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## **The Effect of Interleaved Practice in a High School Chemistry Class**

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The Effect of Interleaved Practice in a High School Chemistry Class

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Northwestern College

An Action Research Project Presented

in Partial Fulfillment of the Requirements

For the Degree of Master of Education

**Table of Contents**

Abstract .....	3
Introduction .....	4
Literature Review .....	7
Interleaving in Athletics .....	7
Academic Skill Interleaving .....	8
Explanations for Interleaving Benefits .....	10
Sequential Attention Theory .....	12
COCAT .....	13
Gaps in the Research .....	14
Summary and the Need for Research .....	15
Methods .....	15
Findings .....	17
Summary of Major Findings .....	20
Limitations of the Study .....	23
Further Study .....	23
Conclusion .....	24
References .....	25

### **Abstract**

Determining practices to produce optimal learning outcomes is a foundational objective for educators. Recent publications have identified the importance of practice sequencing structures (blocked vs interleaved) on learning. While this information has significant value for education, few studies have been conducted in authentic educational environments. This action research involved high school chemistry students ( $n=25$ ) completing a practice assignment covering mole-mass conversions. One group practiced these problems in a blocked organization while the other was interleaved. Immediately following this assignment, students noted their completion time and rated their perceived difficulty. Three days later, students were given an unannounced interleaved assessment of mole-mass conversions. The interleaved group outperformed the blocked group on the assessment by 13%. However, the blocked group outperformed the interleaved group on the assignment by 8%. The interleaved assignment was more time consuming (7.8%) and perceived to be more difficult (12%) than the blocked group. The results from this action research demonstrate that interleaved practice can be utilized in accordance with the sequential attention theory to improve delayed retention of instructional material. Further research should be conducted in authentic educational environments to identify guidelines for determining educational interleaving applications.

## The Effect of Interleaved Practice in a High School Chemistry Class

### Introduction:

A foremost objective of educators is to optimize the rate at which students construct their understanding of academic concepts. The achievement of this pursuit requires teachers to apply research-based strategies for student learning. One of these strategies that shows educational promise in mathematics (Rohrer et al., 2020; Barzagar Nazari & Erbersbach, 2019; Rohrer, Dedrick & Stershic, 2015), presentation of science category learning (Eglinton & Kang, 2017), foreign language pronunciation learning (Carpenter & Mueller, 2013), verbal category learning (Sorensen & Woltz, 2016) and painting style identification (Kang & Paschler, 2012), but is still “relatively unexplored” (Brunmair & Richter, 2019), is the utilization of strategic study sequencing. Study sequencing is primarily categorized in terms of interleaved or blocked practice. *Interleaving* is the process of organizing practice problems to be “systematically intermixed” (Sorensen & Woltz, 2016). *Blocked* practice occurs when similar tasks are practiced together.

In a sample blocked practice assignment covering basic arithmetic, a student might complete five addition problems in a row (skill A), followed by five subtraction (skill B), and then five multiplication problems (skill C). If this blocked assignment had an organization of  $A_1A_2A_3A_4A_5B_1B_2B_3B_4B_5C_1C_2C_3C_4C_5$ , interleaved practice might have an organization of  $A_1B_1C_1B_2A_2C_2B_3A_3B_4A_4C_3A_5C_4B_5C_5$ . Research has suggested that there are different conditions in which blocked or interleaved practice is more effective (Carvalho & Goldstone, 2020; Brunmair & Richter, 2019). The problem is that very few studies have researched this topic in an educational setting (Brunmair & Richter, 2019; Rohrer, 2012). As stated by Brunmair

& Richter (2019) studies involving actual educational materials are “clearly underrepresented” (p. 20).

Sequential attention theory is a prominent explanation describing the cognitive mechanisms involved with blocked and interleaved practice (Carvalho & Goldstone, 2017). The purpose of this action research is to test the application of sequential attention theory to question sequencing of novel computational material in an actual high school chemistry class. Previous research has postulated that interleaving is more beneficial for identifying differences between closely related categories (Carvalho & Goldstone, 2017). In a typical chemistry class, there are many situations where students are learning to distinguish between closely related concepts. No published research on this topic has been conducted with actual high school chemistry students. This action research will examine the effect question sequence (interleaving vs blocking) has on the assessment results of closely related computational concepts in a chemistry classroom.

