Exploring the Effects of Cognitive Flexibility and Contextual Interference on Performance and Retention in a Simulated Environment

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EXPLORING THE EFFECTS OF COGNITIVE FLEXIBILITY AND CONTEXTUAL INTERFERENCES ON PERFORMANCE AND RETENTION IN A SIMULATED ENVIRONMENT

By

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A Dissertation submitted to the Department of Educational Psychology and Learning Systems in partial fulfillment of the requirements for the degree of Doctor of Philosophy

2015
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To my MOM and DAD for their love and Inspiration

&

To my son VIHAAN for giving me this aspiration
ACKNOWLEDGMENTS

To begin with I would like to thank GOD for unceasingly bestowing, on me all blessing that gave me the strength to complete this thesis.

_God lies in the details_, this has been taught practically to me by my advisor and mentor, Dr. Aubteen Darabi. His eye for perfection, precision and performance was the guiding principle that helped me gain knowledge and understanding of the subject. Thanks always remain unending for my supervisor, for helping me to choose this challenging topic, guiding me with impeccable patience, accommodating my mistakes and transforming them into meaningful conclusions. I also wish to express my gratitude to my committee members, Dr. James Klein, Dr. Jonathan Adams and Dr. Insu Paek who shared their expertise and helped me pave the path for successful completion of the work.

It gives me immense pleasure to appreciate the love and affection of my family specially my father (Late Shri Virendra Singh) and my mother (Smt. Leela Singh) for their blessings and inspiration. A special thanks and love goes to my dear husband Vinay and my lovely son Vihaan for their constant support and unconditional love. Oh! What a journey it has been, a constant source of guidance and encouragement came from my sisters, Richa and Reena and their families. I also truly acknowledge the support of my in-laws, my brother-in-laws Vineet and Vivek, and their families.

A special thanks goes to all the friends here at FSU who has provided constant encouragement and support. My friends and family back home in India also needs to be appreciated for their moral boosting talks and sending positive vibes throughout this journey and made it a memorable adventure!!
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ABSTRACT

Computer-based simulations are commonly used to train students when it is exceptionally expensive or very unsafe to practice the skill in the actual situation. Despite the promise of simulative environments, there is an inadequacy in the learning and retention of learned concepts. This study examined the effects of variability of practice provided via contextual interference and cognitive flexibility on learner’s learning and retention of the knowledge in the simulative environment.

To study the effects in this context, two different types of interference conditions were presented to the learners; block interference and random interference. Both the block and random contextual interference groups troubleshoot 8 defects in a chemical simulation, PC Distiller, an alcohol water distillery. For the block interference, all the four sets of one component were performed before the faults on second component sets were introduced, while random orders of the tasks were used in the random interference.

Forty nine freshman engineering students participated in the study. Participants were randomly assigned to the interference conditions: block and random. Participants were also required to complete a cognitive flexibility test to measure the shift of attention, and were measured via Wisconsin Card Sorting Test.

The results showed a significant difference in the learning performance and retention performance of the random interference group. Although, learners in the random interference group scored higher in the retention task, there was no significant difference between the two interference groups on learning and retention. Cognitive flexibility was also found to be having little predictive power of the outcome variable, learning performance and retention performance.
However time spent by the learners in troubleshooting a task had a significant main effect on the learning performance and retention of knowledge. Time on task was negatively related to the scores in the learning performance and retention. Learners from both the block and random interference groups, who took less time to solve the problems scored better.

The findings of this study have several implications for further research. Future studies might focus on learners experience and prior knowledge and use a sample for comparing the experts with the novice learners. In order to raise and produce better results on the learning tasks any information on participant’s motivation could help in situating the learning task in the simulated environment. One key implication for instruction is the usefulness of the random interference condition in improving retention of knowledge which is also supported by the literature. Research considering these implications will provide educators to optimally use the simulative technology in learning and instruction.

The limitations of the study focus on the time and financial constraints, type of instructional material and learner’s motivation. These factors should be considered by other researchers in this field who wish to improve learning in the simulated environment.
UNITED STATES

CHAPTER 1

INTRODUCTION

Context of Study

Computer-based simulations are commonly used to train students when it is exceptionally expensive or very unsafe to practice the skill in the actual situation (Wood, Beckmann, & Birney, 2009). Such simulations have been successfully used in recent years to provide professional training on problem-solving skills with engineering students, and in medical education settings to mitigate ethical tensions and practical dilemmas (Berry Issenberg, McGahie, Petrussa, Gordon, & Scalese, 2005). The success of these simulations relies upon their realistic representation of the complex environment (Ziv, Wolpe, Small, & Glick, 2003), the incorporation of flexibility for the educators to alter the reactions and responses (Issenberg et al., 2005) and the permitting of trainee errors while gaining the worthwhile experiences and insight (Allessi and Trollip, 1991; Wood, Beckmann, & Birney, 2009).

A unique benefit of computer simulations is the open-ended nature that evolves with the interplay of many variables; therefore, participants confront complex problems and make sense of the outcomes of their decisions (Gredler, 2004). Simulations involve tasks such as combat maneuvering skills in military, fault diagnosis in engineering, or recognizing clinical abnormalities in cardiovascular diseases in medical practice. These dynamic tasks give the students an impression of the realistic environment, which motivates them to formulate an advanced knowledge base using skills, and attitudes that support their performance (Vogel et al., 2006).
Despite the promise of simulative environments for developing higher-order thinking skills, creating meaningful learning, and permitting the application of skills to real situations (Norman, Dore & Grierson, 2012) there is an inadequacy in the retention and transfer of learned concepts, as reported in many studies. For example, in a research conducted by Fraser et al. (2009), students only retained partial knowledge for recognizing abnormalities in a clinical cardiorespiratory simulator, which led to decreased performance. So, Proctor, Dunston, and Wang (2006) also reported that in a retention test, part-task training (training provided in separate modules) created better skills retention than whole-task training (single module) for a trench-and-load task using a simulated hydraulic excavator. Garvey and Seiler (1966) found that high school students’ retention of factual and conceptual knowledge of international relations using a simulation activity was not significantly different than a control group. Similarly, participants in the Chandra, Savoldelli, Joo, Weiss, and Naik (2008) study were tested to measure differences in skill acquisition and transfer, comparing a low-fidelity and a high-fidelity model. The authors assumed the high fidelity model would allow for real-world practice, therefore resulting in better learning, but the results did not support this assumption.

The cited studies reveal a reduction in learning, and retention, with an absence of deeper-level information processing based on ill-structured (interacting concepts) and/or nonlinear problems. To remedy this gap, there was a call for learning strategies to enhance students’ metacognitive skills and create advanced knowledge acquisition with deeper levels of understanding of content materials. In response to this call, researchers noted that variability of practice is the most successful technique for increased retention and transfer of learned concepts (Battig, 1979; Magill & Hall; 1990; Shea & Morgan, 1979). Contextual interference (CI) is considered one such strategy to achieve this variability, which is defined as the extent of
interference designed by the structuring of skills in a practice or performance session (Battig, 1979; Magill & Hall, 1990; Shea & Morgan, 1979).

CI is been widely used in the simulated environment for retention and transfer. For example, van Gog, Paas, and van Merrienboer (2006) recommended that interference within practice examples would lead to better retention and transfer of learning, when compared with problem solving. Similarly, Shea, Kohl, and Indermill (1990) suggested that the amount of practice provided during the learning phase, with interference, is a factor responsible for retention performance. Parush, Hamm, and Shtub (2002) also evaluated the effectiveness of CI in simulation practice in learning history. They concluded that combined with the learning history recordings, participants in the Operations Trainer simulator performed better in fulfilling the task of manufacturing; this improvement remained two weeks of removing the learning history mechanism.

Many studies dispute the cognitive underpinnings of the CI effect. Success in the task was attributed to the students’ developed conceptual understanding, thus stored and retrieved information when needed. They recognize, however, that task variability, the manipulation of practice, constructive feedback, time on task and task complexity are factors that interplay with contextual interference and affect the cognitive processing and impact acquisition performance (Albaret & Thon, 1998; Boutin & Blandin, 2010).

**Problem Statement**

Current literature has not considered the problem of learning performance and retention of knowledge from a simulated learning environment using the cognitive flexibility perspective. Flexibility of cognition may influence learning and retention in the contextual interference
setting by dictating the ability of the learner to attain deeper understanding of the concept. Theory of Cognitive flexibility (Spiro, Vispoel, Schmitz, Samarapungavan, & Boerger, 1987) suggests that students should acquire in-depth understanding of content, develop logic surrounding it, and implement the content flexibly in diverse contexts for knowledge application and transfer to occur. Cognitive flexibility (CF) is being described by Spiro and Jehng (1990) as; “the ability to spontaneously restructure one’s knowledge, in many ways, in adaptive response to radically changing situational demands. This is a function of both the way knowledge is represented (e.g., along multiple rather single conceptual dimensions) and the processes that operate on those mental representations (e.g., processes of schema assembly rather than intact schema retrieval)” p. 165.

CF is achieved when students can create schemata for storing and retrieving the learned information (Spiro and Jehng, 1990). The conventional activities of a simulation – a skill or task, a method for participation rules, acceptable responses, and an error rate, fail to consider the full aspects of learning and understanding. Consequently, the superficial learning associated with conventional simulation activities may inhibit a deeper understanding of the learned concept; students may fail to retain the acquired knowledge and skills and thereby report decay in performance (Canas, Quesada, Antoli, & Fajardo, 2003).

To demonstrate systemic knowledge and succeed in the challenging simulated environment, students must understand the availability of alternatives and develop best practices for completing the given problems. This is a complex cognitive task, making students cognitively inflexible (van Merrienboer, Kirschner, & Kester, 2003). Such cognitive inflexibility impairs the ability to think and concentrate (King & Schaffer, 2010), makes it difficult to handle challenges satisfactorily (Sarason, 1984), and with decreased choice consistency, affects learner
performance (Yechiam et al., 2006). Cognitive inflexibility can emanate from multiple sources: variability of task, students effort expended to understand the task, task complexity, time provided to complete the task, learner ability to change cognitive processing strategies to handle the task, steps required to fulfill the task, and/or effort required to handle multiple information sources simultaneously (Canas, Antoli, Fajardo & Salmeron, 2005). Interference from these sources may result in a reduced understanding of the concept, thus affecting learner retention.

In this study, I examine the influence of cognitive flexibility on learning performance and retention of the knowledge gained in a simulated environment. I will also examine how does the interaction between cognitive flexibility and contextual interference (block and random) influence students learning performance and retention. From the cognitive flexibility literature, several behaviors are considered “flexible”, including: multitasking, interchanging two tasks, finding a novel solution, and constructing distinct ideas and knowledge (Ionescu, 2012). The contextual interference effect may be described as the effect of practicing more than one task on the performance (Lee, Wulf & Schmidt, 1992). High contextual interference instigates students to become more engaged in effortful cognitive processes, and is believed to develop schemata that enable them to perform the task (Wrathall, 2004).

