Designing for Conceptual Change:

An Examination of the Cognitive Flexibility Theory

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Abstract

This paper explores the general principles of Cognitive Flexibility Theory along with its theoretical grounding and instructional characteristics. In examining Cognitive Flexibility Theory, and the pedagogical model, Cognitive Flexibility Hypertext, this paper identifies several pitfalls found in hypertext environments and offers recommendations based on previous research. This paper concludes with an in depth examination of a design-based research study conducted by Strobel, Jonassen, and Ionas (2008) followed by their recommendations for further considerations.
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Beyond the introductory period of a knowledge domain yet prior to the application in daily practice, there comes a point when learners must gain an appreciation of the complexity and ill-structured nature of the domain while dispelling the assumptions they have made along the way. Over the course of this paper we will look at one such theory to address this, Cognitive Flexibility Theory, along with its pedagogical model, Cognitive Flexibility Hypertext. We will conclude this paper with an in depth look at a design-based research study conducted by Strobel, Jonassen, and Ionas (2008) to determine how best to apply the principles of Cognitive Flexibility Theory in order to support conceptual change.

Overview

Cognitive Flexibility Theory suggests a series of principles to aid advanced learning through case-centered study within ill-structured knowledge domains. By allowing learners to ‘crisscross’ between multiple perspectives and representations within a nonlinear hypertext environment, learners develop the ability to assemble diverse knowledge sources in order to adaptively fit the needs of a given situation, thus gaining cognitive flexibility. (Spiro, Coulson, Feltovich & Anderson, 1988; Lima, Koehler, & Spiro, 2004). Inspired from a metaphor by Wittgenstein (as cited in Barhoumi & Rossi, 2013, p. 282), Cognitive Flexibility Theory originates from the works of Rand Spiro and colleagues in the late 1980s and serves as the bases for the pedagogical model, Cognitive Flexibility Hypertext (Barhoumi & Rossi, 2013).

At the core of Cognitive Flexibility Theory is the need to improve advanced knowledge acquisition within learners. Spiro et al. (1988) describe advanced knowledge acquisition as the intermediary stage between introductory learning and practiced expertise. The purpose of
introductory learning, they state, is often to develop a general orientation to a knowledge domain through exposure to the content, followed by an assessment of the recognition and recall of that exposure. However, once established, instruction must shift towards advanced knowledge acquisition, which values a deeper understanding of the content that can adaptively fit diverse contexts. Too often during advanced knowledge acquisition, learners develop reductive biases, which lead to an oversimplification of complex and irregular structures and an overreliance on generic abstractions (Spiro et al., 1988). In order to counter the tendency toward reductive bias, learners need to accommodate multiple perspectives embedded in authentic activities in order to reconcile those perspectives with their own personal beliefs. (Strobel et al., 2008).

**Instructional Recommendations**

In regard to the instructional recommendations within Cognitive Flexibility Theory, Strobel et al. (2008) writes:

Cognitive Flexibility Theory recommends providing multiple representations and perspectives on real-world cases and context-dependent knowledge by linking abstract concepts to authentic cases, highlighting the interrelated nature of knowledge via the thematic relations among the cases that require learners to integrate their knowledge into a coherent knowledge base. (p. 68-69)

When applied to the pedagogical model, Cognitive Flexibility Hypertext (CFH), Cognitive Flexibility Theory implies five key principles: (1) case-centered instruction that is (2) complex and contextually derived, with (3) multiple perspectives and representations that (4) allows for nonlinear navigation or ‘crisscrossing’, (5) leading toward authentic learning activities that rely on the assembly of diverse knowledge sources. (Barhoumi & Rossi, 2013; Spiro et al., 1988).
Central to Cognitive Flexibility Theory and its pedagogical model, Cognitive Flexibility Hypertext (CFH), is the role of the case. As knowledge domains become more ill-structured, the generalized principles and theories used in ‘top-down’ approaches become less applicable and often result in oversimplification (Spiro et al., 1988). Case-based knowledge, however, is specific and can highlight variances in application when compared to other cases (Lima et al., 2004). Spiro, Collins, and Ramchandran (2007) describe cases as the “intersection of multiple concepts” (p. 20). Because of the complexity and irregularities found in cases, CFHs typically utilize multiple cases in order to better compare and contrast themes and perspectives (Spiro et al., 1988; Spiro et al., 2007).