Articles for this literature review were found using Google Scholar and the Northwestern College Library Database. The literature selected primarily focused on educational applications and the cognitive mechanisms responsible for learning through blocked or interleaved practice. The terms “interleaving”, “blocked”, “interleaved”, and “blocking” were used to identify articles to be analyzed. Aside from the foundational studies, literature was limited to peer-reviewed journals published between 2011-2021. The peer-reviewed scholarly articles consisted primarily of studies with the exception of a literature review and a meta-analysis.

Interleaving will produce better assessment results than blocked practice when used for solving computational problems from closely related categories in a high school chemistry classroom. According to the sequential attention theory, interleaving helps learners juxtapose different types of problems (Carvalho & Goldstone, 2017). Blocked practice helps students learn

similarities within a particular practice category. This research will be valuable because few studies have occurred in an educational setting. The findings of this investigation will contribute to the limited body of “ecologically valid” (Rohrer, 2012) educational research and will have practical implications that may benefit educational practitioners.

This literature review will begin by looking at the foundational studies for interleaving in fine-motor skill development and educational settings. The various explanations for possible cognitive mechanisms that interleaving, and blocking has on learning will be analyzed. The discriminative contrast hypothesis and the distributed practice hypothesis will be evaluated to explain the interleaving effect. The sequential attention theory will be compared with the recently published yet conflicting COCAT (change one concept at a time) principle. These different viewpoints will be described considering how the published literature has supported or refuted their explanations.

## **Literature Review**

There is a growing field of research focused on study strategies intended to improve student learning. According to Dunlosky et al. (2013), methods such as practice testing, elaborative interrogation, self-explanation and interleaving are considered significantly more effective than commonly used strategies like rereading and highlighting texts. Interleaving has shown to be effective under certain conditions but needs more exploration (Brunmair & Richter, 2019). Considering the importance interleaving may have to maximize learning in educational settings, more empirical research is needed (Rohrer, 2012; Brumair et al. 2013).

## **Interleaving in Athletics**

Some of the first studies about interleaving occurred in athletic settings. A study by Goode and Magill (1986) analyzed participants practicing three different types of badminton serving techniques. One group practiced the serving in a blocked sequence. One group practiced in a semi-random sequence, and the other utilized a random practice sequence. Following two weeks of practice, participants were tested on skill retention. The group that learned the serving in a random sequence significantly outperformed the blocked and semi-random groups on skill retention.

Merbah and Meulemans (2011) evaluated 24 published studies on blocked versus random practice in motor skill development. The consensus of published literature suggests random practice, interleaving, has an advantage in motor skill acquisition. The exact cognitive mechanism for this is unknown, but it is hypothesized that randomly ordered practice requires more “cognitive activity” than blocked practice (Merbah & Meulemans, 2011).



### **Academic Skill Interleaving**

After the foundational work of interleaved practice was explored in motor skill development, it was studied in an educational setting. Rohrer and Taylor (2007) conducted the first known study comparing blocked and interleaved practice in mathematics. This study involved undergraduate students calculating the volumes of geometric shapes. Students were split into a blocked practice group and an interleaved group. The blocked group had similar types of questions aggregated together. The interleaved group had all of the practice problems randomly organized. After the tutorial on how to solve problems, the blocked practice group did better on their assignments. However, a week after the practice lessons, students were assigned a test with eight new questions. The interleaved group scored 43% better than the blocked group (Rohrer & Taylor, 2007).

Taylor & Rohrer (2010) completed a similar study with participants of different grade levels. Fourth graders were given prism-related math problems. There was a blocked practice group and an interleaved practice group. Similar to the previous study, the blocked group performed better on the practice problems, but the interleaved group performed 39% better than the blocked group on a test they took one day later (Taylor & Rohrer, 2010). Other studies have found beneficial interleaving results consistent with this in mathematics (Rohrer et al., 2015; Rohrer et al., 2020; Barzagar Nazari & Ebersbach, 2019; Sana et al., 2017, Foster et al., 2019).

However, these results do not seem to be universal in terms of subject matter. A study by Carpenter and Mueller (2013) looked at interleaving compared to blocking on foreign language pronunciation. Participants were undergraduate students at Iowa State University in a psychology course. They were tasked with learning pronunciations of French words. After a practice session,

they completed an assessment. The blocked group retained pronunciation of the French words better than the interleaved practice group.