The rationale for using cognitive flexibility in a simulated environment is: the complex cognitive task, with the help of contextual interference, will assist students by utilizing their cognition and flexibility to deal with future problems of a similar kind. The simulation works as a system involving an organized scheme of methodology to work. The interacting and interdependent components of the system provide necessary randomness, and the contextual interference is then used to activate student’s cognitive flexibility. The effect of the interplay of
contextual interference and cognitive flexibility greatly impacts individuals’ potential to learn and sustain in the changing environment (Martinez, Brusoni, & Zollo, 2009).

In the current study, two types of CI schedules will be used: (1) blocked schedule, in which the same skill is rehearsed in repetitive fashion, and (2) random schedule, wherein different skills are performed in an unpredictable trial-order. The proposed practice schedules are based on several research findings of the effects of contextual interference (Albaret & Thon, 1998; Lee & Magill, 1983; Shea & Zimny, 1983, 1988). Research indicates that when task variations are practiced in separate blocks, little amount of CI is created; higher levels of CI are achieved when task variations occur randomly (Albaret & Thon, 1998). Research also suggests that blocked practice leads to better learning performance in the training phase, but random practice results in increased retention and improved performance in transfer tasks (Magill & Hall, 1990).

Purpose Statement and Research Questions

The purpose of this study is to determine if cognitive flexibility and contextual interference have an effect on student’s learning performance and improve their retention of concepts acquired in a simulated environment. Two groups will be created with contextual interference (block and randomization) to aid students’ learning. The students’ scores in a complex cognitive task will serve as a measure of learning performance and retention. The time spent to complete the task will also be recorded and will also serve as one of the factors affecting the learning and retention.

The research questions for the study are:
1. What is the effect of cognitive flexibility on students’ learning performance and retention while troubleshooting a problem-solving task in a simulated environment?

2. What is the effect of contextual interference on students’ learning performance and retention while troubleshooting a problem-solving task in a simulated environment?

3. What is the relationship of time taken to troubleshoot a problem-solving task with students’ learning performance and retention in a simulated environment?

4. How does the interaction of cognitive flexibility; contextual interference and time taken affect students’ learning performance and retention while troubleshooting a problem-solving task?

**Hypotheses**

1. Cognitive flexibility will affect an improvement in the student’s learning performance and retention. This is expected because cognitive flexibility will enable the learners to restructure their acquired knowledge in an adaptive response to the challenging situational demands. Therefore, students with high cognitive flexibility will perform better, compared to students with low cognitive flexibility.

2. Random interference will be negatively related to students’ learning performance in complex cognitive tasks. Complex tasks, in random order, require the learner to use critical thinking, and also require a working understanding of the simulated environment. Therefore, the students’ learning performance will be affected. In the retention tasks, students using high interference random problems will perform better compared to those using low interference block problems. This is expected as high interference leads to a deeper and more meaningful learning.
3. Time will be negatively related to students’ learning performance and retention in complex
cognitive tasks. Better understanding of the problem and in-depth knowledge acquired during
the learning session will help the learners to find solution in lesser time. Therefore, it is
expected that less time on task will lead to improved learning performance and retention.
4. The interaction of cognitive flexibility, contextual interference and time will positively relate
to student’s learning performance and retention. Students will have deeper conceptual
understandings due to the flexibility in cognition. In addition, random interference will lead
to effective learning, aid the initial performance, and assist in retention.

Significance of the Study

This study attempts to accomplish some significant additions to the field of Instructional
Systems Design. First, the study applies cognitive flexibility theory in the area of simulations.
Although web-based designs and simulations are widely used in instruction, the importance of
cognitive flexibility therein is not appreciated or recognized often. With increased emphasis in
the uses of systemic thinking for solving problems, the failure of students to do so is evident. The
lack of flexibility in cognition may be the cause for the obstruction of performance in the
simulated environment. This study is an effort to investigate the role of cognitive flexibility in
students’ retention of the learned concept.

Next, this study attempts to provide a solution for improved retention of learned concepts
in the simulated environment. Leading researchers in the field have used diverse approaches to
improve the learning and performance, but have not reached consensus on the best approach.
This study identifies a lack of cognitive flexibility as the cause of poor retention of learned
material. This investigation of cognitive flexibility will provide new dimensions in the design
and development of simulated activities.
Finally, the current study draws attention toward the concept of contextual interference, which may be a useful aid for learning in the simulated environment. Learner contextual interference is created using different problem, or task, presentation formats. This differential interference helps channel the flexibility of their cognition and in turn results in increased retention.

In summary, this study’s contribution to the field of instructional design is to utilize the cognitive flexibility theory in the simulated environment, providing a deeper understanding of the factors related to improved retention of the learned concepts.
# CHAPTER 2

## LITERATURE REVIEW

Table: 2.1. *Organization and Rationale of the Literature Review Section*

<table>
<thead>
<tr>
<th>The overarching goal:</th>
<th>2.1. The contextual interference effect</th>
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<tr>
<td>To improve retention and transfer of the concept learned in the simulated environment.</td>
<td>2.2. The cognitive aspects of the contextual interference effect</td>
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<td>2.3. The interference strategies implemented in a simulated environment to increase retention and transfer</td>
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<th>What has been done?</th>
<th>2.4. The cognitive flexibility theory</th>
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<td>2.1. The contextual interference effect</td>
<td>2.5. The principles of cognitive flexibility theory</td>
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<tr>
<th>What is missing?</th>
<th>2.6. The strategies for retention to be improved by cognitive flexibility</th>
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<td>Cognitive flexibility has not been investigated as a factor affecting retention in simulated environments.</td>
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<th>What is the purpose of this study and why it may work?</th>
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<td>This study intends to use cognitive flexibility with interference, to help in learning and retention.</td>
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Contextual Interference Effect

In educational settings, the contextual interference effect is well studied. Contextual interference refers to the findings that interference generated by a random schedule of a variety of tasks benefits the retention and transfer of knowledge in the blocked practice of similar tasks (Albaret & Thon, 1998). Contextual interference is a variability phenomenon favorable for long-term learning and retention (Magill & Hall, 1990). For example, in a skill based task such as drawing, the block practice schedule has advantage during the training session, but participants with random practice schedule performs better in retention and transfer of learning tasks (Shea & Morgan, 1979). Empirical studies have shown that high contextual interference generated by random practice, results in multiple information processing and creates in-depth knowledge and acquisition of skills at levels not observed in low contextual inference situations (Magill & Hall, 1990; Shea & Morgan, 1979).

When properly designed and implemented, the CI effect could improve the training and acquisition of the cognitive skills and their transfer to novel situations. As suggested by Ritter et al. (2012) active experience of a variety of events improves learner creativity due to improved flexibility. This flexibility helps in breaking old cognitive patterns, overcoming functional fixedness, and making unique associations between concepts (Gulliford, 1967). One such experiment was conducted by Ritter et al. (2012) determining if diversifying experiences increased cognitive flexibility; they immersed students in a simulated environment disrupt their schema with a series unusual and unexpected events such as, violation of laws of physics. The results showed that when the students actively experienced these events, their cognitive flexibility increased.
In another experiment, van Merrienboer, Schuurman, de Croock and Paas (2002), tried to manipulate the cognitive load by increasing the germane load and decreasing extraneous load, which is considered good for schema building. They designed the practice schedule such that extraneous load would be redirected towards the germane load and improve learner retention and transfer. Building on to the practice schedule variation, Helsdingen, van Gog and van Merrienboer (2011), studied contextual interference effects of varied practice schedules on completing a complex judgment tasks and their effect on retention and transfer. They conducted two experiments involving predictive judgment tasks, such as injury cases, damage cases, and traffic cases, and required the participants to prioritize each case based on the required urgency for the police to deal with it. These tests were conducted as “near retention and transfer”, wherein the tests followed immediately after the practice. The random practice group outperformed the block group in both the retention and transfer tests. A separate, interesting finding of this study is that the random order interference was not detrimental to performance during the process of learning, suggesting that random interference results in better outcomes all-around. In the next section, I will focus on the cognitive aspects of the contextual interference effect.

Cognitive Aspects of the Contextual Interference Effect

Learning is a lifelong activity. Learned concepts, however, should be retained in the human memory, which occurs via the use of schemas. Humans can store 7 ± 2 words in their working memory (Baddeley & Hitch, 1974). In order to apply learned knowledge in future tasks, the learned concepts must be stored in long-term memory, for retrieval when needed (Van Merrienboer & Sweller, 2005). Variability of the task creating contextual interference is well established in the literature for assisting in learning and retention. Also in the literature are two
theoretical views, supported by scholars, to explain the CI effect (Boutin & Bladin, 2010). These are known as the *elaboration hypothesis* and the *reconstruction hypothesis*.

The elaboration hypothesis asserts that in random practice situations, students are forced to use descriptive and detailed cognitive processing, as the tasks vary from one another. In this case, the learning is deeper and more diverse, which in turn creates better retention (Shea & Morgan, 1979; Wright 1991). Block practice, on the contrary, does not provide the learner with such opportunities, as the tasks are focused in repetition.

The reconstruction hypothesis postulates that retention occurs due to the spacing effect, provided during the random practice session. Researchers support this idea by suggesting that in random interference, task variations forces learning and the spacing between the similar tasks creates the forgetting (Lee & Magill, 1983; Magill & Hall 1990). The subsequent reconstructive process helps to create better retention and transfer.

Heretofore, the elaborative and reconstructive processing frameworks have highlighted details of the CI effect. These hypotheses were based mainly in the manipulation of the practice schedule. Researchers in the field of CI, however, have studied other strategies to influence the CI effect; these are presented in the next section.

**Interference Strategies Implemented in a Simulated Environment to Increase Retention**

Many strategies have been implemented with contextual interference to facilitate retention and transfer in a simulated environment. In this section, I will review the retention and transfer strategies reported in the literature. These strategies can be grouped into five categories:
1. Worked Examples
2. Influence of Task (Task Complexity)
3. Manipulation of Practice
4. Augmented Feedback
5. Learning History

In the following section, I report retention strategies from the five areas, present the methods of implementation, and present findings of how the strategies have influenced the quality of retention and transfer in the simulated environment.

**Worked Examples**

The effectiveness of instructions and worked examples is based on the cognitive load theory. Researchers in the field of cognitive load advocate the use of instructions to reduce students’ cognitive load, for meaningful learning to occur. Sweller (1988) noted that if students are not provided with strategies to help them problem solve, they would switch to other, trial and error methods which eventually help in performance but require higher cognitive load and are not as effective for learning.

Berge et al. (2013) studied learners ability of procuring visual perceptual skills using worked examples and compared it with the use of instructions in novice medical students. As predicted by the authors, worked example instructions resulted in better retention but failed to show consistency in the transfer tasks. The authors concluded that because the mental effort reported by students, in the transfer tasks was very high, there were no significant differences between the two groups. Van Gog, Kester, and Paas (2011) used a more in-depth design by using three groups to compare methods in problem solving; the group conditions were worked example
only, example-problem pair and problem-example pair. The results of the study were that in the worked example and example-problem pairs groups, students reported less mental effort and were significantly better than those in the problem solving and problem-example pairs. The authors emphasized that providing examples helps the students in developing the schemas necessary for solving complex problems. Another important aspect is that the example being provided holds the key for better performance, since the problem-example pair did not motivate the students to study the example and they failed to recognize the deficiencies in their performances.

