

Summer 2017

# Learning While Using an Instructional Simulation

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Batool, Tayyaba. "Learning While Using an Instructional Simulation" (2017). Doctor of Philosophy (PhD), dissertation, STEM and Professional Studies, Old Dominion University, DOI: 10.25777/3ry7-xp36  
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**LEARNING WHILE USING AN INSTRUCTIONAL SIMULATION**

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A Dissertation Submitted to the Faculty of Old Dominion University in Partial  
Fulfillment of the Requirements for the Degree of

**DOCTOR OF PHILOSOPHY**

**EDUCATION**

**OLD DOMINION UNIVERSITY**

August 2017

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## **ABSTRACT**

### **LEARNING WHILE USING AN INSTRUCTIONAL SIMULATION**

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Learner control is thought to be valuable by some scholars who believe that it allows learners to adapt instructions to their needs while reducing cognitive load (Mayer & Moreno, 2003). Although learner control offers some advantages to the learner, the importance of an instructor cannot be denied. In instructor-controlled settings the instructor provides guidance to the learners. Direct instructional guidance provides information to the learner that explains the concepts and procedures that are to be learned along with the instructional strategy support that is compatible with human cognitive architecture (Kirschner, Sweller, & Clark, 2006). This study compared the effects of learner-controlled simulation to instructor-guided presentation of an instructional simulation. Outcome variables were achievement, cognitive load, time-on-task, instructional efficiency, perceptions of learner control, and attitude for future use.

Results of the study indicated no significant differences between the learner-controlled and instructor-guided treatments for achievement, cognitive load, or instructional efficiency. A significant difference was found between the treatments for time-on-task and the perception of learner control where participants in the learner-controlled group spent significantly less time completing the instruction and reported significantly higher learner-control than those in the instructor guidance with activity group.

*Keywords:* instructional simulations, cognitive load, learner control, instructional efficiency, achievement, mental effort, Nearpod.

## **Explanation/Definitions of terms used in text**

**Problem-based learning (PBL):** “A constructive pedagogical approach in which students work together to find solutions to a complex problem” (Ferreira & Trudel, 2012).

**Simulation:** Pedagogically-mediated activities used to reflect the dynamism of real-life events, processes, or phenomena.

**Instructional simulation:** “A program that incorporates a model the learners can manipulate, and its learning objectives include understanding the model” (Alessi, 2000, p.175).

**Fidelity (of a simulation):** Fidelity refers to how closely a simulation imitates reality (Alessi, 1988). High fidelity means that the simulation resembles reality more closely as compared to a low-fidelity simulation in which some elements of reality are removed.

**Transfer of learning:** A student being able to apply the knowledge gained to a new situation (Alessi, 1988).

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This dissertation is dedicated to my parents who guided me and strived hard to provide me the best education they could. I also dedicate it to my dear husband without whose support and patience I would not have been able to travel the journey of my higher education.

## **ACKNOWLEDGEMENTS**

I thank my advisor, Dr. Ginger Watson, for her attention and time throughout my program. She has been very considerate about my timeline and program requirements and had to spare time from her busy schedule to help me out and meet my deadlines. I will always remember and value her kindness and time she gave me.

I am also thankful to my committee members, Dr. Crompton and Dr. Enderson. Dr. Crompton guided me through what technology to use during my work along with providing great feedback on my drafts. I am grateful to Dr. Enderson's time and feedback despite being very busy with her students working in the field.

I would not have made through my journey without my family. My dad who always encouraged me and my mom who sacrificed so much in life for me and my siblings. My brothers and sisters who, without their support, I may not have been successful.

In particular, I am so very grateful to my husband. His emotional support and encouragement is unmatched.

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## CHAPTER I

### LEARNING WHILE USING AN INSTRUCTIONAL SIMULATION

#### Introduction

For several decades, there has been a worldwide trend towards promoting the use of technology in the processes of teaching and learning. Governments spend handsome amounts of money in support of technology in education because they believe that technology can have a positive impact on learning of the students. According to a report by the British Broadcast system (BBC) the annual global spending on educational technology was worth £17.5bn (\$22.79 bn). In the UK alone the expenditure is £900m (\$1.17bn) and schools in the United Kingdom had 1.3m desktop computers, 840,000 laptops, and 730,000 tablets (Coughlan, 2015). Turgut (2012) noted that although a variety of technologies have made their way to classrooms, computers are still the most commonly used in schools. They provide affordable, individualized learning environments in many forms like tutorials, simulations and gaming. Mayer and Moreno (2002) assert that compared to the traditional book-based learning environments, computer-based learning is a powerful source that has not been fully utilized. Because computers are so widely used in educational settings, the following questions are important to consider: How are computers used most effectively in the classroom? Are the computers just handed to the learners for them to explore on their own (the constructive approach), or do instructors provide guidance as learners use them to achieve the desired objectives?

Learner control within computer-based learning environments is a variable that is often discussed and researched as a method to focus and guide students who are using computers. Learner control is valuable to learners as they adapt instruction to their needs while reducing cognitive load (Mayer & Moreno, 2003). Kay (2001) noted that there is a need to support

lifelong learning because the world changes so quickly that many of the facts that students learn in their formal education may be superseded by the time s/he completes schooling. This increases the need for learners to be equipped with metacognitive skills that will enable them to manage their long-term learning. Kay also warned of the potential risks of learner-control, noting that learners may sabotage the learning environment if they are given too much control over it, accidentally reducing the effectiveness of teaching, and under or over-rating themselves if asked to assess their knowledge. These risks suggest that greater choice and control may put additional load on the learner and may become a distraction from learning.

Instructor guidance is one strategy to reduce load on working memory. Ardac and Sezen (2002) considered computer-based instruction to be effective particularly when learners are provided with external guidance from their instructor. In their study, the participants who received instructor guidance exhibited more gains in both content knowledge and process skills. Instructor guidance is helpful if the educational process is to be effective, but embedding guidance in the system (adaptive guidance) can be very expensive and time consuming. Advisement or coaching has been proposed as a similar but more economical alternative to adaptive strategies (Ross, Morrison, & O'Dell, 1990). In advisement (guidance) the learners are given directions and information necessary for making decisions but are free to choose whether or how to use it (Bell & Kozlowski, 2002).

Enabling the learners to use instructional simulations is one of the many uses of computers in the classroom. Laboratory simulations in which learners perform experiments as they would in a laboratory (Alessi, 2000) such as performing a titration is a type of an instructional simulation. These simulations can provide efficient, effective and highly motivational instructions along with enhancing transfer of learning by teaching complex tasks in

an environment that resembles the real-world setting (Reigeluth & Schwartz, 1989). The simulation used for the current study is a chemistry simulation related to determining the relationship of the solute and the solvent with the molarity of substances. It is adopted from Physics Education Technology or PhET Colorado simulations (<http://phet.colorado.edu>). These simulations are free and easily accessible. The PhET project (<http://phet.colorado.edu>) has developed hundreds of interactive simulations related to various science courses like physics, chemistry, biology, earth science, and mathematics. The simulations are also available for different grade levels along with the translated versions in almost all languages of the world. These simulations run through standard Web browsers (Weiman, Adams, & Perkins, 2008) on different devices like iPads or tablets, chrome books, and desktop computers. They can be integrated into a lecture, as homework assignment (Weiman, Adams, & Perkins, 2008) or as a drill or practice exercise to learn a topic.

Learner control in simulations has rarely been studied and needs to be researched to determine how simulations should be used and to what extent the learners should be provided control over their learning in this environment. The present study compares the effects of learner controlled and teacher-guided presentation of an instructional simulation, on the achievement, cognitive load, time-on-task, instructional efficiency, and attitude of learners' future use.

The theoretical framework for the present study is based on two major ideas that Mayer and colleagues present about learning and learner control; the first one from Mayer and Chandler (2001) the other one from Mayer and Moreno (2002). The first research study investigated learner control. In two experiments, the researchers provided two presentations of narrated animations to two groups of students. In the first experiment, the first group received a presentation in which the participants had control over the pace of the animation. This was

followed by a presentation of the same narration with normal speed. The other group was provided with the same presentation but the narrated animation at regular (normal) speed was provided first followed by the learner paced presentation. In this experiment, the group that received the learner paced presentation first, outperformed the other group in transfer test but not on retention test.

In the second experiment, one group was provided learner control across two narrated presentations of the same material while the second group did not have any control in either of the narrated animations. In both experiments the groups that received learner control before the normal speed (part-whole) presentation outperformed the group that received the learner paced (part) presentation after the normal paced (whole) presentation. Similarly, in the second experiment, the group that was given part-part presentation performed better on the transfer test as compared to the group that was given normal paced (whole-whole) presentations.

In the second study Mayer and Moreno (2002) presented a cognitive load theory of multimedia learning with the help of previous research they conducted with their colleagues. The researchers derived and tested principles of instructional design for fostering multimedia learning. Five aids of computer-based multimedia learning provided in the article are described by the following:

1. Multimedia aids: learners understand better when they are provided words and pictures rather than words alone.
2. Contiguity aids: instead of providing animation and narration successively they should be provided simultaneously.
3. Coherence aids: unnecessary sounds and words should be eliminated from the presentation for the learners to have deep understanding.

4. Modality aids: for deeper understanding, it is better for students to have narration and animation instead of written text and animation.
  5. Redundancy aids: on-screen text, narration, and animation overload the working memory of the learner so it is advisable to provide only narration and animation.
- According to the authors these different factors might aid to prevent visual working memory from being overloaded.

These points should be kept in mind because according to the cognitive load theory, working memory can process only a few elements at a time (Mayer and Moreno, 2002).

The above-mentioned studies (Mayer and Chandler, 2001; Mayer and Moreno, 2002) were used as the theoretical framework of the current study because they provide a comprehensive understanding of: 1) how multimedia learning works and 2) how the effect of learner control on learning can be studied. The treatments of the current study differ slightly from the above research, yet the basic elements are the same. In the current study, the learner-control group was provided full control over the simulation, but there was no narration (slight difference from the Mayer & Chandler study, they provided narration to all the groups). The other group that was guided by the instructor, such that they were provided simulation and narration simultaneously, but they had no control over the presentation.

The five aids of the Mayer and Moreno study were also addressed in the present study. The instructor-guided group was provided narration with the simulation (multimedia aid) to determine the difference between the learner-control group that was provided the simulation without any narration. Secondly, instead of providing simulation and narration successively, they were provided simultaneously (contiguity aid). Third, there were no sounds or unnecessary words in the simulation (coherence aid) and instead of written text and animation the simulation



contained animation and narration (modality aid). Lastly, only animation and narration was provided in the simulation instead of written text, words, and animation to avoid redundancy (redundancy aid).

The above-mentioned two studies were selected because the intention was to determine the difference between the learner control and instructor guidance which is very similar to the Mayer & Moreno study. Because the study included a simulation, the principles of multimedia learning (five aids) suggested in the second study were used to prepare effective and engaging multimedia presentations used in the treatments of the current study.

The two pieces are important to the field because the first study provides research related to self-paced (learner control) compared to normal paced (system or instructor control) instruction. The other study provides a framework to use multimedia in the classroom which is considered very important in this era of technology and multimedia usage in the classroom.

The following hypotheses and research questions were planned to be addressed by the current study:

H1: Post-test scores for the instructor guidance with activity group will be higher than the learner-control group.

H2: Instructor guidance with activity will lead to decreased levels of cognitive load.

RQ1: Which of the two strategies, instructor guidance with activity or learner control, is more efficient in terms of time spent?

RQ2: Will the instructor guidance with activity strategy take more time than learner control?

RQ3: What is the effect of learner control compared to the instructor guidance with activity approach on perceived learner control?

RQ4: What is the impact of learner control on the willingness of participants to adopt instructional simulations in their future classroom as teachers?

## CHAPTER II

### LITERATURE REVIEW

#### **Instructional Simulations**

Simulations according to Wright-Maley (2015) are, “pedagogically mediated activities used to reflect the dynamism of real life events, processes, or phenomena” (p. 8). Thurman (1993) is of the point of view that instructional simulations should have realistic settings in which learners are: provided with a problem, conducting an inquiry, making decisions and taking actions, and receiving information about the ways in which the situation evolves and changes in response to their manipulations. According to Alessi (2000) an instructional simulation is “a program that incorporates a model the learners can manipulate, and its learning objectives include understanding the model” (p.175). Instructional simulations provide a powerful medium for learners to interact with models of the phenomenon being investigated and ultimately to develop their own mental models to support problem-solving and reasoning (Alessi & Trollip, 2001). Alessi and Trollip (2001) pointed out four advantages of instructional simulation compared to more traditional models and media: motivation, transfer of learning, efficiency, and flexibility.

