways in the literature. The first includes CFT conceptual papers. These papers provide theoretical overviews and perspectives on CFT supportive of the information provided above. Second are evidence-based studies that explored the impact of instructional materials informed by CFT on learning. The third are developed cases or guidelines for practices developing instruction using CFT.

Among the evidence-based studies reviewed, many were investigations on adult learners. Content domains ranged from teacher education to police education, and from knowledge development to attitude change. As technology advanced over the years, study environments emerged from hypertext-environments to multimedia-environments. The following examples represent CFT application research conducted at various times during the last three decades. See table 1.

Table 1. Overview of CFT Studies

Citations	**Context**	**Conclusion**
Jacobson, M.J., & Spiro, R.J. (1995). *Hypertext Learning Environments, Cognitive Flexibility, and the Transfer of Complex Knowledge: An Empirical Investigation*.	The social impact of technology – an undergraduate course	The comparison group (using minimal hypertext) performed better on short answer tests while the treatment group (using thematic criss-crossing hypertext) performed better at the problem solving essays. The results supported arguments that the criss-crossing hypertext learning environment supported better advanced learning in the ill-structured domain.
Fitzgerald, G.E. (1997). *An Interactive Multimedia Program to Enhance Teacher Problem-Solving Skills Based on Cognitive Flexibility Theory: Design and Outcomes.*	Teacher education on students with behavioral disorders	Participants reported positive feedback about the multimedia materials while there were no significant changes of their personal perspectives found in the study.
Jonassen, D.H., Dyer, D., Peters, K., Robinson, T., Harvey, D., King, M., & Loughner, P. (1997). *Cognitive Flexibility Hypertexts on the Web: Engaging Learners in Meaning Making.*	Instructional design cases on instructional design, environmental issues, and sexual harassment	In all three cases, all the knowledge were case-driven, and multiple cases were used. All cases were real. Learners were required to construct their understanding, their procedural knowledge which was more transferable. The link of the cases were conceptual, it would allow learners to learn multiple perspectives and concepts of the learning content.
Godshalk, V.M., Harvey, D.M., & Moller, L. (2004). *The Role of Learning Tasks on Attitude Change Using Cognitive Flexibility Hypertext Systems.*	Sexual harassment (affective domain)	Participants who were assigned the role as policy maker perform better than those assigned as juror, their explanation was that policy-making tasks required participants to consider the complexity of the cases and the effects on multiple constituents
Edmunds, D.B. (2007). *The Impact of a Cognitive Flexibility Hypermedia System on Preservice Teachers' Sense of Self-Efficacy.*	Teacher education	Participants' self-efficacy had positive changes; but it was lower than the control group who had field experience instead
Miller, R. (2010). *Applications of Cognitive Flexibility Theory in Cross-cultural Training*.	Foreign police training	The group of police who played all three roles in the multimedia learning environment performed best on both the ethical principles understanding test and the learning transfer task

Jacobson and Spiro (1995) developed a hypertext learning environment for freshman and sophomore university students to investigate the social impact of technology in the 20th century. Results showed that the comparison group (using minimal hypertext) performed better on short answer tests while the treatment group (using thematic criss-crossing hypertext) performed better at problem solving essays. The results supported their argument that the criss-crossing hypertext learning environment supported better advanced learning in the ill-structured domain. The designed learning environment was based on the five principles of CFT, including: multiple knowledge representations; linking and tailoring abstract concepts to different case examples; early introduction of domain complexity; stressing the interrelated and web-like nature of knowledge; and encouraging knowledge assembly. Incorporating these principles suggested that engaging learners in criss-cross scenarios increased their problem solving skills in complex content areas.

There were also two studies that discussed the impact of learning materials, informed by CFT, on teacher education. Fitzgerald et al., (1996) developed a multimedia program to improve teachers' problem solving abilities. They compared the use of the multimedia program in pre-service teachers and in-service teachers. Participants reported positive feedback about the multimedia materials while there were no significant changes of their personal perspectives. Edmunds (2007) also discussed the potential of hypermedia system for teacher education. In Edmunds's thesis (2007), he studied participants' self-efficacy change when using a multimedia system. Positive changes were seen in participants' self-efficacy; however, measures were lower than the control group who had field experience rather than engagement with the multimedia system. These studies suggest that CFT-informed multimedia instruction may be partly supportive of problem-solving skills development, however personal experiences (which may or may not engage learners in cognitive flexibility exercises) may also play a role in depth of learning and application.