*Influence of Task (Task Complexity)*

A complex cognitive task creates an added layer of complexity. According to Schunn and Reder (2001), “dynamic tasks bring to the forefront, the importance of the ability to adapt to changing success rates” (p. 61). Boutin and Blandin (2010) studied task similarity as a source of cognitive interference to determine if a varying degree of task similarity can create contextual interference. The authors found that when the tasks were similar, the participants in the random practice used a longer time interval to learn, but showed enhanced performance. Yet, when the participants were subjected to dissimilar tasks during the practice session, there was no difference between the two groups. This suggests that a CI effect was modulated by the task similarity. In another experiment, De Croock, Van Merrienboer, and Pass (1998) studied differences in the way the information is presented and its effect on performance transfer and mental effort. They used two formats: the expository format – using system principles, examples, and a troubleshooting strategy, and an inquisitor format. The inquisitor format required the participants to study the system principles and troubleshooting strategies, thereafter, and predict the behavior of the system. Contrary to the belief of the researchers, the low contextual
interference group, receiving the problems in the block order, expository format, showed better performance. The authors suggested that the amount of practice and the nature of the transfer task may be the reasons for the failure of their hypothesis. These authors also described a need for a random interference group to help create schemata that might be fragmented from a lack of practice. On the contrary, the low interference group did not need device knowledge and used the general troubleshooting strategy and were more successful than their peers.

**Manipulation of Practice**

Ollis, Button and Fairweather (2005) investigated the effects of manipulation of practice in the form of simple and complex knot tying in professional firefighters. The participant’s performance was measured based on the acquired skill and its retention and transfer. The authors suggest that the high level of interference scheduling can be both “facilitative and debilitative” for the transfer performance. Hall and Magill (1995) investigated whether or not the variability of practice is associated with schema enhancement. The study included two experiments, first experiment had block and random interference groups later, the researchers added a third group in the second stage; a control group which did not receive any kind of practice on the task. The results revealed that variations in the practice are effective when the tasks modification are controlled and focused around the skills which are practiced.

Similarly, Schmidt and Bjork (1992) illustrated that although the focus of the task is learning and retention, yet the variation in task order affects performance. The authors suggest that the retrieval practice which would force the learner to use the stored information from the memory helps in increased retention.
Augmented Feedback

Literature suggests that aside from practice, learning a new skill or task is affected by information feedback (Wierinck, Puttemans, & Steenberghe, 2006) providing the learner with his/her mental and emotional strength. Specific augmented feedback, and the learning of results, motivates students to reach for the performance goal. Wierinck et al. (2006), studied cross-cavity preparation skills in dental students and provided them with tutorial-enriched segmented visual feedback. The two experimental groups were provided with 100% and 66% feedback, respectively and student learning, retention and transfer were measured. The authors discussed that although the continuous feedback is good for learning and achieving desired performance; high frequency feedback increases learner dependence and therefore affects the performance in the retention and transfer tasks. To counteract this effect, and maximize the benefit of the augmented feedback, the authors suggest determining the frequency of the feedback on task complexity and other skill requirements.

Conversely, Wu et al., (2011) experimented with CI and augmented feedback by providing feedback in either every trail or in a faded schedule. They concluded that the faded schedule of augmented feedback helps the learner by facilitating their critical thinking abilities and aids in enhancing cognitive effort for meaningful learning. The authors also noted that the use of the random practice schedule of the CI is more beneficial with the faded schedule, whereas in block practice it fails to facilitate learning.

A similar study was conducted by Scaringe, Chen, and Ross (2002), with students in a chiropractor program. The task involved using a low amplitude chiropractic procedure with a spinal manipulative. The participants were provided with two types of augmented feedback;
qualitative group (received feedback if they performed “over” or “under” the specified force range), and the quantitative group (received feedback after each trial). After 50 trails, retention tests conducted with the groups revealed no differences in retention and no differences in the performance patterns between the quantitative group and the qualitative groups.

**Learning History**

According to Parush et al. (2002), when learning in simulations in a complex pattern, one can benefit from learning history as a teaching tool. Learning history is defined as a record of past states and decisions, and most importantly the consequences of those decisions. In such cases, the students have access to such information, which should help in retention and transfer tasks. Parush et al. (2002) conducted a study with two experimental conditions – with or without recording and assessed learning history. The study used an Operations Trainer simulator to mimic the order fulfillment process in a manufacturing unit. Their findings suggest that the group with access to learning history performed better. Most important, improved performance continued after the removal of the history mechanism.

Similar findings were suggested by Davidovitch, Parush, and Shtub (2008), studying the learning, forgetting, and relearning (transfer) phenomenon in a project management simulative environment. In the study, engineering student participants recorded their learning history either manually or received them automatically by the simulator. The results of the study indicated significant differences between the experimental (with learning history) and control group (without learning history). In the second phase of the study, the authors tested the transfer phenomenon by providing a break period of two and four weeks. The results showed that the history mechanism aided in learning and knowledge gain, which was reflected in better
performance after the break. The authors advocate the use of the learning history as a tool to help the learner maintain record of his/her learning and employ as an aid for future learning.

Various strategies that have influenced the CI effect rely on the cognitive processing phenomenon. There is a need to study the effects of cognitive flexibility, which is pivotal to understanding the contextual interference effect.

**Cognitive Flexibility Theory**

Based on the literature review of the appropriate disciplines, few studies have considered the flexibility of cognition as a limitation in retaining and transferring the learned knowledge. The research on cognitive flexibility suggests that problems in advanced knowledge acquisition are ill-structuredness of the content, and complexity of the concepts and interaction of these with the methods of instruction (Spiro, Coulson, Feltovich & Anderson, 1988). Effective instruction should manipulate cognitive flexibility and as a higher order aspect of cognition, flexibility should affect the individual’s potential to learn and sustain information in the changing environment. Helsdingen, Van Gog and van Merrienboer (2009) state that “when instruction in expert cognitive strategies is combined with a broad set of practice scenarios, the process of generalization of abstract representations is facilitated, leading to more cognitive flexibility and better transfer of judgment skill”( p 8).

**Principles of Cognitive Flexibility Theory**

Spiro et al. (1988) presented the themes to remediate the problems with advanced knowledge acquisition. These themes summarize the principles of cognitive flexibility theory and help the students acquire complex knowledge and transfer ability. The themes are:
Avoidance of Oversimplification

Spiro et al. (1988) suggest that “cognitive flexibility involves the selective use of knowledge to adaptively fit the needs of understanding and decision making in a particular situation” (p.5). Oversimplification leads to dividing the concept into separate compartments, which is against the nature of the complex conceptual knowledge.

Multiple Representations

Spiro et al. (1988) state that, “Cognitive flexibility is dependent upon having a diversified repertoire of ways of thinking about a conceptual topic” (p.5). Multiple representations help the students diversify the conceptual understanding and reason it with relevant perspectives.

Centrality of Cases

When the knowledge to be acquired is very complex and ill structured (having multidimensional individualistic aspects), examples and supporting ideas become very important. Providing only the general principle will not validate the complex nature of the concept.

Conceptual Knowledge as Knowledge-in-use

To attain a deeper understanding of the abstract knowledge, authors suggest that students should divert their attention to determining how the conceptual knowledge is used in practice. This provides an ease in understanding the variability of the abstract concepts.

Schema Assembly

Complex knowledge cannot be retrieved in intact format. For advanced knowledge acquisition of multilevel concepts, authors suggest that emphasis is given to the flexible knowledge structures.
Multiple Interconnectedness

Abstract knowledge cannot be represented in separate blocks of instruction. The presentation of knowledge should be interconnected, such that learner flexibility can be channelized. The interconnectedness of multiple concepts leads to advanced knowledge acquisition.

Active Participation and Guidance for Management of Complexity

Authors suggest that to acquire complex knowledge, the involvement of the learner as an active participant is as important as the mentor for providing guidance. This mentor-mentee relationship helps in managing the complexity of the knowledge.

These guiding principles of the cognitive flexibility theory help students in acquiring complex knowledge. CFT asserts that when learning is meaningful, retention and transfer of knowledge is naturally acquired.

Retention Strategies to be Improved by Cognitive Flexibility

Cognitive flexibility theory assumes that for learning to occur, the learner must develop knowledge and understanding of the concept, and apply it flexibly in diverse contexts. When learning problems are characterized by ill structured domains, there is a need for aiming at in-depth knowledge acquisition which would involve grasping the concepts and applying them in diverse contexts (Spiro et al., 1988) wherein, students’ flexibility of cognition dictates their understanding and decision making (Deak, 2003).

Traditionally, instructions were imparted via linear media (e.g. Textbooks and lectures). Linearity of media results in loss of vital information when content complexity increases, making the content less accessible for the students understanding (Spiro and Jenhg, 1990). A complex cognitive task creates an added layer of difficulty; according to Schunn and Reder (2001)
“dynamic tasks bring to the forefront the importance of the ability to adapt to changing success rates” (p.61). Cognitive flexibility theory provides insight on learning in complex and ill-structured domains. Inflexibility impairs the ability to think and concentrate, this effect appears to have the greatest impact when the task involves a high cognitive demand (King & Schaffer, 2010). Increased inflexibility results in attention deficiency and leads to decreased choice consistency, thus affecting the performance (Yechiam, et al., 2006). By impacting the limited capacity of inflexibility in the working memory, performance is inhibited (Eysenck, 1992). Sarason (1984) pointed out that inflexibility is the response to perceived inability to handle a challenge in a satisfactory manner and therefore decreases the performance of the students. As a higher-order aspect of cognition, flexibility is considered an integral element of decision making, also affecting the individual’s potential to learn and sustain information in the changing environment (Martinez, Brusoni, & Zollo, 2009). The awareness of alternative learning strategies is a social cognition process, which drives the student’s willingness to change (Martin & Anderson, 2001).

An important characteristic that helps individuals pursue complex tasks, such as finding innovative solutions, multitasking, adapting to challenging demands, is cognitive flexibility. It is the property of the cognition that develops with two types of interaction systems: the interaction of various cognitive components and the sensorimotor components.