Transfer of learning refers to the applicability of learned information in the real world. Simulations tend to lead to more transfer of learning as they provide a hands-on experience through the manipulation of a model. Alessi and Trollip (2001) compared the use of a rose gardening simulation to reading a book on the same topic. In the rose gardening simulation, a learner could manipulate soil acidity, water the flowers and perform other activities related to growing plants. The hands-on nature of the learning experience led to better memorization and both near and far transfer of learning when compared to simply reading a book. Norman et al.,

(2012) also reported similar findings regarding instructional simulations in their research, though there was no significant advantage of high fidelity simulation over that with low fidelity. Both participant groups who received instructions with high and low fidelity simulations showed more consistent improvement in performance than the control groups in the study. The present study was conducted with the belief that instructor guidance with activity leads to greater learning transfer in a simulation environment as compared to the learner-controlled group.

Although simulations do not guarantee time efficiency, there is evidence that they do foster it if they are well-designed (Alessi & Trollip, 2001). It is considered that the instructor guidance with activity strategy will be more efficient as participants are more likely to do exactly what an instructor tells them and remain focused, in contrast to the learner-controlled group, in which the participants may be more easily distracted.

### **Learner Control**

Learner control refers to the degree of control learners might exert on their learning (Kraiger & Jerden, 2007). This control may be on time, pace, or order of instructions. Bell & Kozlowski (2002) maintained that supplementing learner control with adaptive guidance may help learners make better decisions and obtain positive results on learning outcomes. Adaptive guidance is expensive and hard to implement, so in this study, instructor guidance and selective advisement were used instead to guide the learners and keep them on task (Ross, Morrison, & O'Dell, 1990). Based on information from the relevant literature, the researcher hypothesized that the participants would be able to use learner control more efficiently with these supports as they would be able to reflect on the degree of their understanding. Rather than relying on mere advisement, the learners were asked to work on an activity and explain how they came up with the answer they provided using the generative strategy for deeper processing and understanding

(Wittrock, 1978, 1990). Learners were asked to provide an explanation of how they derived a certain answer because understanding can become more precise through editing, revising, and generating through writing (Wittrock, 1990).

Learner control with guidance is a strategy in which the instructor directs the attention of the learners towards the core elements of the task while limiting their choices (Kanar & Bell, 2013). Providing information that explains the concepts and procedures to be learned along with a learning strategy support that is compatible with human cognitive architecture is known as direct instructional guidance (Kirschner, Sweller, & Clark, 2006). Mayer (2004) asserted that guided instruction ensures that learners are in contact with the material to be learned. This supports the cognitive processes required for learning. On the other hand, learner control without guidance allows learners to make choices of their own, or make decisions related to the pace, time, or order of instruction. The instructor does not provide any form of guidance to them. Some researchers like Singhanayok and Hooper (1998) argued that learners are more actively involved in learning and may invest more mental effort when they can make decisions on their own. Others, such as Bell and Kozlowski (2002), have reported that learner control (without guidance) is an ineffective instructional strategy, especially when dealing with complex tasks.

Kirschner, Sweller, and Clark (2006) reported in their study that guidance is an essential element of teaching, especially when learners are novices. They contended that unguided instruction is less effective and that there is evidence that it may lead to negative results when learners acquire misconceptions or disorganized knowledge. They believed that the free exploration of highly complex environments might lead to a heavy working memory load, which is hazardous to learning. This situation is problematic in the case of unguided learning because the working memory resources are being used for activities that are unrelated to learning.

Another point that Kirschner, Sweller, and Clark (2006) and Clark, Kirschner, and Sweller (2012) made is that unguided approaches like pure discovery and problem-based learning are inefficient because novices try to search in their long-term memories for solutions to problems that they have no prior knowledge of.

As a rebuttal to Kirschner et al. (2006), Schmidt et al. (2006) and Hmelo-silver, Duncan, and Chin (2006) proposed that problem-based (PBL) and inquiry-based learning are not at all unguided, arguing that scaffolding is provided in both approaches. They maintained that the seven elements in the PBL curriculum allow for flexible adaptation of guidance and management of cognitive load. This adds support in favor of guided learning because it is more congruent with cognitive architecture and works in accordance with the cognitive load theory.

Evidence from controlled experimental studies (Clark, Kirschner, & Sweller, 2012) are in support of fully-guided instruction (Arrastia et. al., 2014; Baroody, Purpura, Eiland, & Reid, 2014; Fathurrohman, Porter, Worthy, 2014; Gunn, & Pomahac, 2015; Holmes et al., 2014; Kim, 2013; Luo, 2015; Roll et al., 2012). Mayer (2004) examined the studies conducted from the 1950s to the late and 1980s related to pure discovery and concluded that it would be a mistake to revive pure discovery as an instructional method. It did not work in those three decades, and there are little chances to believe that it may work in the current era. Clark, Kirschner, & Sweller (2012) are of the point of view that when dealing with information, learners should be clearly shown what and how to do something or to reach at a solution. Partial guidance during instruction is significantly less effective as compared to full guidance especially for novice learners (Clark, Kirschner, & Sweller 2012). This is because the only resource novices have at hand to solve a given problem is their working memory. On the other hand, experts utilize both working memory and the knowledge stored in the long-term memory. Therefore, experts or

learners with prior knowledge require minimal guidance for whom benefits of guided instruction are reversed and even becomes detrimental by the expertise reversal effect (Oksa, Kalyuga, & Chandler, 2008). Still, in another study, it was reported that the guided procedure led to a pessimistic self-evaluation of learning outcomes (Stark, Gruber, Renkl, & Mandl, 1998).

In a study conducted by Kelly, Hager, and Gallagher (2014), students were asked to rate benefits of simulation components. The researchers found out that *facilitated debriefing*, *post simulation reflection*, and *guidance by the academic* received the highest rankings. These results show that the students were more comfortable and learned more when they received guidance while using a simulation.

To prove that computer-based instruction is more effective than traditional instruction, Ardac and Sezen (2002) examined the effect of guided and unguided computer-based instruction in comparison to traditional instruction in a chemistry classroom. The results were in favor of their thesis. They also reported that the effectiveness of computer-based instruction increases when learning is supported with instructor-directed guidance. Support refers to help provided to learners in addition to intrinsic feedback within the simulation. This help can be in the form of a guide, a manual, or a handbook for the learner or the teacher. In the current study, an activity that asked learners to answer questions as they worked with the simulation was used as a support.

### **Cognitive Load**

Cognitive load refers to the processing demands put on the working memory at any specific time. Cognitive load theory contends that short-term memory has a limited capacity when dealing with complex problems (van Merriënboer & Sweller, 2005). Initially, the cognitive load was divided into two categories: intrinsic, and extraneous. Intrinsic cognitive load

is inherent in the instruction. This type of cognitive load cannot be altered by instructional interventions because it is determined by the interaction between the nature of the materials being learned and the expertise of the learner (van Merriënboer & Sweller, 2005). It depends on the number of elements that need to be processed in the working memory, which in turn depends on the extent of element interactivity of materials or tasks that are to be learned. Materials with high element interactivity are difficult to learn. The only way to make them understandable is through creating cognitive schemata or mental models that incorporate the interacting elements.

On the other hand, the extraneous load is not necessary for learning and can be altered by instructional intervention. Extraneous cognitive load depends on the way the instruction is presented it can be reduced by modifying the manner of presentation (Leahy, Sweller, 2011). Intrinsic, extraneous, and germane cognitive loads are additive, which means that if learning is to occur, the total load should not exceed the capacity of the working memory (Kirshner, Kirshner, & Paas, (2008). If both the intrinsic and the extraneous cognitive load are high, learning will be low. Conversely, if the intrinsic cognitive load is low, then a greater extraneous load due to poorly designed instruction will not have as much of a negative effect on learning because the overall cognitive load would remain within working memory limits.

According to van Merriënboer and Sweller (2005), auditory and visual working memories are partially independent. If multiple sources of information (multiple representations) required for understanding are presented only in visual form, they are more likely to overload the visual processor than if the information is presented both in audio and visual (spoken and written) form. In the latter scenario, some of the load is shifted to the auditory processor (Mousavi et. al., 1995).



Germane cognitive load relates to the degree of variability in a presented problem, which influences learners' abilities to identify the similar or relevant features of the problem and distinguish them from the non-relevant ones. This process is required for the schema construction and automation that the learning process requires. An increase in germane cognitive load means an increase in an effort to create schemata for effective learning. When learners are provided guidance while using simulations, they are more likely to exert effort on learning required material instead of expending energy on the unnecessary material, which may deplete their cognitive resources (Kanar & Bell, 2013). Yao and Gill (2009) reported similar findings in their study, in which different annotations were presented to college students. This work found that learner control and cognitive load are negatively related. This means that the higher the learner control, the lower the germane cognitive load, which means that the effort required for learning was lessened as the students used their memory resources for unrelated activities and materials.

Many early research efforts were devoted to finding instructional formats that reduce extraneous cognitive load (van Gog & Paas, 2008). Research efforts have also been directed towards identifying instructional techniques that stimulate learners to invest cognitive resources in activities relevant to learning and also increase the germane cognitive load. Examples of strategies that increase germane cognitive load include self-explanation activities and exercises. Lin and Atkinson (2013) considered that prompting learners to self-explain engages them in cognitive processes to construct mental models (schemas), which foster germane cognitive load. This is because the learners need to exert more effort while explaining.

**Cognitive load and simulations.** Instructional simulations can be considered in line with cognitive load theory, as they are interactive, relate to real problems, and lead the learner

from simple to complex. Alessi and Trollip (2001) contend that simulations can be more conducive to learning compared to some real-life situations because they simplify reality. It can be inferred that by “simplification” the authors mean that certain distracters that the learners might have faced in real life are removed. This implies that intrinsic cognitive load is controlled here, as some interactive elements are removed.

Several studies have reported on how to optimize cognitive load in multimedia, especially in simulations (Lee, Plass, Homer, 2006; Mayer & Moreno, 2010; Mayer & Moreno, 2002; Moreno, 2004) and research suggests a positive correlation between the effective use of instructional simulations and student achievement (Khan, 2011). Similarly, some studies investigated the effect and use of simulation in instructional settings (Kester et al., 2005; Khan, 2011; Teoh, 2011), yet the number of studies investigating the use of simulations by teachers is under-reported and under-investigated. This presents potential issues because it is advantageous to know how teachers benefit and respond to the use of simulations in classrooms, what plans they may have for using them in the future, their perceptions of how useful and how easy they are to use, and their effectiveness in integration simulations for learning.

**Measurement of cognitive load.** There are several measures that assess cognitive load. They can either be subjective or objective. Of the subjective measures, the two most prominent ones are the NASA-TLX developed by Hart and Staveland (1988) and the 9-point Likert-type scale developed by Paas (1992). Though the NASA-TLX has been used in cognitive load research yet, it measures task load on several dimensions including performance; effort; frustration; and mental, physical, and temporal demands. It is a multidimensional scale, so it is normally administered only once at the end of the learning or testing phase. The 9-point symmetrical scale presents participants with one item on which they rate their mental effort on a

numerical value (van Gog & Paas, 2008). It is used by participants to report the mental effort that they exerted while learning or working on certain tasks. It can also be used for multiple measurements during an experiment, as is done in this study— a single measurement was obtained after each question in the post-test. While explaining why not to ask learners to report the difficulty level experienced while using the adapted version of the Paas scale, van Gog and Paas stated that difficulty and effort are two different things. Therefore, asking learners to rate difficulty level and mental effort requires two different questions. It may occur that a learner loses the motivation to exert effort if he/she perceives a task to be too difficult. Also, invested mental effort pertains to a process and will involve more aspects than only the task itself, whereas the task difficulty is related only to the task. Therefore, the measure that asks for invested mental effort and the one that asks for difficulty level will have a very different efficiency outcome. Whether objective or subjective, all cognitive load measures provide indications of cognitive load as a whole. They do not deal individually with any of its constituents: intrinsic, extraneous, or germane cognitive load.