Within each case, learners navigate between a variety of perspectives and representations. Depending on the nature of the CFH, these subheadings may be generally labeled as themes, perspectives, approaches, and/or representations, (Harvey, Godshalk, & Milheim, 2001; Marra, Jonassen, Shen, & Lohani, 2009; Zydney & Grinciewicz, 2010; Strobel et al., 2008), or specifically labeled to meet the needs of the CFH, such as in the example of the business model-based CFH Panteon, which sub-divided cases into various environments, such as Board Meeting, Research Room, Perceptions Report, and Final Diagnosis, with further subheadings to include titles such as Department, Position, and Problem Situation (Lima et al., 2004).

In determining which perspectives and representations to use in a CFH, Strobel et al. recommend considering the uniqueness of the perspective, the relevant issues contained in it, and the contextual issues surrounding the case (2008). The amount of cases, perspectives, and representations utilized within a CFH will vary greatly depending on the scope of the project (Harvey et al., 2001). Small projects, such as Pollution Solution, a socio-scientific CFH for 10th
grade students, may utilize only one case with four perspectives (Zydney & Grincewicz, 2010), whereas Panteon, intended to address diagnosis-solution based problems for graduate business students, incorporated hundreds of perspectives and representations over several cases. (Lima et al, 2004)

Within all CFHs is an element of nonlinear navigation that allows users to crisscross between cases, perspectives, and representations (Spiro, Feltovich, Jacobson, & Coulson, 1992). By crisscrossing these elements, the assumption is that learners will construct a “conceptual landscape” (Spiro et al., 1988, p. 8) allowing for flexible knowledge that can be adapted to solving new problems (Marra et al., 2009) without sacrificing any complexity inherent within the case (Harvey et al., 2001). However, many studies have found that merely crisscrossing links through the hypertext is insufficient for fostering conceptual change within learners (Strobel et al., 2008; Marra et al., 2009; Harvey et al., 2001; Zottmann et al., 2012). In order to effectively utilize the ‘crisscross’ quality of a CFH, support structures must be in place for the creation of student-generated artifacts within the environment (Strobel et al., 2008).

One example of a navigational support structure can be seen in the CFH Panteon. The process of navigating Panteon involves exploring multiple environments, each with their own large set of issues, characters, and conflicting perceptions, of which some information will be very relevant while other points will be less so. In order to manage the large amount of information, Panteon has a feature called PantPad that allows users to “click-capture” perceptions that they find most useful, along with the ability to add notes, observations or commentaries to any perception. As users crisscross the CFH, PantPad functions as hypermedia notebook, collecting and organizing their thoughts in order to better utilize that information during the authentic learning activity, or final report (Lima et al., 2004, p. 382).
The final principle implied in Cognitive Flexibility Theory is the need for authentic learning activities that relies on the assembly of diverse knowledge sources. (Barhoumi & Rossi, 2013; Spiro et al., 1988). In the example of Panteon, once learners have finished collecting relevant perceptions and artifacts on PantPad, they will use that information to write a problem diagnosis and plan of action. Once written, the learner will then contribute their diagnosis and plan of action to a collaborative team discussion surrounding the case (Lima et al., 2004). Therefore, in the Panteon example, learners address a diagnosis-solution based problem by first exploring the complexities of the case individually and then collaborating about the ambiguous solution options.