**Summary**

Contextual interference is considered one of the most important strategies for better retention and transfer of knowledge, even surpassing the benefits of problem solving exercises. Previous research in this area has focused on the manipulations of task, worked examples and/or similar variables, but very little attention has been given to the role of the individual cognitive
aspect and ability to construct schemata for learning. This study attempts to invoke a paradigm shift by changing the focus toward the cognitive aspects of deeper and meaningful learning via the concept of cognitive flexibility. The results of this study will add to the literature regarding the retention and transfer strategies used within the cognitive flexibility perspective. The research questions and hypothesis for this study are:

1. What is the effect of cognitive flexibility on students’ learning performance and retention while troubleshooting a problem-solving task in a simulated environment?
2. What is the effect of contextual interference on students’ learning performance and retention while troubleshooting a problem-solving task in a simulated environment?
3. What is the relationship of the time taken to troubleshoot a problem-solving task on students’ learning performance and retention in a simulated environment?
4. How does the interaction of cognitive flexibility; contextual interference and time taken affect students’ learning performance and retention while troubleshooting a problem-solving task?

a) Cognitive flexibility will affect an improvement in the student’s learning performance and retention. This is expected because cognitive flexibility will enable the learners to restructure their acquired knowledge in an adaptive response to the challenging situational demands. Therefore, students with high cognitive flexibility will perform better, compared to students with low cognitive flexibility.

b) Random interference will be negatively related to students’ learning performance in complex cognitive tasks. Complex tasks, in random order, require the learner to use critical thinking, and also require a working understanding of the simulated environment. Therefore, the students’ learning performance will be affected. In the retention tasks,
students using high interference random problems will perform better compared to those using low interference block problems. This is expected as high interference leads to a deeper and more meaningful learning.

c) Time will be negatively related to students’ learning performance and retention in complex cognitive tasks. Better understanding of the problem and in-depth knowledge acquired during the learning session will help the learners to find solution in lesser time. Therefore, it is expected that less time on task will lead to improved learning and retention.

d) The interaction of cognitive flexibility, contextual interference and time will positively relate to students’ learning performance and retention of knowledge. Students will have deeper conceptual understandings due to the flexibility in cognition. In addition, random interference will lead to effective learning, aid the initial Learning, and assist in retention and transfer.
CHAPTER 3

METHOD

This study aimed at investigating the effect of cognitive flexibility on learning performance and retention of the knowledge gained in a simulated troubleshooting environment. This study also examined if, cognitive flexibility (CF), contextual interference (CI) conditions (block and random) and time on task (TOT), together were interacting to influence students’ learning performance and retention. This section describes the participants, research design, and procedures that were used in the study. It also provides information about the intervention and the instructional materials used in the study.

Participants

Forty nine students enrolled in an undergraduate course for first year engineering in a large southeastern university were the participants in the study. There were 13 females and 36 males. The age group of participants ranged from 18-21 years. In order to inform the students about the scope of the study, I did a short presentation during the class, which provided them with what to expect in the process of study and invited them for participation. The inclusion criterion for participants was to be enrolled in an engineering course. The students were given 20 extra credits for their participants along with a $10 dollars gift card.

Students were randomly assigned to Block and Random Interference groups. There were 25 participants in the block interference group and 24 participants in the random interference groups.
Treatments

Two types of treatments conditions were created for the participants in this study. All participants were required to complete a cognitive flexibility assessment, along with the intervention. Students were then routed randomly into either (1) Treatment A (group 1: block contextual interference) or (2) Treatment B (group 2: random contextual interference). Following instructions were provided to the participants for the treatment.

Welcome: Please login into the given computer with the provided user name. Before you begin, please read the instructions.

1. Go through the introduction of the simulation program.
2. After completing the introduction, begin the experiment session.
3. In the experiment session, you are expected to act as a project coordinator who is controlling the distillation plant.
4. During the experiment session, some faults will begin automatically.
5. These faults will cause the distillation process to deteriorate.
6. As a manager, you are required to identify the fault and react immediately to fix the fault.
7. You have maximum of 5 minutes to identify the location of the fault and fix it.
8. The stopwatch will provide a display for the remaining time available to rectify the fault.
9. You can have multiple attempts to solve the problem.
10. Once you fixed the fault, you can move ahead.
11. If you are unable to fix the fault within the stipulated time, the system will move
ahead and present you with the new problem.

**Materials**

The study was conducted in Week 12 and Week 15 of the spring semester. On the Monday of Week 12, students were assigned to individual computers, pre-sorted and pre-coded for the two treatments. The instructions described for Treatment A and Treatment B conditions were presented to the students before beginning the tasks, using the individual computers. The following participation note will be provided to the students.

*Active participation in this study may help you develop a deeper understanding of content learned in the course. Your participation in the simulated activities will enrich your learning experience and help in the development of skills needed for future work in the industry. You will earn up to 1 credit for participation in this study. For this study, you are expected to:*

1. Participate in all activities related to the study.
2. Not discuss the content or the material of the study with other participants.
3. Follow all written procedures of the study.

On the Monday of week 15, participants came for the retention test. At the beginning of the experiment, students were administered and required to complete the cognitive flexibility test, *Wisconsin Card Sorting Test* (WCST, Grant & Berg, 1948). The manual is authored by Robert K. Heaton (1981). The WCST-128: CV2 is the computer version of the test which takes approximately 10 minutes of time. After completing the WCST, they participated in the retention test.
**Contextual Interference Strategy**

The current study investigates the effects of cognitive flexibility and contextual interference on learning performance and retention. It is expected that random order interference will increase student learning and retention. For the contextual interference task, two treatment conditions were created: the block interference condition and the random interference condition. To produce the contextual interference task, this study used the computer-based simulation, *PC-Distiller*. This simulation is a water-alcohol distillery plant, illustrating a graphical representation of the distillery system. Figure 3.1 shows the overview of the simulation.

![Figure 3.1. Overview of the Simulation](image)

PC Distiller is a simulation called as PROCESS (program for research on operator control in an experimental simulated setting) was developed by Jelsma and Bijlstra, in 1990. It was developed
in response to the training needs of the operators, to be able to train for potentially hazardous conditions. This simulation has helped in conducting research in human control behavior.

According to the authors, the simulation consists of an automatic production process with six proportional integrative differential (PID) controllers, three flow controllers (FC), two level controller (LC), and one temperature controller (TC). These controllers help in measuring the temperature and flow of liquid mixtures in the system, known as the *process value*. Each of the six PID controllers works in conjunction with each other in regards to the opening and closing of the associated valves. The simulator manages the process value in such a way that it remains a stable system.

PC Distiller provides the experimenters control over the system, as the researcher can define the following in the simulation:

- **Subject identification**: The researcher can identify the subject with a code; specify the training condition and also the malfunction to be solved.
- **Process Specification**: The researcher can set the time available, number of attempts to solve the faults and alarm limits for the faults in the system.
- **Malfunction Specifications**: The researcher can specify the malfunctions in the system. Seven types of malfunctions can be created which would create faults in the system, these are, PID controller malfunctions (*the valve is not automatically controlled*), leakage (*fluid flows out of the distillation system*), Alarm failure (*no acoustic signal*), valve malfunction (*valve get stuck*), Incorrect PID adjustment (*discrepancies in actual process value*), false alarm and tank rupture.
Table 3.1 presents an example of fault management procedure, reprinted from Jelsma and Bijlstra’s article.

Table 3.1. *An Example of Fault Management Procedure*

<table>
<thead>
<tr>
<th>If</th>
<th>Then</th>
</tr>
</thead>
<tbody>
<tr>
<td>1) Alarm signal occurs</td>
<td>• Acknowledge acoustic alarm</td>
</tr>
<tr>
<td></td>
<td>• Acknowledge visual alarm</td>
</tr>
<tr>
<td></td>
<td>• Select CID</td>
</tr>
<tr>
<td></td>
<td>• Check trend information on PV</td>
</tr>
<tr>
<td>2) PV exceeds alarm limits</td>
<td>• Check repair list</td>
</tr>
<tr>
<td>3) Controller in not under repair</td>
<td>• Check controller mode</td>
</tr>
<tr>
<td>4) Controller mode is AUTO</td>
<td>• Check trend information on PV</td>
</tr>
<tr>
<td>5) No fluctuations in PV occur</td>
<td>• Check trend information on VP</td>
</tr>
<tr>
<td>6) VP is adjusted to compensate deviation PV-SP</td>
<td>• Check trend information on PV</td>
</tr>
<tr>
<td>7) PV is not approaching SP</td>
<td>• Check trend information on VP</td>
</tr>
<tr>
<td>8) VP has reached/is going to its utmost position</td>
<td>• Conclude- Leakage</td>
</tr>
<tr>
<td></td>
<td>• Report Malfunction</td>
</tr>
</tbody>
</table>

(Jelsma & Bijlstra, 1990, p.1226)
In the present study, during the experiment, the participants were subjected to the malfunctions in the system, which are the troubleshooting tasks. These malfunctions resulted in the failure of the system at the pre-set time and it required the attention of the participants. After a diagnosis is made, and the fault is repaired, the simulation starts to work again. The learning management system in the simulator recorded the score of the participants, time on task, and the number of attempts used by the participants to reach the correct response.

In the current experiment, eight tasks were developed to perform two types of component malfunctions: (1) Fault in the proportional integrative differential controllers, (b) Failure of the valves. Both the block and random CI groups performed 8 defects of malfunctions; 4 defects for both the components. Both the component sets with malfunctions were introduced at least once in each of the six PID controllers (See Appendix D). For the block CI group, all the four sets of one component were performed before the second component set were introduced, while random orders of the tasks were used in the random CI. Participants had five minutes to detect and fix each fault. During this time, participants were allowed to make repeated incorrect diagnoses, as required.

Cognitive Flexibility Measure

To detect the cognitive flexibility of the participants, Wisconsin Card Sorting Test (Grant & Berg, 1948) was used. The cognitive dimension of WCST is the individual’s conceptual ability or is the ability of learning to learn. WSCT is a test for measuring shift of attention, this test requires the participants to sort the cards based on three attributes (color, shape and number). (Figure 3.2 demonstrates the overview of test screen).
WCST helps in assessing the cognitive abilities of abstraction and learning abilities, therefore is very commonly used for measuring the cognitive flexibility. The test provides six scores (1) total correct, (2) total errors, (3) perseverative responses, (4) perseverative errors, (5) Completed categories, and (6) failure to maintain set. The description of the scores is provided in the table 3.2, reprinted from Investigating WCST, Advance Applied Science-GCE A2 Unit.

For CF, this test is used to measure the lack of flexibility by measuring the perseveration. Since flexibility is the ability to change the strategy of problem solving based on the needs of the task (Gonzalez, Figueroa, Bellows, Rhodes & Youmans, 2013), and perseverative errors imply that the answer would have been correct in the previous situation; therefore, it signifies the attribute of flexibility where the subject was not able to change the strategy of problem solving and hence scored incorrect. The manual of WCST recorded the reliability of this test to be .60; it is based on the test designed on Generalizability theory, which measure the true scores of the
participants. Heaton et. al. 1993, states that “Generalizability coefficients of .60 or higher should be regarded as demonstrating very good scale reliability” p.40

Table: 3.2. Description of WCST Scores

<table>
<thead>
<tr>
<th>Score</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Total Correct</td>
<td>• The total number of correct responses in the WCST score sheet.</td>
</tr>
<tr>
<td>2. Total Error</td>
<td>• The total number of incorrect responses in the WCST scoresheet</td>
</tr>
<tr>
<td>3. Perseverative</td>
<td>• The number of incorrect response that would have been correct for the preceding category</td>
</tr>
<tr>
<td>responses</td>
<td></td>
</tr>
<tr>
<td>4. Perseverative Errors</td>
<td>• The number of error where the participant has used the same rule for their choice as the previous choice</td>
</tr>
<tr>
<td>5. Completed categories</td>
<td>• The number of runs of 10 correct responses</td>
</tr>
<tr>
<td>6. Failure to maintain set</td>
<td>• The number of times five or more consecutive correct responses occur without completing the category</td>
</tr>
</tbody>
</table>

In WCST, while taking the test, participants were required to sort the cards based on the rules and the provided feedback “correct” or “incorrect” after every response. The sorting rule changes after certain correct responses, without prior notice, therefore the participants have to adapt their responses based on the feedback and apply it for the next trial. The flexibility of
cognition comes in play here and affects the response of the participant if, they do not shift the attention and continue to make the error even after receiving the feedback “incorrect”.