### **Instructional Efficiency**

When it comes to instructional strategies, educators tend to select the most efficient one. Instructional efficiency is defined as teaching and managing a classroom in a way that yields desired results while using minimum effort, time, and resources normally required (Konrad, Helf, Joseph, 2011). The best rule for teachers to follow when choosing between two strategies that yield the same results in the form of scores is to select the one that requires lesser time, effort, and is less expensive or requires fewer resources. Learner controlled, or minimally guided instructional methods are less efficient as compared to fully guided methods. Because what an instructor can teach in 25-minute demonstration and discussion followed by 15-minute practice

with instructor feedback may take several class periods to learn via minimal guidance (Clark, Kirschner, & Sweller, 2012) or learner controlled method.

To measure instructional efficiency, the adopted method used in this study is adapted from Paas and van Merriënboer's (1993) study. In this method, the difference between standardized self-reported effort and the performance score of each participant is divided by the square root of two. This instructional efficiency measure has been used in several studies, but most of them used the adapted form in which the effort in the learning phase has been used instead of test phase (van Gog & Paas, 2008). Van Gog and Paas (2008) argued that the adapted version may not have posed a problem and may have provided interesting information in studies that focused on instructional formats that reduced learners' mental effort investment in processes that are not effective for learning (extraneous cognitive load). However, its use can be problematic in studies of instructional formats that seek to stimulate learners' germane cognitive load in order to foster learning. The performance score for this study was measured through the post-test, whereas the mental effort was measured through the unidimensional 9-point scale developed by Paas (1992). To state the importance of the use of the scale at the test stage instead of the learning stage, van Gog and Paas (2008) argued that research on the efficiency of learner control and controlling guidance strategies in a simulation are very scarce. Therefore, this study was intended to contribute to this aspect of the teaching and learning processes.

There are also other ways than using performance and invested effort for measuring instructional efficiency (van Gog & Paas, 2008). One such way of quantifying efficiency is to use invested time on task and performance as a parameter.

In their discussion of the importance of measuring invested mental effort in the test phase instead of the learning phase, van Gog and Paas (2008) maintained that it is unknown in the

learning phase exactly which factors have contributed to the effort that has been invested and to what extent they have done so. This is because the instructional conditions differ not only in task format but also in regard to the required cognitive processes, completion time and others.

Whereas in the test phase, all learners have identical test items and invest their effort in the solution process. This gives an equal interpretation of the invested mental effort. The same holds true for time on task. Van Gog and Paas recommended that the original measure based on mental effort ratings and the performance score in the test phase should be used instead of the adapted versions.

### **Attitude for Future Use**

According to Rogers (1983), innovation is an idea, practice, or object that is perceived as new by an individual or another unit of adoption. Diffusion, on the other hand, is “the process by which an innovation is communicated through certain channels over time among the members of a social system” (Rogers, 1983, p.5). In his innovation diffusion theory (IDT), Rogers (1962, 1983) divided individuals into five categories concerning innovation adoption. Rogers describes innovators as individuals who are venturesome and dare to adopt the new system or technology, and early adopters as respectable for adopting the new system or technology to gain respect and prestige in society. Local evangelists are those who contribute to the diffusion process, and early majority individuals are those who adopt technology deliberately without any pressure. Individuals who fall in the late majority category are those who are skeptical and reluctant to adopt technology early. The last category consists of the laggards, those who stick to traditions and are the last to adopt any innovation. Although there is a lot of research on diffusion characteristics of adopter categories, there is a lack of research on the effect of these characteristics on the rate of adoption (Sahin, 2006). The rate of adoption is

defined as the speed that the new idea spreads from one consumer to the other (Mustaffa, Ibrahim, Mahmud, Ahmad, Kee & Mahbob, 2011).

Innovation Diffusion Theory (IDT) argues that potential users decide to adopt or reject an innovation according to their beliefs about the object (Agarwal, 2000). Research on the diffusion of innovations has been widely applied in various disciplines, such as education, sociology, agriculture, marketing, medicine, and information technology and the construction sector (Rogers, 1962, 1983; Larsen, 2011).

Davis (1989) proposed a Technology Acceptance Model (TAM). According to this model, the more the users perceive a technology as useful and easy to use, the more users intend to use it (Xu & Zhang, 2011). Research indicates that the more users find that the technology is easy to use and that less effort is required to use it, the more useful it is considered because the saved effort can be utilized to achieve better job performance (Davis, 1989). Generally, TAM consists of five variables: Perceived ease of use, perceived usefulness, attitude, behavioral intention, and actual usage behavior but the first two are considered the most important ones that affect consumer acceptance of technology (Chen, Liu, & Lin, 2014).

The innovation diffusion theory and TAM are similar in some constructs and complement each other to explain the adoption of Information system/technology (IS/IT) (Lee, Hsieh, & Hsu, 2011). The complexity variable in the IDT can be considered in line with the perceived ease of use of the TAM. Similarly, perceived usefulness is similar to relative advantage in the IDT. Lee, Hsieh, & Hsu. (2011) assert that the integration of these two theories could provide a stronger model than either is in isolation. They report that past studies integrated the two theories and provided good results. They combined the two variables of TAM with the five attributes of innovation of the IDT in their study, similar to what was done in this study. Chen, Liu, & Lin,

(2014) also report that most studies based on TAM have added other relevant research variables for better exploration of user intentions about the technology at hand.

### **Achievement or Learning**

Learning may be defined as a change in long-term memory (Kirschner, Sweller, & Clark, 2006) and it is normally measured with achievement tests. Guidance has not always had a positive effect on learning. In a study conducted by Baydas et al., (2015), the researchers found that the difference between the retention of the participants in a 3D virtual environment was in favor of the unguided exploration group with the possible reason being that the participants found all the information in the environment without feeling any obligation.

This suggests that strategies that make learners more cognitively active (Mayer, 2004) and motivated tend to yield better results on learning. Clark, Kirschner, and Sweller, (2012) reported in their studies that when less skilled or able learners were assigned to less guided instruction, their scores were lower on the posttest. In light of this, it was hypothesized that the participants in the instructor guidance with activity group would perform better as compared to the learner-controlled group for this study since they would be exerting more effort which leads to more germane cognitive load (Lin & Atkinson, 2013).

### **Purpose of Research**

The purpose of this study was to extend previous research on learner control and instructor guidance in simulation-based environments. Its primary objective was to determine whether learner control or instructor control with guidance would improve learning of material when using an instructional simulation. Prior research has examined the effects of learner control in the traditional classrooms (Kanar & Bell, 2013), in tutorials (Hannafin & Sullivan, 2016), and in e-learning (Granger & Levine, 2010). This study was conducted to examine the effects of

learner control and instructor guidance on achievement, perceived cognitive load, efficiency, and attitudes of the use of simulations in the future in a classroom setting— factors that have not been thoroughly investigated in other research studies.

This study addresses the following hypotheses and research questions:

H1: Post-test scores for the instructor guidance with activity group will be higher than the learner-control group.

H2: Instructor guidance with activity will lead to decreased levels of cognitive load.

RQ1: Which of the two strategies, instructor guidance with activity or learner control, is more efficient in terms of time spent?

RQ2: Will the instructor guidance with activity strategy take more time than learner control?

RQ3: What is the effect of learner control compared to the instructor guidance with activity approach on perceived learner control?

RQ4: What is the impact of learner control on the willingness of participants to adopt instructional simulations in their future classroom as teachers?



## CHAPTER III

### METHODS

This chapter describes the methods used in this study. Specific details of participants, study design, instructional treatments, outcome measures, procedures, and analyses are presented.

#### **Participants**

Participants consisted of a purposive sample of undergraduate students enrolled in a pre-service teacher instructional technology course in the college of education at a large urban university in the United States during the fall 2016 semester. Permission was sought from the instructor teaching the classes to recruit her students during the class meetings. Participants were unpaid volunteers who were not offered any extra credit for the participation. Forty participants were recruited and randomly assigned to one of the two experimental groups: the learner-control group (n=20) and the instructor-guided activity group (n=20). There were 17 females and three males in each group. The average age of the participants was 20.8 years (SD=1.32) for the learner control and 20.7 years (SD=2.25) for the instructor guidance with activity group. The age of eldest participant in the two groups was 27 years and that of the youngest was 19 years. The participants completed the study as a non-graded activity related to this content area. The class normally met for an hour and fifteen minutes twice a week. Demographic information was collected via survey and is presented in Table 1 below.

Table 1

*Demographics of Sample*

Treatment	N	Avg. Age	Sex		Taken chemistry as a course		Avg. knowledge level in Chemistry
			<u>Female</u>	<u>Male</u>	<u>Yes</u>	<u>No</u>	
Learner control	20	20.8yrs	17	3	17	3	3.15
Guided with activity	20	20.7yrs	17	3	19	1	2.45

### Research Design and Instructional Treatments

The study utilized a true experimental design with random assignment to treatments. The participants were randomly assigned to one of the two treatments. The learner-control group was not provided with any support or guidance whereas the instructor guidance with activity group was provided an activity to answer a few questions as they went through the simulation and also explain how they came up with the answer. The instructional simulation used for this study was a chemistry simulation on the topic of molarity, selected from PhET Colorado Simulations (<https://phet.colorado.edu>) because they are free and easy to use. Topics covered with this simulation were: solutions, molarity, moles, volume, solubility, and saturation. The simulation presents the relationships between moles of solute, liters of solution, and molarity achieved by adjusting the amount of solute and solution volume. Participants could change solutes from a list of nine to compare different chemical compounds in water (Phet.colorado.edu). No special software was required to run the simulation. It could be run on Microsoft Windows XP, Vista, or Windows 7. Figure 1 provides a screenshot of the simulation.

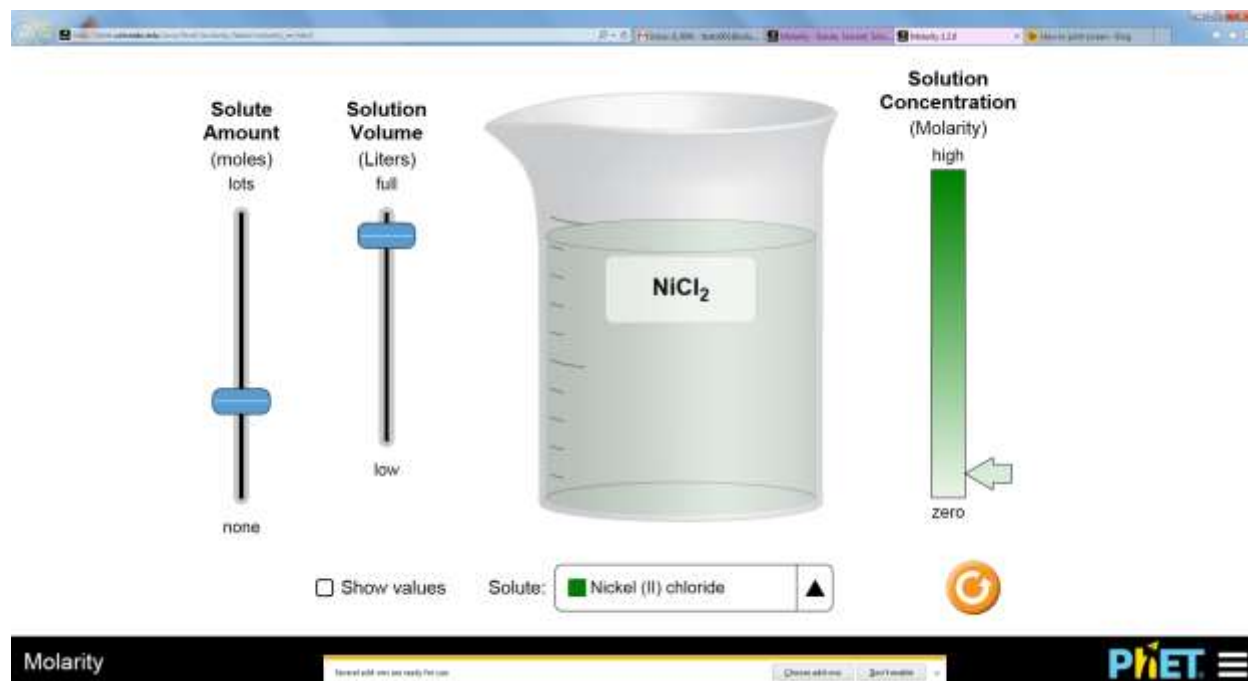


Figure 1. Screenshot of the simulation used in the study.