Godshalk et al., (2004) and Miller (2010) both discussed the impact of the assigned role in a hypermedia learning environment on student learning. The former study focused on attitude change about sexual harassment and the later study focused on ethics principles and learning transfer in foreign police training. Godshalk et al., (2004) found that participants who were assigned the role as policy maker perform better than those assigned as juror. Their explanation was that policy-making tasks required participants to consider the complexity of the cases and the effects on multiple constituents. Miller's (2010) results showed that the group of police who played all three roles in the multimedia learning environment performed best on both the ethic principles understanding test and the learning transfer task. Thus, in both studies, engaging learners in multiple (or complex) roles during learning scenarios led to increased understanding and learning transfer of the content.

While Jacobson and Spiro (1995) concluded that there were five basic features of learning environments based on CFT design guidelines, Jacobson et al., (1996) added a feature suggesting there are six features for critical designing case-based learning environments. They included: using multiple knowledge representations; linking abstract concepts in cases to depict knowledge-in-use; demonstrating conceptual interconnectedness or Web-like nature of complex knowledge; emphasizing knowledge assembly rather than reproductive memory; introducing both conceptual complexity and domain complexity early; with a new feature of promoting active student learning.

Spiro et al., (2006) took these guidelines a step further and introduced a series of modes of *openness and flexibility* that should be embedded in cognitive flexibility systems claiming that each type of *openness* was found in a true cognitive flexibility system. These features included: revealing a comparison and contrast beyond pairs of content concepts; crossroads cases; many cases; conceptual variability; multiple higher-order conceptual themes; multiple theme searches; multiple interconnectedness; nonlinear juxtaposition; perceptual overlays to open perception; opening time. Thus, learning environments informed by CFT could have the ability to engage learners in deep learning from multiple perspectives.

Given the complexity of creating such environments, McManus developed a Hyper-media Design Model based on these tenets of CFT that includes six design steps: "1) define the learning domain; 2) identify cases within the domain; 3) identify themes/perspectives to be highlighted; 4) map multiple paths through cases to show themes; 5) provide learner controlled access to cases; and 6) encourage learner self-reflection." (Simonson, 1997, p. 4). These processes were designed to ensure that CFT-informed learning environments were created at the complexity to engage learners in developing a deeper understanding of both content and its application to ill-structured situations.

Learning Resources Informed by CFT - Possibilities

Instruction is a compilation of informational, instructional, and learning resources (Grabowski & Small, 1997), each providing a building block upon which to purposively support learning. Whereas informational and instructional resources support the overall content and direction of instruction, the learning resources, whether in analogue, digital or social/human format fully engage learners in learning processes. By integrating CFT tenets into learning resources students can be engaged with content from multiple perspectives being flexible in their thinking. Embedding features likes multiple and complex cases that depict knowledge in-use, multiple roles in which the learners consider content, and activities that support linking concepts to multiple cases support learning. They go beyond comparison of cases and lead to development of better understanding of ill-structured problems, enhanced problem-solving abilities, and deeper understanding of content. However, the varied research results suggest that additional research is needed to examine the characteristics of cognitive flexibility as informing the design of (and process of designing) learning resources.

Synthesis

Cognitive Flexibility Theory provides instructional designers and informed-educators with a framework to develop the learning environments and scenarios that can engage learners more effectively in developing deep knowledge (and application) for ill-structured problems. The keys to building such learning environments include: using multiple knowledge representation; using multiple cases linked to abstract concepts; rearranging, decomposing, and establishing of connections among cases; and early introduction to domain complexity. As research has shown, the type of learning tasks in which learners engage can also influence his or her advance learning in ill-structured domain, thus the learning task itself should require learners to think comprehensively from multiple perspectives.

CFT provides guidelines for developing learning resources that allow learners to transfer knowledge to diverse and multiple situations. Evidence such as undergraduate students' higher performance on problem solving (Jacobson & Spiro, 1995), policy trainers' improvement in the affective domain (Godshalk et al., 2004), and the positive changes of preservice teachers' self-efficacy (Edmunds, 2007) provide support for the incorporation of CFT tenets in learning resources. However, Cognitive Flexibility Theory is only one dimension that may influence the value of resources in facilitating deep learning. Other factors may include the abilities of learning resources to engage learners in meaning making (Wilhelm-Chapin & Koszalka, 2016), reflection (Koszalka, 2016), and appropriate types and levels of learning suggested by the expected learning outcomes (Yang & Koszalka, 2016). The RIDLR team is developing and researching learning resources that incorporate multiple dimensions to support higher order thinking and the development of learning assessments.

References

Dennis, J.P., & Vander Wal, J.S. (2010). The cognitive flexibility inventory: Instrument development and estimates of reliability and validity. *Cognitive Therapy and Research*, 34(3), 241-253.