**Study Design and Power Analysis**

*Study Design*

This is an experimental research using the regression with the interaction effect between the two predictors was used for the study. (Figure 3.3 presents the model for the study)

![Figure 3.3. Model for the Research](image)

Participants were randomly divided into two groups based on the categorical variable contextual interference. Group one with treatment A were provided with the block interference and group two with treatment B were provided the random interference. Participants took the retention test after 2 weeks of the intervention. Table 3.3 presents the design of the study.
**Power Analysis**

Statistical power is defined as the probability that the researcher will reject the null hypothesis, when it is false (Cohen, 1992). Power is a function of sample size (N), effect size, and alpha level; it can be computed using a specified level of alpha level ($\alpha$), the desired power and the expected effect size (Cohen’s $d$). According to Cohen (1988; 1992), a power of .80 is desired in the field of behavioral sciences. This provides the researcher an 80% chance of correctly rejecting the null hypothesis. In general, as the sample size increases, so does the power of the test. Therefore, in order to ensure the required sample size, a power analysis is conducted.

To determine the required sample size for this study, I conducted a priori power analysis using G*Power 3.1 software (Faul, Erdfelder, Buchner, & Lang, 2009) in the planning stage. In order to do the regression analysis, the suggested sample size for a desired effect size ($f^2$) of 0.3, an alpha level ($\alpha$) of 0.05, and an 80% (0.80) power rating was forty five participants.
Procedures

The procedures of the study are illustrated in Table 3.4

Table 3.4. Procedure of the Study

<table>
<thead>
<tr>
<th>Task</th>
<th>Group 1</th>
<th>Group 2</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Week 12</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Participate in the introduction of the troubleshooting task.</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>2. Participate in the troubleshooting, learning task.</td>
<td>Treatment A</td>
<td>Treatment B</td>
</tr>
<tr>
<td><strong>Week 15</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Complete the Wisconsin card sorting test for cognitive flexibility.</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>2. Participate in the troubleshooting, retention task.</td>
<td>yes</td>
<td>yes</td>
</tr>
</tbody>
</table>

*Note. Students’ scores in the simulated tasks were recorded by the LMS of the simulator during the experiment.*

The participants were asked to complete the following tasks, according to the following schedule:

- In week eleven of the semester:
  
  Students indicated their consent to participate in the study.
• In week twelve of the semester:

Students read the instructions at the beginning of the experiment, at individually assigned computers. Students then followed the self-paced computer-assisted instruction program, introducing them to the general information of the simulation and providing troubleshooting instructions for the simulated malfunctions.

Students then performed the given troubleshooting task on individually assigned computers. Eight tasks were given in each condition, with a time limit of five minutes per task.

• In week fifteen of the semester:

Students read the instructions for the experiment at assigned computers. Students were required to take the Wisconsin Card Sorting Test, for cognitive flexibility, followed by attempting the troubleshooting simulated task, using the individually assigned computers. Eight tasks were given to the students, with a time limit of five minutes per task.

**Variables**

**Independent Variables**

*Type of treatment.* For the problem-solving simulation task, group one was provided with block interference wherein they received all four malfunctions of one component set, followed by the four malfunctions of second component set (see Appendix D). While group two was provided with random interference, here all the participants solved malfunctions in random order
of the component set. For the retention task, both the groups received the same problems, from the problem solving session in week 12, but in the random order.

*Cognitive flexibility.* Cognitive flexibility was measured in the week 15 of the experiment. It is a continuous variable and its scores were used in the regression analysis to calculate the predictability of the outcome variable (Learning performance and retention).

*Time on task.* The time taken by the participants was also recorded by the software. These scores were used in the regression analysis to calculate the predictability of the outcome variable (Learning performance and retention).

**Dependent Variables**

*Scores on the Learning performance and Retention Task.* The scores of the participants in each malfunction were recorded by the software. As suggested by Darabi, Nelson, & Palanki (2007), there is very little room in the actual chemical plant for errors, therefore only the first-time correctly diagnosed performance were considered a valid response, in the study. For learning performance, the participants received two treatment conditions with varying order of the tasks, but for the retention the participants received same order of the tasks.

**Data Analysis**

Multiple regression analysis which allows us to examine the roles of several predictors was carried out to calculate the main effect of cognitive flexibility and contextual interference on the outcome variables i.e. learning performance and retention. F-test which is an omnibus test was conducted which was followed by t-test to examine the contribution of each predictor. Another important aspect of the study is to find the differences between two treatments; therefore, I
calculated the mean scores across both the groups. I was also interested in finding the interaction between cognitive flexibility and contextual interference. So, I conducted the regression analysis for interaction to find out whether or not there is a significant interaction effect.

**Model for Regression**

In order to understand the main effects of contextual interference, cognitive flexibility and time on learning and retention, the following model of regression was used.

\[
\text{Performance} = b_0 + b_1 \text{CI}_i + b_2 \text{CF}_i + b_3 \text{TOT}_i + e_i
\]

\[
\text{Retention} = b_0 + b_1 \text{CI}_i + b_2 \text{CF}_i + b_3 \text{TOT}_i + e_i
\]

Where,

\(b_0 = \text{Intercept, i.e the value of } Y \text{ when all the predictors are 0.}\)

\(b_1 \text{CI}_i = \text{Regression coefficient for mean difference of contextual interference groups}\)

\(b_2 \text{CF}_i = \text{Regression coefficient for cognitive flexibility}\)

\(b_3 \text{TOT}_i = \text{Regression coefficient for time on task}\)

\(e_i = \text{Error}\)
CHAPTER 4

RESULTS

This chapter presents the result of the study. The presentation is organized according to the sequence of the analysis, which is descriptive statistics of the outcome and predictor variables, regression analysis for the learning performance and retention scores. An exploratory analysis and effect size of the results will close the chapter.

Descriptive Statistics for the Outcomes

Students performance scores ranged from 0 to 4, (Possible scores were 0 to 8). Table 4.1 presents the descriptive statistics of students’ learning performance grouped by contextual interference conditions. Figures 4.1 and 4.2 presents the spread of the performance data.

Table 4.1. Descriptive Statistics for Students’ Learning Performance Scores

<table>
<thead>
<tr>
<th>Contextual Interference groups</th>
<th>N</th>
<th>Mean</th>
<th>Std. Deviation</th>
<th>Skewness</th>
<th>Std. Err of Skewness</th>
</tr>
</thead>
<tbody>
<tr>
<td>Block</td>
<td>25</td>
<td>1.92</td>
<td>1.35</td>
<td>-.064</td>
<td>.464</td>
</tr>
<tr>
<td>Random</td>
<td>24</td>
<td>1.88</td>
<td>1.39</td>
<td>.137</td>
<td>.472</td>
</tr>
<tr>
<td>Total</td>
<td>49</td>
<td>1.90</td>
<td>1.35</td>
<td>.036</td>
<td>.340</td>
</tr>
</tbody>
</table>
Figure 4.1. Distribution Histogram of Students’ Learning Performance Scores

Figure 4.2. Box Plots of Students’ Learning Performance Scores
Students’ score on retention of chemical simulation troubleshooting ranged from 0 to 5 (Possible scores were 0 to 8). The descriptive statistics of retention scores are presented in the table 4.2. Figures 4.3 and 4.4 presents the spread of retention data.

Table 4.2. Descriptive Statistics of Students’ Retention Scores

<table>
<thead>
<tr>
<th>Contextual Interference groups</th>
<th>N</th>
<th>Mean</th>
<th>Std. Deviation</th>
<th>Skewness</th>
<th>Std. Err of Skewness</th>
</tr>
</thead>
<tbody>
<tr>
<td>Block</td>
<td>25</td>
<td>2.08</td>
<td>1.38</td>
<td>.360</td>
<td>.464</td>
</tr>
<tr>
<td>Random</td>
<td>24</td>
<td>2.67</td>
<td>1.63</td>
<td>-.324</td>
<td>.472</td>
</tr>
<tr>
<td>Total</td>
<td>49</td>
<td>2.37</td>
<td>1.52</td>
<td>.042</td>
<td>.340</td>
</tr>
</tbody>
</table>

Figure 4.3. Distribution Histogram of Students’ Retention Scores
A total of 40 minutes was allocated for performing either the learning performance or retention task. The tasks included solving eight problems according to the design of the study. Time on task (TOT), the time taken by the students to complete the tasks, was measured in seconds by simulation program. TOT for learning performance ranged from 521 to 1977 seconds and TOT for retention ranged from 369 to 1619 seconds. The descriptive statistics of TOT for learning performance and retention is provided in the tables 4.3 and 4.4 respectively.
Table 4.3. *Descriptive Statistics of TOT for Learning Performance*

<table>
<thead>
<tr>
<th>Contextual Interference groups</th>
<th>N</th>
<th>Mean</th>
<th>Std. Deviation</th>
<th>Skewness</th>
<th>Std. Err of Skewness</th>
</tr>
</thead>
<tbody>
<tr>
<td>Block</td>
<td>25</td>
<td>1146.28</td>
<td>355.98</td>
<td>.704</td>
<td>.464</td>
</tr>
<tr>
<td>Random</td>
<td>24</td>
<td>1260.29</td>
<td>319.79</td>
<td>.819</td>
<td>.472</td>
</tr>
<tr>
<td>Total</td>
<td>49</td>
<td>1202.12</td>
<td>340.117</td>
<td>.644</td>
<td>.340</td>
</tr>
</tbody>
</table>

Table 4.4. *Descriptive Statistics of TOT for Retention*

<table>
<thead>
<tr>
<th>Contextual Interference groups</th>
<th>N</th>
<th>Mean</th>
<th>Std. Deviation</th>
<th>Skewness</th>
<th>Std. Err of Skewness</th>
</tr>
</thead>
<tbody>
<tr>
<td>Block</td>
<td>25</td>
<td>772.12</td>
<td>311.21</td>
<td>1.002</td>
<td>.464</td>
</tr>
<tr>
<td>Random</td>
<td>24</td>
<td>858.63</td>
<td>253.19</td>
<td>.525</td>
<td>.472</td>
</tr>
<tr>
<td>Total</td>
<td>49</td>
<td>814.49</td>
<td>284.70</td>
<td>.703</td>
<td>.340</td>
</tr>
</tbody>
</table>

Figure 4.5. Average TOT on First Time Correct Response in Learning Performance Tasks
Figure 4.5 and 4.6, Compares the learners average TOT in first time correct responses based on the CI conditions.