The participants were given an instruction sheet on which they were to note the start and end time along with the number of molarity tests conducted. Participants in the learner-control group were asked to go through the simulation, recording any solute that they skipped along with any solute that they tested more than once. The other group (instructor guidance with activity group) were encouraged to follow the instructions provided by the researcher and go through a step-by-step process for the accompanying activities which prompted the participants to explain how they came up with the answers they provided. All participants completed the posttest afterward.

All participants worked on a simulation on a single topic in a classroom. The following paragraphs explain specifically how the treatments differed.

**Learner control.** Participants of this group were asked to open the link (which was shared by the researcher via Nearpod) to the simulation and manipulate the variables on their own. No support or guidance was offered to them, but an instructional sheet was provided with simple instructions asking the participants to fill in the demographic information, open and work with the simulation and then take the post-test and the survey at the end (Appendix A). They were instructed that they could use the provided sheets to take notes if they wanted. The instructor, the researcher, and a graduate student of computer science were present to answer any questions and provide any technical help if required. No content-related help was provided. Participants were also asked to record their work on the simulation in the form of screen casts. For this purpose, Screencast-O-Matic was used to record and verify that participants completed simulation tasks.

**Instructor guidance with activity.** The second group of participants was provided step-by-step guidance and they had to follow any directions given to them. The participants were also prompted to provide self-explanations of how they reached their answer after every activity (see Appendix B). There no learner control of the simulation for this group, as parts of the simulation were directed by the researcher. The instructor guidance was recorded in video form with the help of Screencast-O-Matic and broadcast to the class using Nearpod software. The total duration of the video was ten minutes, but it was paused after four minutes, and the participants were asked to answer questions number one and two in their activity documents. The video was resumed after they had recorded their answers and continued until the end. The researcher used a script for this instruction that was prepared in advance of the experiment (see Appendix H). Provision of activity with the assignment and providing the content information in the form narration in the video is in line with de Jong and van Joolingen (1998). Their research contends that providing direct access to domain information is more be effective if the information is

presented concurrently with the simulation and is available at the appropriate time when it is needed in the instruction. They also support that providing learners with assignments has a clear effect on the learning outcomes (de Jong & van Joolingen, 1998, p.16).

### **Nearpod**

Nearpod is a free app available for the iPad, iPhone and iPod touch (Delacruz, 2014). It can be accessed from [www.nearpod.com](http://www.nearpod.com) for Windows. Educators can use it to create interactive lessons, and for synchronized learning in the classroom or for distance learning. To make lessons interactive, polls, slides and quizzes can be embedded. The teacher creates an account and log in. To share the lesson, a pin code appears on the teacher's screen which can be shared via email or social media. Learners, and in this case participants, can see the screens it but cannot make changes in the lesson— there is no learner control. The instructor uses the system to guide the learners and direct the workspace. Learners can participate in the polls or take the quiz. Delacruz (2014) reports that Nearpod is considered a new app as it was launched in 2012. Though there are reports about how instructors have responded to it, research related to it is scarce. In this regard, the present research represents a step towards contributing to research literature about the use of this application. In this study, this application was used to share the simulation with both the groups. For the learner-control group, only the link of the simulation was shared, while the pre-recorded video of the simulation was shared with the instructor-guidance group.

### **Screencast-O-Matic**

Screencast-O-Matic is software that records interactive screen content in video files and needs neither installation nor downloading (Steiner, 2010). It has a record time of 15 minutes which was sufficient for recording interactions in the current study. The software captures on-screen activities and saves it in multiple formats, such as an MP4. The saved video can be

retrieved for use later. In this study, it was used by the instructor to record planned interactions of the simulation screen along with the audio of the instructor guidance for that treatment. It was also used by the participants of the learner-control group to record their work using the simulation. Participants saved their videos and sent them to the researcher via email or published them on YouTube. The videos were later downloaded by the researcher for verification of work.

### **Dependent Measures**

**Achievement.** Learner achievement and performance was measured through posttest. The researcher developed the test using a table of specifications indicating how each item aligned with the objectives and proposed level of learning. Content for the posttest was validated by three experts, two of whom were graduate students in the chemistry program, and one who had been teaching chemistry at the secondary school level. The test is comprised of eight multiple choice items, measuring lower and higher levels of learning. Test were calculated using one point for each item for a total possible score of 0-8. Internal consistency reliability of the achievement test for this study with all 40 participants was .51 using the KR-20. The copy of the table of specifications is in Appendix C and the posttest in Appendix D.

**Cognitive load.** Cognitive load was measured after each item of the posttest for each group. The participants were asked to rate their invested mental effort on a 9-point Likert-type scale adopted from Paas (1992) from 1 (very, very low) to 9 (very, very high) (Appendix F).

Cognitive load was rated while the participants were using the simulation after each activity (instructor guidance activity group) and in the post-test after each item. The mean cognitive load was calculated both for the simulation and the post-test for each participant. For the post-test, the cognitive load was measured eight times, once for each test item. Score per item for each participant was calculated across all eight items. The total possible score per item

ranged from 0-9. Reliability of the scale, according to Paas (1994), in two studies was  $\alpha = .90$  and  $\alpha = .82$ . Internal consistency reliability for the eight items in the scale for all 40 participants in this study was  $\alpha = .87$ .

**Instructional efficiency.** The efficiency of instructional condition scores (adapted from Paas & van Merriënboer, 1993) was calculated based on the measures of participants' performances on post-test, and self-reported measures of mental effort. Each participant's score on the post-test score was combined with the relevant measure of effort for that problem. The efficiency of the instructional method was calculated in the following way:

Participant's performance measure and invested effort measure were standardized, which provided each participant's Z-score for both the measures which were then used to calculate the efficiency of the instructional method with the help of the following formula:

$$E = z \text{ performance} - z \text{ mental effort} / \sqrt{2}.$$

The relationship between time on task and the performance of the participant was one measure of efficiency.

**Time on task.** The participants were required to note both the start and the end time. This time was considered time on task and was used as an additional measure of efficiency.

**Attitude.** A survey based on Davis's (1989) perceived ease of use and perceived usefulness combined with Innovation Diffusion Theory (Rogers, 1983) was used to measure the willingness of the learners to use simulations in their future classrooms. The instrument was adopted from Pankratz, Halfors, and Cho (2002) with modifications for this study (Appendix G). The survey has a well-established reliability of  $\alpha = 0.98$  for relative advantage/compatibility and  $\alpha = 0.71$  for observability (Pankratz, Halfors, Cho, 2002). No permission was sought to modify and use Pankratz, Halfors, and Cho's questionnaire, as it is already in the public domain. One

item (*My interaction with work would be clear and understandable*) from the Davis (1989) perceived ease of use was omitted as it did not fit the present study. A final survey was comprised of 24 items. Five out of 24 items, (e.g., *Using simulation will have no effect on students' learning*), were reversed scored. A seven-point Likert scale was provided for each item, to measure participants' attitudes regarding the future use of simulations in their classrooms. Reliability of the overall scale for this study was  $\alpha = 0.89$ .

**Learner control.** A five-item survey based on research developed by Yao & Gill (2009) was used to assess perceptions of learner control (Appendix G). Participants recorded their ratings for each item on five-point Likert-type rating scale ranging from 1 ("strongly disagree") to 5 ("strongly agree"). The total score was calculated as a mean across all five survey items. The reliability of this scale for this study was measured to be  $\alpha = 0.89$ . The reliability of the Yao and Gill (2009) scale was  $\alpha = .85$ .

## **Procedure**

The research was conducted at a large urban university in the southeastern part of the U.S. The participants were pre-service teachers in a technology course. The instructor was contacted, and the whole process about how the research would be conducted was discussed in detail. The researcher prepared the posttest with the help of two graduate level chemistry students and a former chemistry teacher at the high school level. All participants, whether in the learner control or instructor guidance with activity group, were provided instructions for the study. This strategy was adopted to ensure that content was the same across all treatments. Both groups were given instructions separately, and an instructional sheet was provided (see Appendices A & B). The simulation used was selected from PhET chemistry simulations, and it



was assumed that it was built with consideration of Mayer's principles of cognitive load as cognitive load is one of the measures of this study.

The participants were informed about the study. They were in a technology course and were to learn about simulations as part of this course later in the semester. They were told that their participation would be helpful for them, but that participation was entirely voluntary. No extra credit or monetary incentive was provided. They were provided consent forms, and only those who consented were recruited for participation and randomly assigned to a treatment group.

The two groups were instructed separately during different periods of time. Participants in the learner-control group were provided a link to the simulation via Nearpod and were asked to work through the simulation. They were also told to open the Screencast-O-Matic application and record while they worked on the simulation. The recorded videos were then either sent to the researcher via email or posted on YouTube where the researcher retrieved them later using the names of the participants. This was done to verify that the participants were actually completing what was asked of them and the time was spent on the task at hand. The participants took a posttest after completing the simulation and recorded mental effort ratings with each posttest question. Participants then completed the learner control and attitude surveys. The instructor guidance with activity group was given a recorded video of the simulation with audio narration by the researcher. This guided group had to rate their mental load after each activity in their instruction sheet as instructed by the researcher. The researcher paused the video at specific times and asked participants to work on the related activity and then resume. There was no fixed time given to the participants, and they were free to use as much time as they wanted. The participants were provided a sheet on which they noted the start time and the end time.

Participants of the learner-control group had to note the number of molarity tests conducted, and they also noted any solute skipped along with any solutes that was tested more than once. The participants then took a posttest (Appendix D) prepared by the researcher.

Table 2 links hypotheses and the research questions, measures and scores obtained, with the statistical design. All the data was analyzed by the Statistical Package for Social Sciences (SPSS).

Table 2

*Hypotheses, Research Questions, and Analytical Design*

No	Hypothesis/ Research Questions	Dependent variable	Measure/Scores	Analysis
1	Posttest scores for the instructor guidance with activity group will be higher than the learner-control group	Each participant's posttest score	Posttest score (0-8)	One-way ANOVA (with the two treatments)
2	Instructor guidance with activity leads to decreased levels of cognitive load.	Self-reported cognitive load for each participant	Mean cognitive load (0-9) during instruction and during post-test	One-way ANOVA (with the two treatments)
RQ1	Which of the two strategies; Instructor guidance with activity or learner control prove to be more efficient?	Efficiency score of each participant on the posttest problems	Efficiency: Using formula posttest and CL for the posttest items.	One-way ANOVA (with the two treatments)
RQ2	Will the instructor guidance with activity strategy take more time as compared to learner control?	Time on task for each participant	Mean time to complete instruction	One-way ANOVA (with the two treatments)
RQ3	What is the effect of learner control versus instructor guidance with activity on perceived learner control?	Self-reported learner control through the learner control check list	Mean perception of learner control	One-way ANOVA (with the two treatments)

No	Hypothesis/ Research Questions	Dependent variable	Measure/Scores	Analysis
RQ4	What is the relationship between the learner control or instructor guidance with activity and the willingness of the participants to adopt instructional simulations in their future classrooms as teachers?	Attitude of the participants (survey questions)	Mean attitude for future use	One-way ANOVA (with the two treatments)

## Summary

Details of participants, study design, instructional treatments, outcome measures, procedures, and analyses are presented in this chapter. Participants were forty (34 female and six male) undergraduate students of a pre-service teacher education course. Participants were assigned to either a learner-control or instructor-guided treatment. Participants for both groups completed a simulation (one learner controlled and the other instructor-controlled), a posttest, an attitude survey, ratings of perceived cognitive load, and a survey of perceived learner control.

The learner-control group was provided a link to the simulation via Nearpod and interacted with the simulation without any interference from the researcher (i.e., instructor). The instructor-guided group was provided a recorded simulation and directed by the researcher (i.e., instructor) to work through an activity along with the simulation.

A comparison of the achievement level, cognitive load, the efficiency of the two strategies, and the perceived learner control between the two groups was made with the help of one-way ANOVA and the results provided in the next chapter.

## CHAPTER IV

### RESULTS

This study aimed to test two hypotheses and four research questions. All the hypotheses and the research questions were analyzed quantitatively. This chapter presents the results of the analyses used and evaluation of the effects of learner control and instructor guidance on achievement, cognitive load, instructional efficiency, time on task, attitudes, and learner control.