This study mentioned some of the potential implications of their findings (Carpenter & Mueller, 2013). They echoed the notion of Dunlosky et al. (2013) that guided practice may be necessary for interleaving to be beneficial. They also noted that this study didn't test retained information over a longer period of time like previous studies (Rohrer & Taylor 2007; Taylor & Roher 2010).

Pan et al. (2019) provided further insight to the findings of the Carpenter & Mueller study (2013). They found that blocked practice in a single session learning of Spanish verb conjugation performed better or equal to interleaved practice, but interleaved practice performed better over multiple practice sessions. Considering the long-term benefits of interleaved practice, the researchers suggested a "blocked-to-interleaved schedule" to foreign language learners.

Brunmair & Richter (2019) completed a meta-analysis of interleaved learning. They compared the findings of 59 studies containing similar structures of interleaved and blocked groupings. They found that interleaved learning is more successful with visual and mathematical tasks. For example, studies have demonstrated better results with interleaving when assessed on naturalist painting recognition (Kang & Pashler, 2012), discriminating categories of alien cartoons (Carvalho & Goldstone, 2017), matching definitions with terminology (Carvalho & Goldstone, 2021) and organic chemical compound recognition (Eglington & Kang, 2017).

However, interleaving tends to be less advantageous for learning related to words (Brunmair & Richter, 2019). Blocking has shown to be more effective for writing definitions (Carvalho & Goldstone, 2020) and learning new names for categorizing common objects (Sorensen & Woltz, 2016).

### **Explanations for Interleaving Benefits**

The benefits of blocked or interleaved learning sequence will vary depending on the type of task (Sorensen & Woltz, 2016). Multiple hypotheses have been proposed to describe the cognitive mechanisms to explain this phenomenon. The *interleaving effect* refers to situations in which interleaving outperforms blocked practice. Two hypotheses that attempt to explain the interleaving effect are the *discriminative contrast hypothesis* and the *distributed practice hypothesis*. The discriminative contrast hypothesis suggests that individuals identify similarities and differences between problems when interleaved practice is utilized (Foster et al. 2019).

Studies have shown that spacing out practice repetitions leads to greater learning than massed practice (Metcalfe & Xu, 2016; Barzagar Nazari & Ebersbach, 2019; Schutte et al.,2015). Rohrer et al. (2014) suggested that the learning gains from interleaved practice resulted from the inherent spacing between similar types of practice problems. Temporal spacing between similar problems is the proposed mechanism for the distributed practice hypothesis.

A study of remote and in-persons undergraduate students from Kent State analyzed blocked vs interleaved practice of mathematics concepts (Foster et al. 2019). Two groups of participants (interleaved and blocked) completed the practice and assessment in person and the other two groups were remote (interleaved and blocked). The in-person participants completed all of the practice problems in one sitting. The remote-learning participants completed the practice problems over multiple sittings.

The in-person interleaving, and remote interleaving groups outperformed the blocked groups in an assessment of these math concepts. The remote interleaving group had the best assessment results. Since the remote interleaving group had the most spacing between practice

attempts, this experiment supports the distributed practice hypothesis (Foster et al. 2019). If the discriminative contrast hypothesis was the only factor leading to the interleaving effect, the results between both interleaving groups should be in favor of the in-person group. Foster et al. (2019) was clear to point out that the discriminative contrast hypothesis may play an important role in these findings, but the distributed practice hypothesis was a better explanation for the experimental results.

While the experiment by Foster et al. (2019) supports the distributed practice hypothesis, other experiments more heavily support the discriminative contrast hypothesis. Carvalho & Goldstone (2014) conducted a study to see if the benefits of interleaving are directly related to the increased time delay between questions. This experiment was designed to test the distributed practice hypothesis. One group of participants completed interleaved practice problems without a time delay and the other group had a time delay. The experimental results suggested that interleaving is not effective due to time delays in a single sitting. Other experiments involving time delays with interleaving have found similar results (Birnbaum, Kornell, Bjork & Bjork, 2013; Kang & Paschler, 2012; Zulkipli & Burt, 2013; Sana et al., 2017). These results suggest that the distributed practice hypothesis isn't the sole mechanism for the interleaving effect.