![Figure 4.6. Average TOT on First Time Correct Response in Retention Tasks](image)

**Cognitive Flexibility**

To provide a measure of their CI, each student took the WCST which measures, shift of attention, and requires the participants to sort the cards based on three attributes (color, shape and number). WSCT provides variety of scores as described on page 40 of this manuscript. In the WCST, the measure for CF is “the ratio of number of errors attributed to perseveration over the total number of errors made” (Gonzalez, Figueroa, Bellows, Rhodes & Youmans, 2013; p.2). These authors have called the ratio as percent perseverative error. I have used the same measure for the purpose of this study. The histogram and box plot in figures 4.7 and 4.8 presents the spread of percent perseverative error. Descriptive statistics of the scores for all participants is provided in the table 4.5.
Table 4.5. *Descriptive Statistics of WCST (Cognitive Flexibility)*

<table>
<thead>
<tr>
<th>Variables</th>
<th>N</th>
<th>Mean</th>
<th>Std. Deviation</th>
<th>Skewness</th>
<th>Std. Error of Skewness</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Correct</td>
<td>49</td>
<td>70</td>
<td>8.72</td>
<td>.534</td>
<td>.340</td>
</tr>
<tr>
<td>Total Error</td>
<td>49</td>
<td>17.71</td>
<td>13.17</td>
<td>2.65</td>
<td>.340</td>
</tr>
<tr>
<td>Perseverative Error</td>
<td>49</td>
<td>6.45</td>
<td>2.32</td>
<td>1.54</td>
<td>.340</td>
</tr>
<tr>
<td>% Perseverative Error</td>
<td>49</td>
<td>48.96</td>
<td>23.76</td>
<td>.292</td>
<td>.340</td>
</tr>
<tr>
<td>Perseverative Responses</td>
<td>49</td>
<td>9.43</td>
<td>3.81</td>
<td>1.50</td>
<td>.340</td>
</tr>
<tr>
<td>Completed Categories</td>
<td>49</td>
<td>5.88</td>
<td>.60</td>
<td>-5.99</td>
<td>.340</td>
</tr>
<tr>
<td>Failure to maintain set</td>
<td>49</td>
<td>.43</td>
<td>.64</td>
<td>1.24</td>
<td>.340</td>
</tr>
</tbody>
</table>

Figure 4.7. Distribution Histogram of Students’ CF Scores
Regression Analysis

Test for Basic Assumptions

There are various assumptions to be made in a multiple regression analysis including assumptions on the outliers, collinearity of data, independent errors, random normal distribution or errors, non-zero variances, and homoscedasticity and linearity of data.

In this study, all the above assumptions were tested for both the learning performance scores and retention scores.

Outliers. For detecting outliers, an analysis of standard residuals was carried out for both the performance scores and retention scores, it showed that data contained no outliers.

For learning performance scores: (Std. Residual Min = -1.94, Std. Residual Max= 2.22)
For retention scores: (Std. Residual Min = -2.25, Std. Residual Max= 1.98)

**Collinearity.** Menard (1995), suggested that to detect collinearity the values for tolerance should be more that 0.2 and values for VIF should be less than 10 (Myers, 1990). Based on these cutoff values, the data indicated that multicollinearity was not a concern. The values for learning performance scores are: (For, Contextual Interference, Tolerance= .96, VIF =1.03, Cognitive Flexibility, Tolerance =.99, VIF = 1.00 and for Time, Tolerance = .96, VIF= 1.03). The values for retention scores are: (For, Contextual Interference, Tolerance= .98, VIF =1.02. For, Cognitive Flexibility, Tolerance =.99, VIF = 1.00 and for Time, Tolerance = .98, VIF= 1.01).

**Independent Errors.** This assumption states that the residuals are not correlated. To test this assumption, Durbin-Watson statistic was calculated for both the learning performance and retention scores. The residuals are considered uncorrelated if the Durbin-Watson statistic is approximately 2 (Montgomery & Peck, 1982). The data met the assumption of independent errors for learning performance (Durbin-Watson value = 2.12) and retention scores (Durbin-Watson value = 2.35).

**Non-Zero Variances.** The data also met the assumption of non-zero variances for both learning performance scores (Total Performance, Variance= 1.84, Cognitive flexibility, Variance = 564.5; Performance time, Variance = 115679.6) and for retention scores (Total Retention, Variance= 2.32, Cognitive flexibility, Variance = 564.5; Retention time, Variance = 81054.4).

**Random Normally Distributed Errors, Homoscedasticity and Linearity.** The histogram of standardized residuals for both the learning performance and retention scores (presented in figures 4.9 and 4.10) indicated that the data contained approximately normally distributed errors. These figures also contain the approximately normal P-P plot of standardized residual, for both learning and retention scores.
Figure 4.9. Distributions of Standardized Residual for the Learning Performance Scores

Figure 4.10. Distributions of Standardized Residuals for the Retention Scores
The scatterplots of standardized residuals (figure 4.11) showed that the data are meeting the assumptions of homogeneity of variance and linearity. The spread of the data is due to the scores obtained in the simulated troubleshooting task.

![Figure 4.11. Scatter plots of Standardized Residual for Learning performance and Retention Scores](image)

Multiple regression analysis was done to find out the main effect of, Contextual Interference conditions (CI), cognitive flexibility (CF) and Time on Task on learners learning performance and retention. The bivariate correlation matrix presented in table 4.6 and the scatterplots figures 4.12 and 4.13 between predictors (TOT, CF & CI groups) and the outcomes variables (performance and retention) supports the choice of multiple regression as the statistical method for detecting the main effects in this study.
Table 4.6. Bivariate Correlations among Learning Performance, Retention, % Perseverative Error, Performance Time and Retention Time

<table>
<thead>
<tr>
<th>Subscale</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Learning performance</td>
<td>-</td>
<td>.633</td>
<td>.183</td>
<td>-.483</td>
<td>-.497</td>
</tr>
<tr>
<td>2. Retention</td>
<td>-</td>
<td>.071</td>
<td>-.352*</td>
<td>-.550</td>
<td></td>
</tr>
<tr>
<td>3. CF</td>
<td>-</td>
<td>.009</td>
<td>-.033</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Performance TOT</td>
<td>-</td>
<td>.593</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. Retention TOT</td>
<td>-</td>
<td>-</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Correlation is significant at the 0.05 level

Figure: 4.12. Scatter plots for Predictors (CF and TOT) and Outcome Variable (Learning Performance)

Interaction between the Predictors

To begin with, I wanted to find whether there is an interaction between the predictors, CI groups, TOT and CF. The interaction term was created and explored in SPSS. There was no
statistically significant interaction for either performance \((t = 1.433, p = .159)\) or for the retention \((t = .695, p = .491)\).

Figure 4.13. Scatter plots for Predictors (CF and TOT) and Outcome Variable (Retention)

CF and TOT were the continuous variables, but CI is a categorical variable with 2 levels, (block and random). I was interested in finding out whether the mean scores of CI groups are significantly different from each other. Therefore, regression analysis was conducted with dummy variables; block CI was the reference group and coded as 0.

**Regression for Learning Performance Scores**

For learning performance, as one of the outcome variables, participant’s scores ranged from 0 to 4, which mean no correct diagnosis to 4 correct diagnoses of the simulated problems. I found that CF, CI groups and TOT explains a significant amount of variance in the learning performance scores of the participants \((F (3, 45) = 5.868, p < .05, R^2 = .28)\). Review of estimated regression coefficients revealed that, the slope of CI groups was not statistically different from each other \((Beta = -.310, t (45) = -.896)\). Main effect of CF was insignificant \((Beta = .193, t (45) = .896)\).
= 1.523). However TOT has significant main effect on the learning performance scores \((Beta = -0.505, t(45) = -3.933, p <.05)\), which suggests that with one unit increase in time, the predicted performance score decreases by 0.016, holding constant CF. Table 4.7 presents the results of the regression.

### Table 4.7. Regression Statistics for Learning Performance Scores

<table>
<thead>
<tr>
<th>Model</th>
<th>B</th>
<th>Std. Error</th>
<th>Beta</th>
<th>t</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>CF</td>
<td>0.011</td>
<td>0.007</td>
<td>0.193</td>
<td>1.523</td>
<td>0.135</td>
</tr>
<tr>
<td>Performance TOT</td>
<td>-0.016</td>
<td>0.004</td>
<td>-0.505</td>
<td>-3.933</td>
<td>0.000</td>
</tr>
<tr>
<td>CI</td>
<td>-0.310</td>
<td>0.346</td>
<td>-0.115</td>
<td>-0.896</td>
<td>0.375</td>
</tr>
</tbody>
</table>

#### Regression for Retention Scores

For the other outcome variable, retention; participant’s scores ranged from 0 to 5 representing no correct diagnosis for the simulative problem to 5 correct diagnoses. The results of the regression are presented in the table 4.8.

### Table 4.8. Regression Statistics for Retention Scores

<table>
<thead>
<tr>
<th>Model</th>
<th>B</th>
<th>Std. Error</th>
<th>Beta</th>
<th>t</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>CF</td>
<td>0.003</td>
<td>0.008</td>
<td>0.048</td>
<td>0.393</td>
<td>0.696</td>
</tr>
<tr>
<td>Retention TOT</td>
<td>-0.023</td>
<td>0.005</td>
<td>-0.533</td>
<td>-4.292</td>
<td>0.000</td>
</tr>
<tr>
<td>CI</td>
<td>0.366</td>
<td>0.374</td>
<td>0.121</td>
<td>0.977</td>
<td>0.334</td>
</tr>
</tbody>
</table>

In this regression, I found that CF, CI groups and TOT explains a significant amount of variance in the retention scores of the participants as well \((F(3, 45) = 7.061, p < .05, R^2 = .32)\). Review of estimated regression coefficients revealed that, the slope of CI groups was not
statistically different from each other \( \beta = .167, t (45) = 1.550 \). Main effect of CF was insignificant \( \beta = .048, t (45) = .393 \). However TOT has significant main effect on the performance scores \( \beta = -.533, t (45) = -4.292, p < .05 \), which suggests that with one unit increase in time, the predicted retention score decreases by 0.023, holding constant CF.

**Exploratory Analysis**

In order to explore the data and its pattern, I tested a new model, where the retention scores were regressed with learning performance scores, along with other predictors (CF, CI and TOT). The results of regression are presented in the table 4.9.

<table>
<thead>
<tr>
<th>Model</th>
<th>B</th>
<th>Std. Error</th>
<th>Beta</th>
<th>t</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>CF</td>
<td>-.002</td>
<td>.007</td>
<td>-.038</td>
<td>-.346</td>
<td>.731</td>
</tr>
<tr>
<td>Retention TOT</td>
<td>-.012</td>
<td>.005</td>
<td>-.279</td>
<td>-2.237</td>
<td>.030</td>
</tr>
<tr>
<td>CI</td>
<td>.505</td>
<td>.326</td>
<td>.167</td>
<td>1.550</td>
<td>.128</td>
</tr>
<tr>
<td>Learning performance</td>
<td>.566</td>
<td>.141</td>
<td>.504</td>
<td>4.014</td>
<td>.000</td>
</tr>
</tbody>
</table>

In this exploratory analysis, the result indicated that CF, TOT, CI and performance scores explains 50% variance in the retention scores \( F (4, 44) = 11.102 p < .05, R^2 = .50 \). Review of estimated regression coefficients showed the main effect of performance \( \beta = .566, t (44) = 4.014, p < .05 \) and TOT \( \beta = -.279, t (44) = -2.237, p < .05 \).
**Paired Sample t-test**

In order to compare the differences in learning performance and retention scores of the two CI groups (Block and Random), I conducted a paired sample t-test. Table 4.10 shows the results of the analysis. There is a significant difference between the scores of learning performance and retention in the random CI group \((t (23) = 2.942, p = .007)\). Figure 4.14 presents the estimated marginal means.