#### **Hypothesis I**

The first hypothesis predicted that the instructor guidance with activity group would score higher than the learner-control group. In this study, the posttest developed by the researcher was used to measure participants' achievement following instruction. A one-way, between-subjects ANOVA was conducted to evaluate the effect of learner control on posttest achievement. The independent variable was experimental treatment—learner control or instructor guidance with activity, while the dependent variable was achievement. The results of ANOVA indicated that there is no significant difference of achievement between the two groups,  $F(1,38) = .89, p > .05$ . The  $\eta^2$  was very small, .02. The assumption of homogeneity of variance was violated, Levene's Test,  $F(1,38) = 2.64, p = .11$ , yet post-hoc were not performed because the groups were smaller than three. Table 3 shows the means and standard deviations for each of the experimental treatment groups.

Table 3

<i>Means and Standard Deviations of Posttest Scores of the Two Instructional Strategies</i>		
Treatment Group	<i>M</i>	<i>SD</i>
Learner control	6.65	1.08
Instructor guidance with activity	6.25	1.55

## Hypothesis II

The second hypothesis predicted a decreased level of cognitive load for the instructor guidance with activity group. A one-way ANOVA was conducted to evaluate the effect of the two experimental treatments on the cognitive load measured during the post-test. The results of ANOVA indicate no significant difference in the cognitive load of two groups,  $F(1, 38) = .56$ ,  $p = .45$ . The  $\eta^2$  was also very small (.01) indicating that little variance in the measure of cognitive load could not be explained by the experimental treatments. The means and standard deviation of the experienced cognitive load of the two groups are provided in Table 4.

Table 4

*Means and Standard Deviations of Cognitive Load Experienced by the Two Groups*

Treatment Group	<i>M</i>	<i>SD</i>
Learner control	3.69	1.62
Instructor guidance with activity	3.30	1.64

## Research Question I

Which of the two strategies, instructor guidance with activity or learner control, is more efficient?

Two separate one-way ANOVA's were conducted to compare the two treatment groups on instructional efficiency measured as z-scores and as a calculated efficiency score of reported time on task divided by posttest score. There were no statistically significant difference in instructional efficiency between the groups for z-scores,  $F(1,38) = .017$ ,  $p = .89$ , nor for the efficiency score based on performance and time on task,  $F(1,38) = 2.56$ ,  $p = .11$ . Table 5 provides

the means of effort, performance, and the relative treatment efficiency of the two treatments and Table 6 shows the means of performance score, time on task, and efficiency.

Table 5

*Mean Z-Scores for Effort, Performance, and Efficiency*

Treatment	Performance score	Effort	Instructional Efficiency
Learner control	6.65	0.12	0.02
Controlling guidance	6.25	-0.12	-0.02

Table 6

*Mean Scores for Performance, Time on Task, and Efficiency*

Treatment	Performance score	Time on Task	Instructional Efficiency
Learner control	6.65	17.35	3.43
Instructor guidance with activity	6.25	30.92	1.90

**Research Question II**

Will the instructor guidance with activity strategy take more time than learner control?

To address this question, a one-way ANOVA was conducted to compare means of time on task between experimental groups. The results of the ANOVA indicated a significant difference between the two groups,  $F(1, 22) = 15.46, p = .001$ . The  $\eta^2$  was also large, .41 and indicated that 41% of the variance in the time on task could be explained by the differences in the two experimental treatments. Table 7 provides the means and standard deviations for time on task for both experimental groups.

Table 7

*Means and Standard Deviations for Time on Task Spent by the Two Groups*

Treatment Group	<i>M</i>	<i>SD</i>
Learner control	17.35	3.43
Instructor guidance with activity	30.92	1.90

The findings for the research question indicate that the participants of the instructor guidance with activity group took significantly more time when compared to the learner-control group. On average, the difference of time taken between the two groups was 13.57 minutes hence the result was as predicted.

### **Research Question III**

What is the effect of learner control compared to the instructor guidance with activity approach on perceived learner control?

A one-way ANOVA was conducted to answer this question and a significant difference was found between the two groups for perceived learner control,  $F(1, 38) = 86, p < .01$ . The  $\eta^2$  was large (.69) and indicated that 69% of the variance was attributable to the difference in the treatments. The mean and standard deviation of the perceived learner control of the two groups is provided in the Table 8. The learner-control group reported higher perceived learner control ( $M=23.30, S.D. = .65$ ) as compared to the instructor-guidance group ( $M=14.72, S.D. = .65$ ).

Table 8

*Means and Standard Deviations of Perceived Learner Control by the Two Groups*

Treatment Group	<i>M</i>	<i>SD</i>
Learner control	23.30	.65
Instructor guidance with activity	14.72	.65

The results of this analysis are in accordance with the control provided to the two groups. As the learner-control group was provided more control over the simulation, they reported higher levels of control more as well.

#### **Research Question IV**

What is the impact of learner control on the willingness of participants to adopt instructional simulations in their future classroom as teachers?

A one-way ANOVA was conducted to evaluate this effect. The results of ANOVA found no significant difference between the two groups,  $F(1, 38) = .35, p = .55$ . The  $\eta^2$  was very small (.009) and indicated that almost no variance existed between the groups. Table 9 gives the mean and standard deviations of the attitudes of both groups towards the future use of simulations.

Table 9

*Means and Standard Deviations of Attitude towards Future Use of Simulation for the Two Groups*

Treatment Group	<i>M</i>	<i>SD</i>
Learner control	112.35	16.11
Instructor guidance with activity	108.95	19.78



Table 10 presents a mean responses of participants to the survey items using the 7-point Likert type scale (1 being extremely unlikely and 7 being extremely likely). Results indicate that both groups are willing to adopt simulation in their future classroom.

Table 10

*Summary of Survey Responses*

No	Survey item	Average Responses	
		Learner control group (n=20)	Instructor guidance with activity group (n=20)
1	Using simulations in my job would enable me to accomplish tasks more quickly	4.87 (Slightly agree)	4.52 (Slightly agree)
2	Using simulations would improve my learners' performance	4.97 (Slightly agree)	5.22 (Slightly agree)
3	Using simulations while teaching would increase my productivity	4.85 (Slightly agree)	4.77 (Slightly agree)
4	Using simulations would enhance teaching effectiveness	4.80 (Slightly agree)	4.97 (Slightly agree)
5	Using simulation would make it easier to achieve my class objectives	4.75 (Slightly agree)	4.77 (Slightly agree)
6	I would find simulations useful in my job	4.90 (Slightly agree)	4.97 (Slightly agree)
7	Learning to use simulations would be easy for me	5.05 (Slightly agree)	4.62 (Slightly agree)
8	I find it easy to get simulations to do what I want them to do	4.55 (Slightly agree)	3.77 (Slightly agree)
9	I find simulations to be flexible to interact with	5.30 (Slightly agree)	4.27 (neutral)

No	Survey item	Average Responses	
		Learner control group (n=20)	Instructor guidance with activity group (n=20)
10	It will be easy for me to become skillful at using simulations	5.35 (Slightly agree)	4.42 (neutral)
11	I find simulations easy to use	5.15 (Slightly agree)	4.72 (Slightly agree)
12	Using simulations is compatible with the teaching-learning activities in my school	5.05 (Slightly agree)	4.72 (Slightly agree)
13	Using simulations fits well with the way I like to work	4.25 (neutral)	4.47 (neutral)
14	Using simulations would require our school to make substantial changes to our prevailing teaching practices	3.50 (Slightly disagree)	3.52 (neutral)
15	It will be difficult to train teachers and staff to use simulations	4.30 (neutral)	5.07 (Slightly agree)
16	It will be complicated to use simulations in any program	4.85 (Slightly agree)	4.52 (Slightly agree)
17	It is okay for me to try out simulations on a limited basis before full implementation	5.35 (Slightly agree)	4.78 (Slightly agree)
18	Instructors/students will like the changes if simulations are used	4.80 (Slightly agree)	4.42 (neutral)
19	Using simulations will enhance my effectiveness on the job	4.45 (neutral)	4.62 (Slightly agree)

No	Survey item	Average Responses	
		Learner control group (n=20)	Instructor guidance with activity group (n=20)
20	Using simulation will enhance the quality of education in our school	5.15 (Slightly agree)	5.07 (Slightly agree)
21	Using simulation will have no effect on students' learning	5.05 (Slightly agree)	5.32 (Slightly agree)
22	Use of simulations requires more work than can be done with the prevailing system	4.10 (neutral)	4.42 (neutral)
23	Even if my school did not encourage the use of simulations, I would like to use it in my courses	4.00 (neutral)	4.07 (neutral)
24	Overall I find use of simulations to be advantageous for my school and the academic work	4.58 (Slightly agree)	4.82 (Slightly agree)

## Summary

The study failed to show significant differences in posttest, cognitive load, attitude, and instructional efficiency. Significant differences were found for perceived learner control and time on task. Both treatment groups showed a positive reaction to the study and to the learner control conditions they experienced. Participants in both groups appeared highly motivated and interested in the study. Participants in the learner-control group reported significantly higher perceived learner control and significantly lower time for completion than the participants in the instructor guidance with activity group.

## CHAPTER V

### DISCUSSION AND CONCLUSIONS

#### **Significant Findings**

The purposes of this study were to determine the effects of learner control and instructor guidance with activity on achievement, cognitive load, instructional efficiency, perceived learner control, and participants' attitudes towards the future use of simulation. Several findings contradicted the predictions made, as no significant differences were found in the two treatment groups for achievement and cognitive load. Significant differences were found between the learner-controlled and instructor-guided treatments for time on task and perceived learner control such that participants in the learner control condition spent significantly less time on task and reported higher levels of learner control than the instructor-guided condition which spent significantly more time on task and reported lower levels of learner control. This chapter reviews the results of the study with respect to each of the outcome variables, relating findings to prior research.

#### **Achievement**

The two experimental groups performed in a similar manner and no significant differences were found for achievement. One possible reason that no significant differences in achievement were found between the groups could have been that the posttest, which was developed by the researcher, was not sufficient to measure differences between the groups. The number of test items was small limiting variability in scores. Though three chemistry experts were consulted and the test was approved by them, it is possible that they understood the molarity concepts but were not thoroughly aware of the need to separate groups on their knowledge.

Another reason for the lack of differences in achievement could be linked to motivation. Though we do not have direct evidence, both groups in this study were motivated as it was part of their curriculum to study simulations, and according to the instructor, they were excited to participate. High level of motivation in both groups could have affected the results. Participants were in placed in a meaningful instructional setting (Morrison, Ross, & O'Dell,) which could have increased their motivation. However, it is also possible that instructor guidance had a small, detrimental effect on the motivation of the participants (Kanar & Bell, 2013).

The lack of significant differences in achievement could also be due to lack of differences between learner and instructor control. This finding is in accordance with a Swaak and de Jong (2001) study in which they compared learner-controlled and system-controlled groups. They found that providing guidance during activity as a support to a simulation environment or giving the learners full control over the environment did make much difference in their study. This finding is also in line with Aly, Elen, & Willems, (2005). They hypothesized that when computer-assisted learning is provided to learners, those working with a program-control format could have significant gains over those using the learner-control version. However, significant differences were not found between the two groups.

The difference between the scores of the activity and the posttest showed that the activity helped the participants and may have acted as a pretest. It appears that the students worked more confidently in the posttest where they scored better without much difference in cognitive load. The activity may have worked as a pretest which alerted the learners to material in the posttest. In this regard, Hartley (1971) reported that to know the effect of a pretest on the achievement of students, it is recommended that interim tests within the study be removed. In doing so, his research led to poorer performance of students. According to Hartley, the findings suggested that

pretests not only alert learners of what is required and prepare their expectations, but also seem to assist in the organization of other related material so that it is easily remembered.

### **Cognitive Load**

There were no significant differences in cognitive load for the treatment groups in the current study. No significant difference in the cognitive load measure is also in line with Swaak and de Jong (2001) study. They measured the participants' cognitive load with the help of a pop-up electronic questionnaire, the SOS (Subject matter difficulty, Operating the system, and Support provided) scale to measure the cognitive load of two groups having varying levels of control over the simulation environment. The authors did not find significant difference in the cognitive load of the two groups.