More common in CFH environments are dilemmas, which Jonassen describes as often being the most ill-structured and unpredictable of problems (2011). Examples of dilemma-based CFHs include addressing sexual harassment in the workplace (Harvey et al., 2001), ethical engineering issues (Marra et al., 2009), perspectives within socio-ecological issues (Zyne & Grincewicz, 2011), and modern perspectives in the study of religion (Strobel et al., 2008). Within each of these CFHs, learners were asked to accommodate the multiple perspectives found in the CFH and display that accommodation through a final activity. As a result, activities that required greater amounts of accommodation, such as with Pollution Solution, which specifically asked students to reflect the multiple perspectives in their final report (Zydney & Grincewicz, 2011), found greater success in meeting their desired outcomes than activates that had less strenuous guidelines, such as in the Sexual Harassment CFH which asked students to develop a policy statement or offer a jury-based up/down vote based on the cases studied (Harvey et al., 2001).
Study Analysis

Although Cognitive Flexibility Theory suggests a series of principles to improve advanced knowledge acquisition, it lacks the sufficient design guidelines needed to ensure successful implementation, leaving most designers to rely on their own common sense (Strobel et al., 2008). Spiro et al. (1992) may state this sentiment best with: “There are many ways that hypertext systems can be designed, and there is good reason to believe that a large number of those do not produce successful learning outcomes.” (p. 67-68). In order to address this lack of definition, Strobel et al. conducted a design-based research study over a three-year period in which they developed an evolving hypertext authoring system called Crisscrossing. During the study, which was situated in different subject areas and contexts, the research team studies the effects of Crisscrossing through three iterative cycles as they continued to develop and improve the system based on the feedback of the study (2008). Below is an analysis of their findings.

During the first iteration, the study focused on the usability experience of 15 undergraduate students from a midwestern university in the United States in the final 6 weeks of a semester long class on religious studies. Within this portion of the study, Crisscrossing included 3 cases based on religious controversies. Each case contained at least 15 perspectives, which included eyewitness accounts and thematic interpretations of underlying issues, and multiple traces, which included documents, accounts, or artifacts absent of interpretation or implied meaning. Examples of questions students were to ask while investigating each case include:

- How would Emile Durkheim interpret that particular perspective/phenomenon?
• What position would Victor Turner make of a particular statement of a religious leader of that time?

The final activities of the class included a synthesis activity in which students designed a monument that would take into consideration the symbols, rituals, and architectural elements found among the cases (this activity reflected one of the cases that focused on Mount Rushmore). Students were also asked to write essays that connected various themes with the theories studied.

Results from the observations and interviews conducted during initial cycle found that students slowly adapted to the nonlinear nature of *Crisscrossing*, but once mastered, found it favorable. However, because of the structure of the CFH, students had to use external resources (such as Word or PowerPoint) during their final activities and struggled with referencing materials found in *Crisscrossing*. Cycle 1 ended with the conclusion that *Crisscrossing* needed to provide more student-owned and student-controlled features and support structures in order to foster student ownership.

During the second iteration of *Crisscrossing*, Strobel et al. addressed recommendations found in Jacobson and Archodidou’s 2000 article regarding Knowledge Mediator framework (as cited in Strobel et al., 2008, p. 72) which suggested giving users the ability to: comment on existing documents, construct new links between documents, provide rationales for their linking, add new cases, perspectives, and themes, attach artifacts like pictures, audio, and video files, and create paths through the information structure. In essence, these authoring tools added a strong constructivist element to the CFH by allowing learners to construct and manipulate their own learning (Schunk, 2012).
In Cycle 2, Strobel et al. expanded their study to include 60 undergraduate students in a midwestern university taking a history of religion class. The purpose of this portion of the study was to examine the impact Crisscrossing had on developing conceptual complexities among students with different levels of background knowledge. Because of the volume of data collected, the study was later pared down to 22 students.