<table>
<thead>
<tr>
<th>CI</th>
<th>Mean</th>
<th>Std. Deviation</th>
<th>t-test</th>
<th>df</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Random Pair: Retention: Performance</td>
<td>.792</td>
<td>1.318</td>
<td>2.942</td>
<td>23</td>
<td>.007</td>
</tr>
<tr>
<td>Block Pair: Retention: Performance</td>
<td>.160</td>
<td>1.106</td>
<td>.723</td>
<td>24</td>
<td>.476</td>
</tr>
</tbody>
</table>

Figure 4.14. Estimated Marginal Means of Block and Random CI
Effect Size

To calculate the strength of the relationship between two groups of participants (block and random) in terms of CI conditions. I calculated the effect size for the paired sample t-test. Using the following formula:

Cohen's $d = M_1 - M_2 / \sqrt{[(s_1^2 + s_2^2) / 2]} = .792 - .160 / \sqrt{[(1.31)^2 + (1.10)^2] / 2} = .522$

It resulted in the effect size of Cohen’s $d = .522$ which is categorized between medium to large effect (Cohen, 1988).
CHAPTER 5

DISCUSSION AND CONCLUSION

This study investigated the effects of contextual interference, cognitive flexibility and time-on-task on students’ learning performance and retention in a simulated troubleshooting environment. The study used an experimental design with two interference conditions based on the variability of the task: block and random. Participants were randomly divided into two interference conditions. The guiding questions were:

1. What is the effect of cognitive flexibility on students’ learning performance and retention while troubleshooting a problem-solving task in a simulated environment?
2. What is the effect of contextual interference on students’ learning performance and retention while troubleshooting a problem-solving task in a simulated environment?
3. What is the relationship of the time taken to troubleshoot a problem-solving task on students’ learning performance and retention in a simulated environment?
4. How does the interaction of cognitive flexibility, contextual interference and time taken affect student’s learning performance and retention, while troubleshooting a problem-solving task?

In order to answer these questions, quantitative data were collected on each of the following outcome measures (1) Learning performance, (2) retention. The first-time-correct (FTC) scores in the simulated troubleshooting tasks were used as measures of participants’ performance and retention.

This chapter will discuss the results of such investigations, including the limitations of the study and future research.
Findings

Cognitive Flexibility

The hypothesis that learner’s cognitive flexibility affects performance and retention was not supported. This finding might be due attributed to the mean of percentage of perseverative error, which is the measure of cognitive flexibility in the WCST. This mean was 48.96 with the standard deviation of 23.76. This suggests that most of the participants are in the mid spectrum in cognitive flexibility, which likely contributed to the little predictive power of cognitive flexibility.

The limitations of the testing instrument might also be one of the contributors to the hypothesis failure. The WCST has two termination criteria’s, 1) the completion of six categories (each sequence of 10 consecutive correct responses), or 2) all 128 cards; whichever is first. The WCST termination criteria result in differences in the number of cards provided to the participants. The number of cards tested can vary from as few as sixty-five to the full one hundred twenty-eight cards. These cutoff rules create a wide range of variability and may contribute towards the instability of the obtained scores. A confirmatory factor analytic study conducted by, Greve, Stickle, Love, Bianchini & Stanford (2005), suggested that having two discontinuation rules could result in a failure to detect some deficits in certain populations. In this study, only two of the participants completed all one hundred twenty-eight cards; the cards provided to the participants ranged from sixty-eight to the full one hundred twenty-eight.

A second possible contributor to the hypothesis failure is the inflexibility generated by the high cognitive demand of the task. Inflexibility impairs the ability to think and concentrate (King & Schaffer, 2010), and makes it difficult to handle challenges satisfactorily (Sarason,
Inflexibility also affects the limited capacity of working memory resulting in inhibited performance (Eysenck, 1992).

The overall the mean scores in the troubleshooting tasks were very low for the Learning performance (1.90) and retention (2.37) sessions. A closer look at the troubleshooting task may help in understanding the inflexibility of cognition caused by the task complexity.

The troubleshooting tasks required the participants to implement the principles and concepts learned in the instructional module. Although, the participants learned of the various problems that could occur in the system and how to solve them, they did not receive any worked examples, feedback or just in time information, other than solving two problems on their own. Helsdingen, Van Gog and van Merrienboer (2009) suggested that “when instruction in expert cognitive strategies is combined with a broad set of practice scenarios, the process of generalization of abstract representations is facilitated, leading to more cognitive flexibility and better transfer of judgment skill” (p 8). In my study, the lack of worked examples or tutored problems could have added an extra layer of complexity in troubleshooting the tasks and possibly lead to inflexibility of cognition.

**Contextual Interference**

The hypothesis that participants in the block interference condition will have better scores in the performance task, while those in the random interference condition will perform better in the retention task was not supported. There is not enough evidence to claim that the interference groups were statistically different from one other as hypothesized.

My rationale for this hypothesis was based on the evidence that, learners with the random interference would develop deeper understanding of the content, and thus gain an in-
depth knowledge because of high interference (Magill & Hall, 1990). This argument was confirmed in the study. The learners in the random interference group had significant differences in their performance and retention scores ($t(23) = 2.942, p < .05$). Thus, the high interference created due to variability of practice did help the learners in acquisition of skills at levels not observed in low contextual inference situations (Shea & Morgan, 1979). This finding is in line with Wrathall (2004), who suggests that high contextual interference instigates students to become more engaged in effortful cognitive processes, which is believed to enable them develop schemata that help them to successfully perform the learning task. Similar findings were reported in the literature, for example, Helsdingen, van Gog and van Merrienboer (2011), reported that the random interference group outperformed the block interference group in an experiment involving predictive judgement tasks.

The lack of support for this hypothesis might be due to the following reasons:

*Scoring Requirements of the Task.* The scoring was based on the first time correct responses only, although the participants were allowed multiple attempts in the allotted time. This was designed to provide the real world experience to the participants, because in the actual chemical plant there is no room for errors. This lack of getting a composite score irrespective of number of attempts likely contributed in the failure of the hypothesis.

*Experience of the Participants.* The participants in this study were freshmen in their first semester in the College of Engineering. They were the “pre-engineering” students in their first semester prior to selecting a specific engineering major. This reason, in addition to the lack of experience with simulations, and deficit of relevant instructional environment could have contributed to the results. Although all of the students had an engineering background, their level
of interest in the chemical engineering and amount of experience with the simulations was not recorded. It is difficult to judge from the data collected in the study if they had prior knowledge of problem solving within the simulative environment.

**Learning Environment.** The participants received extra credit and were also financially compensated for their participation. These conditions might have compromised the general participant attitude towards the study. In the absence of an authentic learning environment, there may have been a barrier against learners asking questions when encountering doubts, Hence, it would have been more beneficial to embed the study in a course, as a relevant assignment.

**Time on Task**

The two hypotheses speculating on the relationship of TOT were supported in the study. According to the results learners who spent less time to troubleshoot a task will have better performance was supported. Additionally, learner who spent less time to troubleshoot a task also performed better in retention task. I attribute these findings to the fact that learners who took shorter time to solve the tasked problems applied what they gained from the instructional module presented at the beginning of the experiment.

TOT had similar effect on accomplishing the retention task, where the participants who had taken shorter time demonstrated a better retention. The participants’ higher retention may be due to the in-depth knowledge of the concepts they gained during their exploration on the performance task and they were able to retrieve the compound information from instruction and their performance experience.
Interaction between CF, CI and TOT

There was no significant interaction between cognitive flexibility, contextual interference and time used on performance or retention scores. The bivariate correlation matrix also suggests that the correlation between these variables was not significant at 0.05 levels. This was due to the fact that the study refuted the hypothesis that flexibility of cognition affects learners’ performance and retention. There was also no significant group difference between the block and random interference conditions. These findings provide evidence for the insignificant interaction between the cognitive flexibility, contextual interference and time variables.

Conclusion

The mixed results of this study, also found in the literature reveal that there are still many questions to be answered in this area. There was a significant difference between the performance and retention of participants in the high interference group, but the two interference conditions were not statistically different from each other. The findings of this study failed to show an effect of cognitive flexibility on the performance and retention capabilities of the learners. However the time used on task does significantly impact the performance and retention.

The goal of the study was to explore the interplay of contextual interference and cognitive flexibility, and determine if it would impact human capabilities to learn and sustain information. Cognitive flexibility theory suggests that as a higher order of cognition, flexibility helps in advanced knowledge acquisition. To attain this flexibility; oversimplification of concepts should be avoided, schema assembly from rigidity to flexibility should be facilitated and multiple representations of the topic should be provided. The downside of this is increase in cognitive load, which hampers the learner’s concentration and ability to learn. The variability of
practice and the complex cognitive task may not assist in flexibility of the cognition, but the interference effect was significant in this study.

**Limitations**

There were many factors which may have contributed to the limited scope of this study. These factors are (1) time and financial constraints, (2) the type of instructional material and (3) participants motivation

*Time and Financial Constraints*

Given the time and financial constraints, I only created two groups (1) block and random learning groups and (2) random performance and retention groups. This resulted in an inability to test other group combinations like: (1) block performance with random retention, (2) random performance with block retention and (3) random performance with random retention. These groups would have been useful to better understand the relationships among interference and flexibility by comparing the mean differences and related analyses. Future studies with these conditions could benefit by shedding light on these groups ‘dynamics.

*Instructional Material*

The audio-visual presentation that provided instruction for working the simulation may have been insufficient and also a factor limiting the results of the study. The presentation was developed according to the principles of learning and instruction. Worked examples and tutored problems representative of the learners’ future troubleshooting tasks should be included in the material. Also, the amount of time the participants had to complete the tasks may not have been significant. This may have contributed to the cognitive load and affected their performance and retention.
**Learners Motivation**

This study was not implemented as part of a regular engineering course, but in a supplementary campus environment. This separation may have caused the learners to question the relevance of the material, and the usefulness of preparing for the tasks in the simulated environment. Learners participated in the study were awarded with extra credit and financially compensated. Additional data collected on the motivational aspects of the learners could have helped to understand the results in a new light.

**Suggestions for Future Studies**

With an increased awareness of executive functions, such as cognitive flexibility and their role in knowledge acquisition and in depth understanding of the concept, studies that focus on the relationships of learning and flexibility are in demand. Although a direct impact of flexibility was found insignificant in this study, other factors like learner motivation, instrument limitations, an authentic environment and the improvement of instructional materials, could be modified in future research, in this area.