Though not significant, a slight difference in the means of cognitive load shows a decreasing trend from the learner control to the guidance with the self-explanation group. This result corresponds with van Merriënboer and Sweller's (2005) claim that if multiple sources of information required for understanding are presented only in visual form, they are more likely to overload the visual processor as compared to if it is presented both in audio and visual (spoken and written) form. In this way, some of the load is shifted to the auditory processor (Mousavi et al., 1995). This may explain outcomes in the present study as the participants in the learner-control group were only provided with the simulation in visual form, whereas the participants of the instructor guidance with activity group were provided with audio narration as well.

### **Instructional Efficiency**

The greatest instructional efficiency occurs when performance scores are the greatest while the effort score are the least (Tuovinen & Paas, 2004). Though no significant difference was found in the groups regarding instructional efficiency in the current study, the means of the

learner-control group were slightly higher than the instructor guidance with activity group. It is feasible that a more in-depth interaction with the simulation and coverage of more instructional content would should greater differences in instructional efficiency.

According to Kalyuga (2012), efficient learning can achieve the desired effects in minimal time with optimal cognitive effort. In this sense the learner control strategy, though not significantly different in the efficiency measure for this study, required less time with similar achievement as compared to the instructor guidance group. Based on the definition by Kalyuga (2012), the learner-control group in this study was more efficient than the instructor-controlled group.

### **Time on Task**

The instructor-guidance group took more time perhaps because the simulation was controlled by the researcher (i.e., instructor). It is possible that the participants in this group spent more time working on the instructional activities, while the participants in the learner-control did not. This result is in line with Lin and Atkinson (2013) who reported that participants in their study who were prompted to self-explain spent more time compared to those who were not.

### **Perceived learner control**

The participants were asked to rate their perception of the control that they had on their learning. The results were significant in favor of the learner-control group who reported significantly greater learner control than the instructor-control group. There is little research in this area and more research aid in our understanding of the tradeoff between learner control and achievement, time, and cognitive load. In the current study, a scale was developed using the work of Yao & Gill (2009). The reliability of this scale was measured to be  $\alpha = 0.89$ . These results indicate favorable results for the instrument and its use in future work.

### **Attitude of the participants to adopt instructional simulations for future use**

Though no significant difference was found between the two groups in regard to using the simulation in the future, the slight mean differences that were in favor of the learner-control group. This may be due to the learner-control group actually using the simulation and thus those participants were able to see that the simulation was easy to use and useful, whereas the instructor-control guidance did not use the simulation and could only see the video of the simulation, so they may have found it useful but had no first-hand experience. In this way, the learner-control group proved to be more in favor of using simulations in the future compared to the instructor-control group. This is in line with Davis's (1989) assertion that when users perceive that an innovation (technology) is easy to use when they find it useful, adopting it more easily. This is due in part to the fact that users' attitude towards the (innovation) is formed based on their experience with it (Sun, 2016). The participants in this study were enrolled in a technology course and were expecting to learn about the use of simulation as part of the curriculum. It is expected that when the learning experience is relevant to the student, an increased level of acceptance of the innovation (system) occurs (Manochehri & Sharif, 2010). That may explain the lack of significant difference between the groups for future use of simulations.

### **Summary**

Based on the results, it can be concluded that in a specific context, the molarity of substances, the learner control, and the instructor-control strategy are equivalent with regard to learning, cognitive load, and efficiency. Also, whether learners have complete learner control or



are directed by the instructor, they will have similar attitudes towards the use of simulations in their future classrooms as teachers.

### **Limitations**

As with many studies, this study has limitations. First, the sample size was low. Only 40 students consented to participate in the study. Only two classes instructed by the same person were included. Both classes were selected from a single institution, and the use of convenience sample may further limit the external validity of the study and the results may not be generalizable. Second, as the posttest was created by the researcher who was not a subject matter expert and the total number of items on the test was limited to eight. The items were not refined as no pilot test was conducted. Third, the study was part of an ungraded classroom assignment, which may have led to low incentives on the part of participants. Its reliance on the self-reported data to measure cognitive load may be a threat to its internal validity. A future direction for research may be to utilize a think-aloud protocol for this purpose (Morrison, 2013). The short duration of the study (only one class session) may have affected the results. Another limitation could be using to the simulation directly without provision of content knowledge. The self-reported knowledge level and grade may not have been sufficient to determine preexisting knowledge. Another threat to validity is the fact that the simulation used may not be generalizable to all forms of simulations (Morrison, 2013). A very simple and basic simulation with moderate fidelity was used for this study. As simulations vary greatly according to the underlying model, the overlay, and per the level and course, the results of this simulation may not be generalized. It is considered that the results of the study may have been different had the above-mentioned limitations been mitigated.

### **Implications**

This study demonstrated that learner control is a better strategy than instructor guidance with activity in regard to time spent and perception of learner control. However, there was no significant difference between the two groups on the achievement of learners and their cognitive

loads. This research has attempted to determine the difference between the two strategies in a simulation environment, yet it was determined that the results were not significantly different.

For future research, it is recommended that the study be replicated for the validity of the results with a larger random sample from a diverse population based on the increasing diversity of learners in computer-aided learning environments (Aly, Elen, & Willems, 2005). Using a more complex simulation is also recommended. Future research should consider a balanced sample with both genders to avoid any possible influence of gender on the results. Research should also continue to determine the most effective and efficient strategy to be used in a simulation learning environment. It is also recommended that the study be replicated with a few additions. The participants should first be provided with a knowledge base of the topic covered in the simulation following a test which can be considered a pretest. After they have sufficient information the simulation should be provided following the posttest and the results of both tests should be compared to determine the benefit of the simulation.

Subject matter experts should be involved in the research. It is even better that the researcher informs the subject matter expert about the whole processing detail and let her/him to teach the class along with evaluating the activities and the test.

## **Conclusion**

The study was conducted to determine the difference between instructor guidance with activity and the learner control when learning from instructional simulation. Both treatment groups completed a simulation in which the learner-control group had full control over the simulation, while the other group was provided a video of the simulation and had no control over it. After the simulation, the participants of both groups completed a posttest, rate their perceived cognitive load, took a survey related to the perceived attitude towards the future use of the

simulation, and rated their perceived learner control. Overall, no significant differences were found between the learner-control and the instructor-controlled groups regarding achievement, cognitive load, and instructional efficiency. Yet, significant differences were found between the groups regarding time on task and the perception of learner control. The learner-control group spent significantly less time on completing the given task and scored comparatively higher (6.65) than the instructor guidance activity with group (6.25), though the difference in score was not significant. In this sense, it may be said that the learner-control group was comparatively better in terms of efficiency, though the two groups were not found significantly different with regard to the mean efficiency score.

Though the five aids or principles of multimedia presentation provided by Mayer and Moreno (2002); multimedia, contiguity, coherence, modality, and avoidance of redundancy principles were followed yet superiority of the instructor guidance with activity group was not seen as compared to the learner-control group. The learner-control group did not prove to be better than the other group as it was in case of the Mayer and Chandler (2001) study where the former group outperformed the later. A possible explanation proposed for the absence of differences between the two groups was that both groups were from the same university and the same class taught by the same instructor. Other types of learners may have taken more responsibility of their own learning (Swaak & de Jong 2001). The learners may also have behaved differently if they were asked to score a specific percentage of points to get a class grade or an extra credit. In the present study, they were just experimenting and rehearsing for the simulation class they had to take with their instructor without a specific goal in mind.

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**APPENDIX A****DEMOGRAPHIC SHEET  
(Learner Control)**

Please fill the following form with information as accurate as possible

Name: \_\_\_\_\_ Gender: \_\_\_\_\_ Age: \_\_\_\_\_, Qualification:  
\_\_\_\_\_, Level of education: \_\_\_\_\_

Have you ever taken any chemistry class? Yes No

If yes, in which year and at which level Year \_\_\_\_\_ Level \_\_\_\_\_ Grade \_\_\_\_\_

On the scale 1 to 10 (very very low to very very high) how much do you rate your level of knowledge in chemistry especially molarity?

Answer: 1 2 3 4 5 6 7 8 9 10

**Instruction sheet**

Please fill the following carefully

Time of starting the simulation: -----, ----- Time of ending: -----, -----

Please open and go through the molarity simulation. You can manipulate as much variables as you can and take as much time as you want. Please fill in the following as you work with the simulation.

Number of solutes worked with:

Number of solutes used more than once:

You are welcome to take notes in the space provided below. At the end, you will have to take a test based on the simulation.

## APPENDIX B

### DEMOGRAPHIC SHEET (Instructor Guidance)

Please fill the following form with information as accurate as possible

Name: \_\_\_\_\_ Gender: \_\_\_\_\_ Age: \_\_\_\_\_, Qualification:  
\_\_\_\_\_, Level of education: \_\_\_\_\_

Have you ever taken any chemistry class? Yes \_\_\_\_\_ No \_\_\_\_\_

If yes, in which year and at which level Year \_\_\_\_\_ Level \_\_\_\_\_ Grade \_\_\_\_\_

On the scale 1 to 10 (very very low to very very high) how much do you rate your level of knowledge in chemistry especially molarity?

Answer: 1    2    3    4    5    6    7    8    9    10

#### Instruction sheet

Please fill the following carefully

Time of starting the simulation: -----, ----- Time of ending: -----, -----

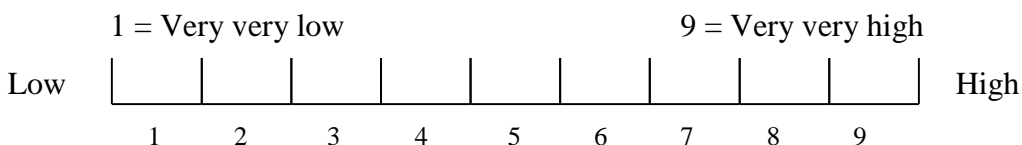
Please open the molarity simulation and answer the following questions as you go on experimenting with the simulation. After answering the question please rate the effort level you had to make to answer the question.

1. Notice the difference of the change of color of the solution as you change the quantity of solute or the solution. What do you notice?

Answer:

In your own words explain why did this difference occur?

On the given scale of one to nine rate the effort you had to exert to grasp this topic (solve this item)



2. Did you notice that the molarity changes with the change in the quantity of the solute or the solution? In fact, it increases with the increase of solute but decreases with an increase in the volume of the solution i.e., **Molarity= moles of solute/liters of solution**. In other words: **Molarity= mol/liter**. (Note we can also play around with the formula. To calculate the number of moles, the formula will be **Mol= Molarity x liter of solute** and in order to calculate the solute per liter the formula to be used will be **Solute per liter= Number of Moles/ given Molarity**)

Can you explain this expression in your own words?

On the given scale of one to nine rate the effort you had to exert to grasp this topic (solve this item)

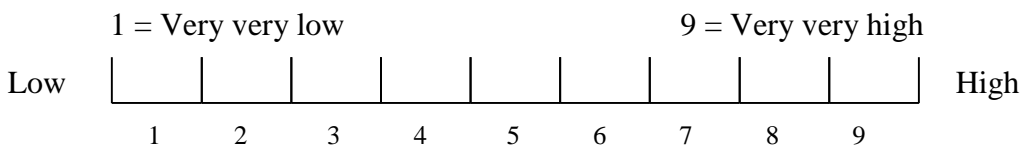
3. Using the formula **M= mol/lit**, calculate the molarity of 0.25 moles of HCL which is dissolved in a 0.5 lit of water. (You can work in the space provided below).

Work Space:

Answer:

In your own words, can you explain how you came up with this answer?