Edmunds, D.B. (2007). *The impact of a cognitive flexibility hypermedia system on preservice teachers' sense of self-efficacy*. Unpublished Master's Thesis. University of North Carolina at Chapel Hill.

Fitzgerald, G.E. (1997). An interactive multimedia program to enhance teacher problem-solving skills based on cognitive flexibility theory: Design and outcomes. *Journal of Educational Multimedia and Hypermedia*, 6(1), 47-76.

Godshalk, V.M., Harvey, D.M., & Moller, L. (2004). The role of learning tasks on attitude change using cognitive flexibility hypertext systems. *The Journal of the Learning Sciences*, 13(4), 507-526. DOI: 10.1207/s15327809jls1304_2

Grabowski, B.L., & Small, R.V. (1997). Information, Instruction, and Learning: A Hypermedia Perspective. *Performance Improvement Quarterly*, 10(1). 155–166.

Jacobson, M.J., & Spiro, R.J. (1995). Hypertext learning environments, cognitive flexibility, and the transfer of complex knowledge: An empirical investigation. *Journal of Educational Computing Research*, 12(4), 301-333.

Jacobson, M.J., Maouri, C., Mishra, P., & Kolar, C. (1996). Learning with hypertext learning environments: Theory, design, and research. *Journal of Educational Multimedia and Hypermedia*, 5(3-4), 239-281.

King, P.M. & Kitchener, K.S. (1994). Developing reflective judgment: Understanding and promoting intellectual growth and critical thinking in adolescents and adults. San Francisco: Jossey-Bass.

Koszalka, T.A. (2016). *Reflection and its application to learning resources.* Accessed August 2016: http://ridlr.syr.edu/publications/

Krems, J.F. (1995). Cognitive flexibility and complex problem solving. In P.A. Frensch & J. Funke (Eds.) *Complex Problem Solving: The European Perspective*, (pp. 201-218), NY: Psychology Press.

Martin, M.M., & Rubin, R.B. (1995). A new measure of cognitive flexibility. *Psychological Reports*, 76(2), 623-626.

Miller, R. (2010). *Applications of cognitive flexibility theory in cross-cultural training*. Doctoral Dissertation. The University of New Mexico.

Simonson, N. (1997). Design considerations in converting a stand-up training class to web-based training: Some guidelines from cognitive flexibility theory. *Journal of Interactive Instruction Development*, 10(3) 3-9.

Spensley, F., & Taylor, J. (1999). The development of cognitive flexibility: Evidence from children's drawings. *Human Development*, 42(6), 300-324.

Spiro, R.J., Collins, B.P., & Ramchandran, A.R. (2007). Modes of openness and flexibility in cognitive flexibility hypertext learning environments. *Flexible Learning in an Information Society*, 18-25.

Spiro, R.J., Coulson, R.L., Feltovich, P.J., & Anderson, D.K. (1988). Cognitive Flexibility Theory: Advanced Knowledge Acquisition in Ill-Structured Domains. *Technical Report No. 441*.

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.M. Duffy & D.H. Jonassen (Eds.), *Constructivism and the Technology of Instruction: a Conversation* (pp. 57-76). Hillsdale, NJ: Lawerence Erlbaum Associates.

Spiro, R.J., Feltovich, P.J., Jacobson, M.J., & Coulson, R.L. (1995). Cognitive flexibility, constructivism, and hypertext: Random Access instruction for advanced acquisition in ill-structured domains. In L.P. Steffe & J. Gale (Eds.), *Constructivism in Education*. Hillsdale. NJ: Lawrence Erlbaum Associates.

Spiro, R.J., & Jehng, J.C. (1990). Cognitive flexibility and hypertext: Theory and technology for the nonlinear and multidimensional traversal of complex subject matter. *Cognition, Education, and Multimedia: Exploring Ideas in High Technology*, 205.

Spiro, R.J., Vispoel, W.P., Schmitz, J.G., Samarapungavan A., & Boerger A.E. (1987). Knowledge acquisition for application: Cognitive flexibility and transfer of training in ill-structured domains. *Technical Report No. 409.*

Wittgenstein, L. (1953). *Philosophical Investigations.* New York: Macmillan.

Wilhelm-Chapin, M.K., & Koszalka, T.A. (2016). *Generative learning theory and its application to learning resources.* Accessed August 2016: http://ridlr.syr.edu/publications/

Yang, T., & Koszalka, T.A. (2016). *Level of engagement and its application to learning resources.* Accessed August 2016: http://ridlr.syr.edu/publications/