The findings of this study have several implications for further research. Future studies might focus on learners experience and prior knowledge and use a sample for comparing the experts with the novice learners. In order to raise and produce better results on the learning tasks any information on participant’s motivation could help in situating the learning task in the simulated environment. One key implication for instruction is the usefulness of the random interference condition in improving retention of knowledge which is also supported by the literature. Research considering these implications will provide educators to optimally use the simulative technology in learning and instruction.
In conclusion, this study rejected the assumption that cognitive flexibility affects learner’s learning performance and retention in a simulated troubleshooting task, but it provided support for the idea that random interference creates better retention abilities. This was based on evidence showing significant differences in the performance and retention scores of the participants. These results contribute to the understanding and further development of improved simulated learning activities.
APPENDIX A

IRB APPROVAL MEMO

The Florida State University
Office of the Vice President For Research
Human Subjects Committee
Tallahassee, Florida 32306-2742
(850) 644-8673 · FAX (850) 644-4392

APPROVAL MEMORANDUM

Date: 11/4/2014

To: Rinki Suryavanshi

Address: 3302 Stone Building 1114W call St. Tallahassee, Fl, 32306-4453
Dept.: EDUCATIONAL PSYCHOLOGY AND LEARNING SYSTEMS

From: Thomas L. Jacobson, Chair

Re: Use of Human Subjects in Research
EXPLORING THE Effects of Cognitive Flexibility AND Contextual Interference on Retention and Transfer Performance in a simulated environment

The application that you submitted to this office in regard to the use of human subjects in the proposal referenced above have been reviewed by the Secretary, the Chair, and one member of the Human Subjects Committee. Your project is determined to be Expedited per per 45 CFR § 46.110(7) and has been approved by an expedited review process.

The Human Subjects Committee has not evaluated your proposal for scientific merit, except to weigh the risk to the human participants and the aspects of the proposal related to potential risk and benefit. This approval does not replace any departmental or other approvals, which may be required.

If you submitted a proposed consent form with your application, the approved stamped consent form is attached to this approval notice. Only the stamped version of the consent form may be used in recruiting research subjects.

If the project has not been completed by 11/3/2015 you must request a renewal of approval for continuation of the project. As a courtesy, a renewal notice will be sent to you prior to your expiration date; however, it is your responsibility as the Principal Investigator to timely request renewal of your approval from the Committee.

You are advised that any change in protocol for this project must be reviewed and approved by the Committee prior to implementation of the proposed change in the protocol. A protocol change/amendment form is required to be submitted for approval by the Committee. In addition, federal regulations require that the Principal Investigator promptly report, in writing any unanticipated problems or adverse events involving risks to research subjects or others.

By copy of this memorandum, the Chair of your department and/or your major professor is reminded that he/she is responsible for being informed concerning research projects involving human subjects in the department, and should review protocols as often as needed to insure that the project is being conducted in compliance with our institution and with DHHS regulations.

This institution has an Assurance on file with the Office for Human Research Protection. The Assurance Number is FWA00000168/IRBnumber IRB00000446.

Cc: Aubteen Darabi, Advisor
HSC No. 2014.13012
APPENDIX B

INFORMED CONSENT FORM

Informed Consent Form

A study of the effect of Cognitive Flexibility and Contextual Interference on Retention and Transfer of Knowledge in a simulated environment

You are invited to participate in a research that investigates the effect of cognitive flexibility and contextual interference on retention and transfer of knowledge. I, Rinki Suryavanshi, am conducting this study under the direction of Dr. Aubteen Darabi. I am a graduate student in the department of Educational Psychology and Learning Systems, College of Education. I am asking you to read this consent form and ask me any questions before you agree to participate in this study.

The objectives of this study

The purpose of this study is to investigate the effects of cognitive flexibility and contextual interference on retention and transfer performance in a simulated environment.

Procedures

To participate in this study, you will be asked to do the following. First, you will be asked to fill up a survey, which will ask for your demographic information, including your name, major, status in the program, and your knowledge and experience about the simulations. Second, you will be asked to participate in the cognitive flexibility test, where you will be asked to play a game of selecting choices based on the changing schedules of reinforcement. Third, you will be asked to participate in the simulated distillation plant as a project manager and will be given some problems related to the distillation process. The simulated distillation plant will deteriorate which would hamper the process of distillation. You will be required to identify these faults and fix them. There will be 8 such problems, and the total task will be completed within 80 minutes.

I will collect data on your responses to the survey, cognitive flexibility test, and your score in the simulation. No other personal information will be collected and used for conducting this study. You will need to sign on the consent form and give it back to me.

Risk and benefits of being in the study

The study has no anticipated risks for you. You may be able to share resources, knowledge, opinions, and aspects with others regarding some specific topics being practiced. There is no direct benefit to you in participating in the study. But active participation in this study may help you develop a deeper understanding of content learned in the course. Your participation in the simulated activities will enrich your learning experience and help in the development of skills needed for future work in the industry. This study will also provide data for the field of instructional design of simulative activities, which will benefit learners and contribute to the knowledge in this field.

HSC # 2014.13012
Confidentiality

The participants’ data is confidential to the extent allowed by law. Each participant will not be identifiable in any reports we might publish. Research records will be stored securely in UCC 4600 and only researchers of this study have access to the records. The records will be destroyed two years after this study is completed.

Voluntary Nature of the Study

Participation in this study is voluntary. Your decision of participating or not will not affect your current or future relations with the university. You can withdraw from the study at any time during the research with no effects on your participation in other program or courses. Any concerns and questions can be directed to any of the following at any time during the course of the study:

FSU Human Subjects Committee
2010 Levy Street, Research Building B, Suite 276
Tallahassee, FL 32306-2742
Tel: 850-644-7900
Email: humantissues@fsu.edu

Advisor: Aubteen Darabi
305 University Center C
FSU, Tallahassee, FL 32306
Tel: ___________
Email: ___________

Researcher: Rinki Suryavanshi
4616 University Center C
FSU, Tallahassee, FL 32306
Tel: ___________
Email: ___________

Your participation is highly appreciated.

Statement of Consent

I have read the above information; I consent to participate in the study.

Printed Name ____________________________________________

Signature ___________________________ Date ____________________

HSC # 2014.13012
APPENDIX C
LETTER OF COOPERATION FROM FAMU

Florida Agricultural and Mechanical University

Letter of Cooperation

March 24, 2015

To the institutional Review Board (IRB) at Florida State University (FSU):

This letter of cooperation is provided on behalf of Florida Agricultural & Mechanical University (FAMU) with regard to the research study titled, "EXPLORING THE Effects of Cognitive Flexibility AND Contextual Interference on Retention and Transfer Performance in a simulated environment" Aubteen Darabi, Ph.D., Associate Professor at Florida State University (FSU), is the Principal Investigator (PI), and Ms. Rinki Suryavanshi, Doctoral Student (FSU) will serve as the Co-Principal Investigator (Co-P).

As the President-designee at FAMU, I or my designee understand FAMU's involvement to consist of: approximately 100 students enrolled in an undergraduate course in the engineering and chemistry department will be invited to participate. The students are required to complete multiple assignments in their regular classes: one of the assignments will be substituted for the study. The RESEARCHER will send the invitation for participation in the study. IT WILL BE COMMUNICATED TO THE STUDENTS THAT PARTICIPATION IN THE STUDY IS VOLUNTARY AND THEY COULD CHOOSE TO PARTICIPATE IN THE RESEARCH OR COMPLETE THE REGULAR ASSIGNMENT. THEIR DECISION OF NON PARTICIPATION WOULD NOT AFFECT THEIR GRADES OR RELATIONSHIP WITH THE TEACHER OR THE SCHOOL. The inclusion criteria for the participants is the prior completion of a basic engineering course. All the participants will take a cognitive flexibility test prior to the intervention. Students will be randomly assigned into either high or low interference groups.

Finally, it is understood that the researcher's study will be carried out following sound ethical principles, that participant involvement in this research study is strictly voluntary, and that the researcher will provide confidentiality of research data, as described in the research protocol indicated in this letter and approved by the researcher's Institutional Review Board (IRB).

Sincerely,

[Signature]

IRB Administrator
Division of Research
Room 219 Science Research Center
1515 South Martin Luther King
Tallahassee, FL 32307-3800

AMERICAN INSTITUTE OF PLANT Teens, INC.
## APPENDIX D
### DESCRIPTION OF TROUBLESHOOTING TASKS

#### Troubleshooting Tasks

<table>
<thead>
<tr>
<th>Task Number</th>
<th>Component</th>
<th>Malfunction</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Feed Valve</td>
<td>Valve Stuck</td>
</tr>
<tr>
<td>2</td>
<td>Residue Valve</td>
<td>Valve Energy Failure</td>
</tr>
<tr>
<td>3</td>
<td>Reboiler Steam Valve</td>
<td>Valve Stuck</td>
</tr>
<tr>
<td>4</td>
<td>Distillate Valve</td>
<td>Valve Energy Failure</td>
</tr>
<tr>
<td>5</td>
<td>Level Controller 41</td>
<td>PID Random Malfunction</td>
</tr>
<tr>
<td>6</td>
<td>Flow Controller 13</td>
<td>PID Minimum Value</td>
</tr>
<tr>
<td>7</td>
<td>Level Controller 42</td>
<td>PID Random Malfunction</td>
</tr>
<tr>
<td>8</td>
<td>Flow Controller 11</td>
<td>PID Maximum Value</td>
</tr>
</tbody>
</table>

#### Sequence of Tasks

<table>
<thead>
<tr>
<th>Performance</th>
<th>Retention</th>
</tr>
</thead>
<tbody>
<tr>
<td>Block Group</td>
<td>Random Group</td>
</tr>
<tr>
<td>Task 1</td>
<td>Task 2</td>
</tr>
<tr>
<td>Task 2</td>
<td>Task 8</td>
</tr>
<tr>
<td>Task 3</td>
<td>Task 6</td>
</tr>
<tr>
<td>Task 4</td>
<td>Task 1</td>
</tr>
<tr>
<td>Task 5</td>
<td>Task 5</td>
</tr>
<tr>
<td>Task 6</td>
<td>Task 3</td>
</tr>
<tr>
<td>Task 7</td>
<td>Task 4</td>
</tr>
<tr>
<td>Task 8</td>
<td>Task 7</td>
</tr>
</tbody>
</table>
REFERENCES


BIOGRAPHICAL SKETCH

Rinki Suryavanshi, joined the Instructional Systems and Learning Technology program at The Florida State University in Fall 2010. She received her Master’s degree in Zoology from Maharaj Sayajirao University, in India. She also has double bachelors from the same university; one in Zoology and another in Education. Rinki is highly interested in human performance technology and evaluation of program with an instructional design perspective. She utilizes her skills and knowledge of measurement and statistics in conducting the research studies and pursues the innovative approaches and design principles in creating online and face to face instructional modules.

Rinki is an active academician; she has presented in many conferences, conducted research studies, published in peer-reviewed journals and also served as a reviewer for empirical journals in the field of instructional systems. She served as a treasurer of the Instructional Systems Students’ Association for two consecutive years. She is been awarded for her excellent performance in academics as well as for student services. She was in the Dean’s list for a perfect GPA. Received an award for Outstanding International Student in the Instructional Systems Program (2012, Florida State University). She was nominated for excellent Students Services, and also nominated for Excellent Performance by a Doctoral Student at the Program of Instructional systems.

Rinki has worked as a graduate research assistant at the Learning Systems Institute at FSU since she joined the Instructional Systems program. She worked on creating and evaluating student tutorials from K-12 based on the Florida State Standards. She is a talented, self-motivated professional with a bright future ahead of her!!