Results from cycle 2 found that students utilized Crisscrossing mostly around due dates for assignments but tended to use it more with each subsequent assignment (1250 hits/day for case one, 1500 hits/day for case 2, and 1750 hits/day for case 3). However data also suggested that students rarely reviewed cases once the assignment was completed. Students also confirmed during interviews that they did not read many of the perspectives but concentrated on either those perspectives they found interesting or which were highlighted by the professor. However students did respond that this structure provided greater insight into the emotions and psychology that underlined the historic events. Because of the added authoring abilities, all of which were viewable by the entire class, Strobel et al. also found that the CFH had become overwhelming for many students, leading many to oversimplify and even linearize their use of the nonlinear structure of the CFH. This led Strobel et al. to conclude that students need stronger scaffolding when dealing with multiple perspectives (2008), reflecting the original sentiment expressed by Spiro et al. (1988) that learners need to be active participants, with tutorial guidance and scaffold support to management of the complexities.

During the third iteration, Crisscrossing was rebuilt using a combination of server-side (PHP) and cliente-side (JavaScript) scripting technologies along with a database (MySQL) to store student work and system settings. This allowed users much greater control over what and how they would view material but also required that they label document categories. Within
this environment, users were able to construct three types of entities: documents, links, and paths. Documents included any text or media resources, links included explicit relationships created between documents along with an explanation of the relationship, and paths allowed for a linear sequence between documents that could be shared with others. This last element was added as a type of scaffolding in response to issues found in cycle 2.

In cycle 3, Strobel et al. focused on an upper-level undergraduate course in marketing strategies that emphasis causal reasoning in regards to monetary, environmental, and population trends. In this environment, Crisscrossing provided a triadic representation of the cause and effect relationship, with the third component being the mechanism. A challenge in the traditional approach to this subject has been that when readers approach a causal map, they often struggle with making sense of it without a deeper explanation into what the author was thinking. Results from the study concluded that Crisscrossing helped bridge this gap by providing support for more in depth explanations. Crisscrossing also forced students to not only think deeper about the causal relationships they created within the program, but also in how they would describe and name each construct they added to the environment. Strobel et al. found that “these processes brought a deeper level of understanding of causal maps than the students were able to achieve before.” Students also reported that they felt their instructor would better understand their reasoning because of this process. An analysis of their artifacts indicated that students performed better at creating their maps and representing links, but it also revealed that student still struggled with dissociated the mechanisms and labeling their constructs.

The final conclusions of design-based research study were that a) regardless of the design, nonlinear knowledge structures are difficult for students to interpret and the strategies
needed to interpret and integrate nonlinear models are seldom possessed even by college students. b) Student-owned and student-controlled features and support structures are needed to allow for the creation of student-generated artifacts within the environment. c) As complexity increases, students who feel overwhelmed by the interlinked structures tend to oversimplify and revert to linear searches through the environment. d) Further focus is needed into more visual and conceptual representations of knowledge structures (Strobel et al., 2008).

**Conclusion**

In reflecting on the information provided in this paper, what stands out the most is the role of reductive bias during advanced knowledge acquisition. Spiro et al. (1988) writes: “Misconceptions of advanced material result both from interference from earlier, simplified treatments of that material and from a prevailing mode of approaching the learning procession in general.” (p. 5). As a result, Cognitive Flexibility Theory recommends a case-based approach that incorporates multiple perspectives. However, as seen in the research of Strobel et al. (2008), this in itself is not enough to dissuade the natural reductive biases found in students. Rather, in order to truly enjoy the affordances created by multiple perspectives and nonlinear crisscrossing, support structures must be present within the Cognitive Flexibility Hypertext in order to force students to think deeper and articulate their reasoning greater than what they would have naturally done had those structures not been in place. When considering support structures, therefore, we must consider both design-based structures, such as learner-controlled features, and instructional-based structures, such as authentic activities that reflect conceptual change. In doing so, we are much more likely to develop the tools necessary for students to experience the conceptual change needed in advanced knowledge acquisition.
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