On the given scale of one to nine rate the effort you had to exert to grasp this topic (solve this item)



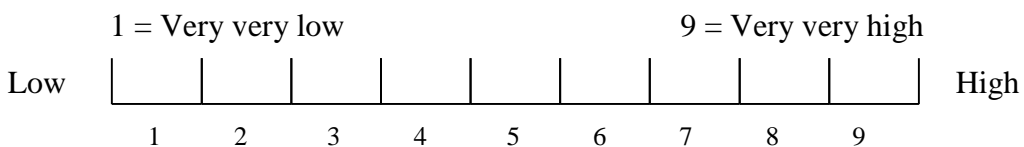
4. Now calculate the number of moles of a solute which is used to make 0.75liters of solution whose molarity is 0.25 (Note: M= moles/L)

Work space:

Answer:

Explain how you came up with this answer:

On the given scale of one to nine rate the effort you had to exert to grasp this topic (solve this item)



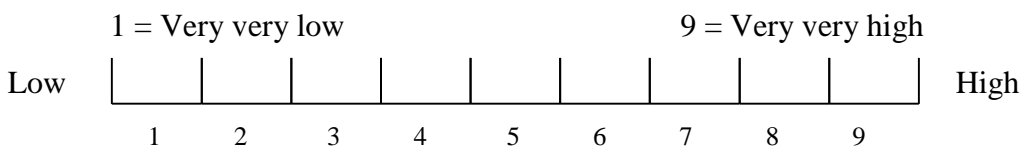
5. How much solution will we be able to get if we have 0.35 moles of a solute and the solution obtained is 0.45M?

Work space:

Answer:

How did you did get this answer?

On the given scale of one to nine rate the effort you had to exert to grasp this topic (solve this item)

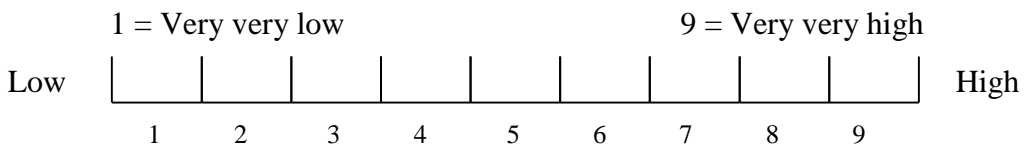


6. At a certain point while working with the Potassium permanganate ( $\text{KMnO}_4$ ) you see the term, “saturated” in the beaker. What do you think saturated means?

Answer:

What made you come to this answer?

On the given scale of one to nine rate the effort you had to exert to grasp this topic (solve this item)





## APPENDIX C

### TABLE OF SPECIFICATIONS

Table of specifications

Objectives	Remember	Understand	Apply	Evaluate
Describe the relationship between volume and amount of solute to concentration		1		1
Explain how solution color and concentrations are related	1			
Calculate the concentration of solution in units of molarity (mol/L)		1	2	
Compare solubility limits between solutes	1			
Use molarity to calculate dilution of solution			1	
Total = 8				

## APPENDIX D

### POSTTEST

(prepared by the researcher)

Please go through the given examples first and then work on the given questions

Example 1: Using the formula  $M = \frac{\text{mol}}{\text{lit}}$ , calculate the molarity of 0.20 moles of HCL which is dissolved to make 0.5 liters of solution.

Answer: In the above question, what is given is:

Number of moles = 0.20 mol.

Quantity of solute = 0.5 liters

What is required = Molarity (M) = ?

On substituting the values in the given formula  $M = \frac{\text{mol}}{\text{lit}}$

$$M = \frac{0.20}{0.5} \\ = 0.4$$

Example 2: How many moles of a solvent will be required to make 0.5 L of 0.25M solution?

Answer: In the above question, what is given is:

Molarity (M) = 0.25

Quantity of solute = 0.5 liters

What is required = moles of solvent = ?

The given formula =  $M = \frac{\text{mol}}{\text{lit}}$

So  $\text{mol} = M \times L$

On substituting values in the formula:  $\text{mol} = M \times L$

$$\text{mol} = 0.25 \times 0.5 \\ = 0.125$$

Example 3: Give the formula to calculate the solvent in liters.

Answer: The given formula for Molarity:  $M = \frac{\text{mol}}{\text{lit}}$

So  $M \times \text{lit} = \text{mol}$ .

Then  $\text{lit} = \frac{\text{mol}}{M}$

Now please pick the answer that you think is most accurate. Each question carries two points.

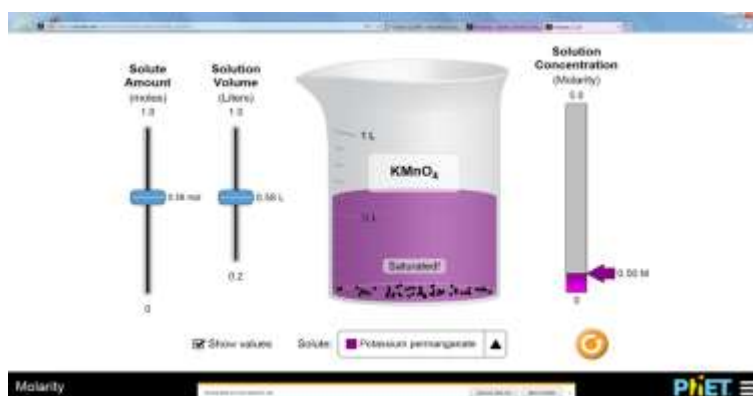
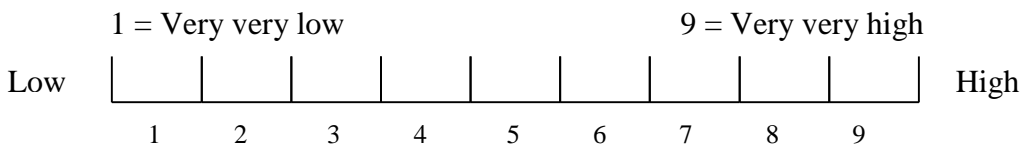
After answering the question please rate the effort level you had to make to answer the question.

The screenshot shows a digital simulation for calculating molarity. On the left, there are two vertical sliders. The first slider is labeled 'Solute Amount (moles)' and has a value of 0.20 mol. The second slider is labeled 'Solution Volume (Liters)' and has a value of 0.50 L. To the right of these sliders is a beaker containing a yellow liquid, labeled 'K<sub>2</sub>CrO<sub>4</sub>', with a 0.5 L mark on its side. At the bottom of the interface, there is a 'Show values' checkbox and a 'Solute' dropdown menu currently set to 'Potassium chromate'.

1- The molarity of the solute in the above picture will be

- 1.00 M
- 2.00 M
- 3.00 M
- 4.00 M

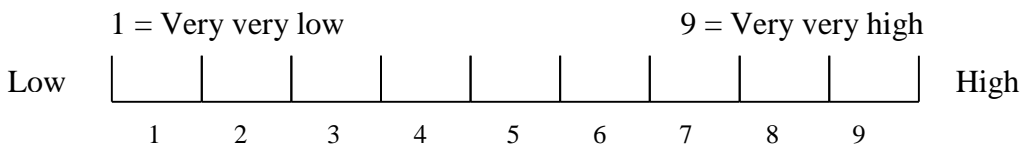
On the given scale of one to nine rate the effort you had to exert to solve this item.



2- In the above picture the solution is saturated. What do you understand by the term, “saturated?”

- No more solvent can be added
- No more solute can be added
- The solute is less than required to make the solution
- The solvent is less than required to make the solution

On the given scale of one to nine rate the effort you had to exert to grasp this topic (solve this item)



3- How many moles of potassium permanganate ( $\text{KMnO}_4$ ) will be required to make half a liter of 0.25M solution?

- 25 mol.
- 50 mol.
- 125 mol.
- 150 mol.

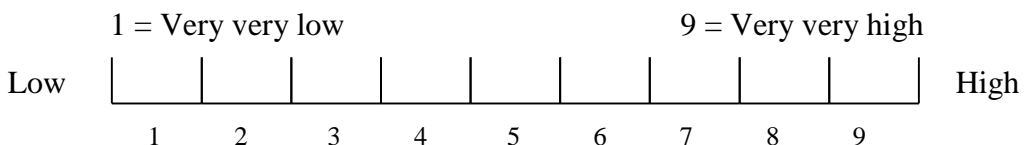
On the given scale of one to nine rate the effort you had to exert to grasp this topic (solve this item)



4- As the quantity of the solute increases, the color of the solution becomes:

- darker
- lighter
- Opaque
- Milky

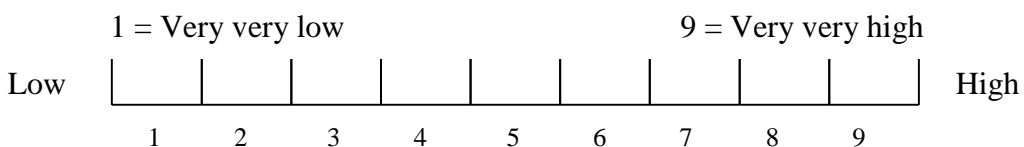
On the given scale of one to nine rate the effort you had to exert to answer this question.



5- If you dissolve 0.85 moles of Nickel Chloride ( $\text{NiCl}_2$ ) to make 0.5-liter solution. What will be the molarity of the solution?

- 1.00 M
- 1.50 M
- 1.70 M
- 1.75 M

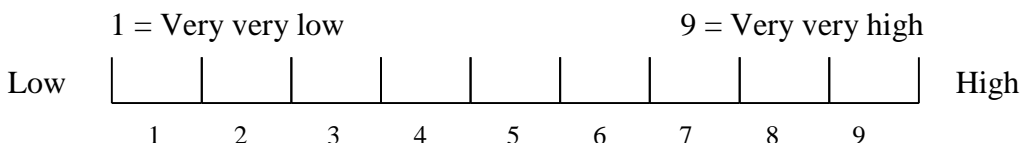
On the given scale of one to nine rate the effort you had to exert to grasp this topic (solve this item)



6- How much solution will Mary be able to get if she adds 0.23 moles of a solute and obtains a 0.45M solution?

- 0.23L
- 0.45L
- 0.51L
- 0.55L

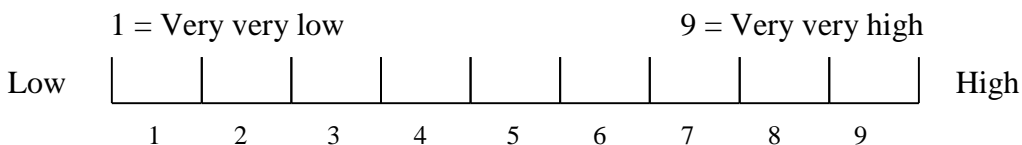
On the given scale of one to nine rate the effort you had to exert to grasp this topic (solve this item)



7- John is working in chemistry lab and wants to have 1L of 0.1M solution. How much solute will he dissolve in the solvent?

- 0.1moles
- 0.2moles
- 0.3moles
- 0.4moles

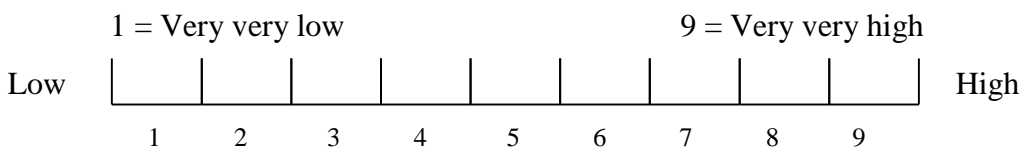
On the given scale of one to nine rate the effort you had to exert to grasp this topic (solve this item)



8- A chemist wants to make some 0.1M solutions how many moles of the solute will he need to make 0.5L of the solution?

- 0.03
- 0.05
- 0.04
- 0.01

On the given scale of one to nine rate the effort you had to exert to grasp this topic (solve this item)

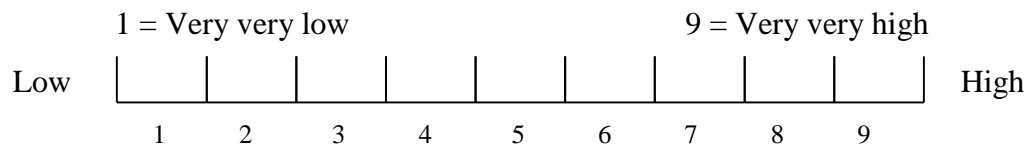


**APPENDIX E****KEY TO CORRECT ANSWERS**

Item Number	Correct Answer	Possible points
1	a	1
2	b	1
3	c	1
4	a	1
5	b	1
6	c	1
7	a	1
8	b	1

**APPENDIX F****9-POINT LIKERT SCALE FOR COGNITIVE LOAD  
(adopted from Paas (1992))**

On the given scale of one to nine rate the effort you had to exert to grasp this topic (solve this item)



## APPENDIX G

### MEASUREMENT SCALE ADOPTION OF INNOVATION

(Please tick the scale which you consider correct per your own experience and perception.) The continuum ranges from extremely likely to extremely unlikely as below:

Extremely likely= 7, Quite likely= 6, Slightly likely=5, Neither= 4, Slightly unlikely=3, Quite unlikely=2, Extremely unlikely=1

#### Perceived usefulness

Using simulations in my job would enable me to accomplish tasks more quickly.

Likely								Unlikely
	Extremely	Quite	Slightly	Neither	Slightly	Quite	Extremely	

Using simulations would improve my learners' performance.

Likely								Unlikely
	Extremely	Quite	Slightly	Neither	Slightly	Quite	Extremely	

Using simulations while teaching would increase my productivity.

Likely								Unlikely
	Extremely	Quite	Slightly	Neither	Slightly	Quite	Extremely	

Using simulations would enhance teaching effectiveness.

Likely								Unlikely
	Extremely	Quite	Slightly	Neither	Slightly	Quite	Extremely	

Using simulation would make it easier to achieve my class objectives.

Likely								Unlikely
	Extremely	Quite	Slightly	Neither	Slightly	Quite	Extremely	

#### Perceived ease of use

Learning to use simulations would be easy for me.

Likely								Unlikely
	Extremely	Quite	Slightly	Neither	Slightly	Quite	Extremely	



I find it easy to get simulations to do what I want it to do.

Likely        Unlikely

Extremely Quite Slightly Neither Slightly Quite Extremely

I find simulations to be flexible to interact with.

Likely        Unlikely

Extremely Quite Slightly Neither Slightly Quite Extremely

It will be easy for me to become skillful at using simulations.

Likely        Unlikely

Extremely Quite Slightly Neither Slightly Quite Extremely

I find simulations easy to use.

Likely        Unlikely

Extremely Quite Slightly Neither Slightly Quite Extremely

### Perceived attributes of adoption of simulation

Using simulation is compatible with the teaching-learning activities in my school.

Likely        Unlikely

Extremely Quite Slightly Neither Slightly Quite Extremely

Using simulation fits well with the way I like to work.

Likely        Unlikely

Extremely Quite Slightly Neither Slightly Quite Extremely

Using simulation would require our school to make substantial changes to our prevailing teaching practices.

Likely        Unlikely

Extremely Quite Slightly Neither Slightly Quite Extremely

It will be difficult to train teachers and staff to use simulations.

Likely        Unlikely

Extremely Quite Slightly Neither Slightly Quite Extremely

It will be complicated to use simulations in any program.

Likely        Unlikely

Extremely Quite Slightly Neither Slightly Quite Extremely

It is okay for me to try out simulations on a limited basis before full implementation.

Likely        Unlikely

Extremely Quite Slightly Neither Slightly Quite Extremely

Instructors/students will like the changes if simulations are used.

Likely        Unlikely

Extremely Quite Slightly Neither Slightly Quite Extremely

Using simulations will enhance my effectiveness on the job.

Likely        Unlikely

Extremely Quite Slightly Neither Slightly Quite Extremely

Using simulation will enhance the quality of education in our school.

Likely        Unlikely

Extremely Quite Slightly Neither Slightly Quite Extremely

Using simulation will have no effect on students' learning.

Likely        Unlikely

Extremely Quite Slightly Neither Slightly Quite Extremely

Use of simulations requires more work than can be done with the prevailing system.

Likely        Unlikely

Extremely Quite Slightly Neither Slightly Quite Extremely

Even if my school did not encourage the use of simulations, I would like to use it in my courses.

Likely        Unlikely

Extremely Quite Slightly Neither Slightly Quite Extremely

Overall, I find use of simulations to be advantageous for my school and the academic work.

Likely        Unlikely

Extremely Quite Slightly Neither Slightly Quite Extremely

## APPENDIX H

### CHECKLIST FOR PERCEPTION OF LEARNER CONTROL

Please rate the level of control that you perceive you had in the whole experiment.  
The continuum ranges from strongly agree to strongly disagree as following: -  
5 = Strongly Agree, 4 = Agree, 3 = I don't know, 2 = Disagree, 1 = strongly Disagree

I had control over how to access and work with the simulation

Agree	<div style="display: flex; justify-content: space-between; height: 20px; border-bottom: 1px solid black;"> <span style="width: 20%;"></span> <span style="width: 20%;"></span> <span style="width: 20%;"></span> <span style="width: 20%;"></span> <span style="width: 20%;"></span> </div>	Disagree
	5                  4                  3                  2                  1	

I had choices over which ever solute to choose and work with

Agree	<div style="display: flex; justify-content: space-between; height: 20px; border-bottom: 1px solid black;"> <span style="width: 20%;"></span> <span style="width: 20%;"></span> <span style="width: 20%;"></span> <span style="width: 20%;"></span> <span style="width: 20%;"></span> </div>	Disagree
	5                  4                  3                  2                  1	

I was free to work with as many solutes as I wanted to

Agree	<div style="display: flex; justify-content: space-between; height: 20px; border-bottom: 1px solid black;"> <span style="width: 20%;"></span> <span style="width: 20%;"></span> <span style="width: 20%;"></span> <span style="width: 20%;"></span> <span style="width: 20%;"></span> </div>	Disagree
	5      5                  4                  3                  2                  1	

It was up to me to vary the quantity of the solute or the solvent

Agree	<div style="display: flex; justify-content: space-between; height: 20px; border-bottom: 1px solid black;"> <span style="width: 20%;"></span> <span style="width: 20%;"></span> <span style="width: 20%;"></span> <span style="width: 20%;"></span> <span style="width: 20%;"></span> </div>	Disagree
	5                  4                  3                  2                  1	

I am satisfied with the provided control

Agree	<div style="display: flex; justify-content: space-between; height: 20px; border-bottom: 1px solid black;"> <span style="width: 20%;"></span> <span style="width: 20%;"></span> <span style="width: 20%;"></span> <span style="width: 20%;"></span> <span style="width: 20%;"></span> </div>	Disagree
	5                  4                  3                  2                  1	

Give completed questionnaires to your class rep or your instructor.

Thank you for your time,  
Tayyaba Batool  
Student Ph.D. ID&T  
Old Dominion University Norfolk, VA

**APPENDIX I**  
**SCRIPT FOR THE VIDEO**  
**(Instructor guidance)**

Hi everybody! Today we are going to learn from a simulation.

As you see in front of your screen there are three things; solute amount in moles, solution volume, and solution concentration or molarity (the cursor is moved over the three spinners in the simulation).

This is a beaker in which you see a solution (the researcher points at the beaker). A solution is normally a liquid that has something mainly a solid that is called a solute is dissolved in it.

Right now, we have a solution of drink mix. If we click over here to show values, we'll get the values of the solute and the volume of solution. We see the volume of the solution here and the molarity displayed over here (cursor being moved).

Now both the amount of the solute and the volume of the solution are 0.5 moles and 0.5 liters or half a liter. If we keep the amount of the solution constant and try to change the volume of the solution, let's see what happens?

So, if we start increasing the volume, you see the color of the solution lightens up while the molarity becomes lower. You can see again while I am increasing the solution volume, you see the changes in the color and the molarity.

Now if you bring the solution volume to a constant to 0.5 liters or half liter again and try to change the moles of the solute. First, we try to increase it. Now notice that that as I am increasing the solute amount, the color of the solution is darkening while the molarity is increasing.

Now if I start decreasing the amount of the solute, notice that the color of the solution is becoming lighter and molarity is becoming lower. (At this point the researcher paused the video and asked the participants to go to their activity and answer question number one and two).

Bring it to a constant and let's change the solute. Let's get a different color and have gold chloride. Now we have 0.5 moles and 0.5 liters of solution and the molarity is 1.00. Now what I am going to do is decrease the volume of the solution. While I am decreasing the volume, you can see the color is becoming darker and the molarity is increasing. Now let's bring it to 0.5 liters again and let's increase the solute amount. The same effect can be seen again, the color of the solution is darkening and the molarity is increasing. Now if we decrease the solute amount, the solution becomes lighter and the molarity decreases. From here what we understand is that molarity is a relationship between amount of solute in moles and the volume of solution in liters. It means that if we divide the amount of solute in moles by the volume of solution liters, we get molarity of that solution.

The other thing that we noticed is that the amount of solute is directly proportional to molarity while the volume of solution is indirectly proportional to molarity. It means that as we increase the solute, the molarity increases and if we decrease it, it will decrease. If we increase the volume of the solution, molarity decreases and when we decrease the volume, molarity increases.

Let's try another solute. Let us try Potassium permanganate. Let's bring the volume here to a constant by increasing the solution volume and decreasing the amount of the solute.

The volume of the solution is almost one liter and the amount of the solute is 0.343 mol. If we go on increasing the amount of the solute, note the color of potassium permanganate is darkening and molarity is increasing. At a certain point, these black dots or crystals of Potassium

permanganate appear (the mouse is moved around the crystals) in the bottom of the beaker. This means the solution is saturated. Saturated means no more solute can be dissolved in the solution. If you go on increasing the amount of solute, more crystals appear in the bottom. It means the solution is becoming supersaturated and molarity is increasing of course.

Let's change the solute again. This time let's go to Nickel chloride. It is a different color. Let's bring the solution volume to 0.5 liters and let's bring the amount of solute to 0.5 as well. Here the molarity is 1.00M because of you divide 0.5 moles by 0.5 liters you get one.

Now let's work with the solute first. Let's increase it. We are increasing the amount of the solute and the color of the solution is darkening and molarity is increasing. We kept the volume of the solution constant at 0.5L. Now see that at 0.981 moles and 0.5 liters, the molarity is 1.962 M. Let us increase the volume of the solution. As we go on increasing, the molarity goes on decreasing.

So, that's it for today. Now you go to the papers given to you and work on them. Good luck.

**Note:** Throughout the video the researcher kept on moving the mouse and pointing toward whatever was being explained.

## APPENDIX J

### VITA

#### Tayyaba Batool

#### EDUCATION

Old Dominion University, Doctoral candidate Instructional Design and Technology  
Dissertation: Effects of learner control when using instructional simulation.

Allama Iqbal Open University Islamabad, M.Ed.  
Science Education (2006)

Fatima Jinnah Women University Rawalpindi, M.Sc.  
Behavioral Sciences (2000)

P. A. F. College of Education Chaklala Rawalpindi, B. Ed.  
Biology, Chemistry (1998)

Government Post Graduate College for Women Jhelum, B.Sc.  
Chemistry, Botany, Psychology (1997)

#### PRESENTATIONS

Batool, T., and Watson, G. S. (2015, July). Use of mobile phones for interaction in distance education. At the AACE EdMedia conference Quebec, Montreal, Canada.

Batool, T., Watson, G. S., Morrison, G. R. (2015, November). Diffusion of Social Networking in Distance Education in Pakistan. AECT, Indianapolis.

Watson, G. S., Batool, T., and Enderson, M. (2015, November). Design showcase, Excelets as efficient and effective modeling tools. AECT, Indianapolis.

Batool, T., and Watson, G. S. (2016, April). Evaluation of Excelets as an effective modeling tool. VMASC ODU, VA.

Batool, T. (2016, April). Diffusion of Social Networking in Distance Education in Pakistan. Graduate Achievement Day, ODU Norfolk, VA.

Watson, G.S., Batool, T., Enderson, M. (2016, July). Design considerations in Excelets: interactive excel spread sheet. AACE Elearn conference Washington DC.

RESEARCH IN PROGRESS

Batool, T., Watson, G. S., Morrison, G. R. (2016). Perception of teachers and students related to diffusion of social networking in distance education in Pakistan.

PROFESSIONAL EXPERIENCE

Teaching Science	2002-2011
Government Girls High School Miana Mohra	

Teaching Science	2011-2012
Government Girls High School Kauntrila	

SERVICE AND LEADERSHIP

2013-2014	Secretary Muslim Students Association Old Dominion University, Norfolk, VA.
2015	Treasurer Muslim Students Association Old Dominion University, Norfolk, VA.
2014	Chair Academic Performance, International Students Advisory Board (ISAB). Old Dominion University Norfolk, VA
2015	Vice President, International Students Advisory Board (ISAB). Old Dominion University Norfolk, VA

PROFESSIONAL ORGANIZATIONS

Association of Educational Communication and Technology (AECT)  
 American Educational Research Association (AERA)  
 Association for the Advancement in Educational Computation (AAACE)