Carvalho & Goldstone (2014) suggested that interleaving is primarily successful due to cross-categorical comparisons. This suggestion favors the discriminative contrast hypothesis. Interleaving is best when categories are relatively similar and blocked practice is most effective when there is low similarity within a group. This implies that interleaving should be used in relatively short time intervals, so that cross-categorical comparisons can be made. In an experiment by Eglington & Kang (2017), two organic molecules were presented simultaneously for participants to compare. Following the presentation, participants completed a test of organic

molecule categorization. The interleaved group performed the best. Eglington & Kang (2017) suggested that the results were consistent with the discriminative contrast hypothesis because participants analyzed the juxtaposed examples to identify differences between both categories.

Kang & Pashler (2012) conducted an experiment comparing simultaneous interleaving with spaced interleaving of novel paintings. This experiment provided insight on the mechanisms involved with interleaving. The participants who simultaneously interleaved outperformed the spaced interleaving group. The results of this experiment suggest that the interleaving effect occurred due to discriminative contrast instead of distributed practice (Kang & Pashler, 2012).

Birnbaum et al. (2013) continued the work of Kang and Pashler (2012) by constructing a series of experiments involving the categorization of butterfly and bird images. In one of these experiments, a group completed interleaved practice without spacing, and the other group completed interleaved practice with time between each repetition. The spaced interleaved condition performed worse than the interleaved group that practiced without a delay. The results of this study support the discriminative contrast hypothesis.

### **Sequential Attention Theory**

Carvalho & Goldstone (2015) noticed the gaps in the discriminative contrast hypothesis and the distributed practice hypothesis in relation to the interleaving effect. Carvalho & Goldstone (2015) suggested a more thorough explanation known as the *sequential attention theory*. This theory suggests that as learners encounter novel material, they compare and contrast material using similarities and differences. Different practice sequences (blocked and interleaved) result in differing patterns with attention (Carvalho & Goldstone, 2017). When there is a high degree of difference between problems within a category, blocking tends to be more effective (Carvalho & Goldstone, 2014). Carvalho & Goldstone (2017) suggest this effect is due

to the way blocking directs attention to “characteristic properties” of a particular topic. Interleaved practiced showed improved performance when the test required discrimination between two concepts (Carvalho & Goldstone, 2021).

## **COCAT**

Abel, Brunmair & Weissgerber (2021) recognized that most research on blocked and interleaved practice had only examined classification of concepts on one categorical level. The literature supporting the sequential attention theory and the discriminative contrast hypothesis is limited in scope because most concepts are constructed with various levels of categorization. For example, *pizza* belongs to the categories of *Italian*, *dairy*, *carbohydrate*, and *bread* among others. Abel et al. (2021) sought a more robust explanation for sequencing effects across multiple categories.

Abel et al. (2021) conducted an experiment with a 2 x 2 factorial design. The first two conditions were the study sequence between subjects (interleaved vs blocked). The other two conditions were whether categories within those subjects were blocked or interleaved. The study found that sequences that combined interleaving in one dimension while blocking the other did better than sequences that blocked or interleaved both conditions. These findings aren't compatible with the discriminative contrast hypothesis or the sequential attention theory because they suggest that interleaving shouldn't help within-category comparisons (Abel et al. 2021).

Abel et al. (2021) proceeded to suggest a novel COCAT (change one category at a time) principle. When skills are practiced with interleaving in one dimension and blocking on another, individuals are able to identify common characteristics and distinctions between the two categories. If both dimensions are interleaved, individuals will have a tendency to confuse “changing characteristics” (Abel et al., 2021). If blocking is used on both dimensions,

individuals will have a tendency to confuse “common characteristics”. This principle is supported by a recent study. Yan & Sana (2021) constructed an experiment involving undergraduate students who were tasked with studying concepts from two domains (physics and statistics) in various sequencing (blocked and interleaved). Learning was best when one level was interleaved and the other level was blocked (Yan & Sana, 2021).

### **Gaps in The Research**

The effect of interleaving is still in its early stages. There are many applications in which it hasn't been studied. There is a lack of empirical evidence to determine the context in which interleaving is of highest utility (Yan & Sana, 2021). According to Brunmair & Richter (2019), minimal studies have looked beyond mathematical tasks, visual items and expository texts. For this reason, Brunmair & Richter (2019) consider that the research blocked, and interleaved practice is “relatively unexplored”. Birnbaum et al. (2013) suggest that findings from their experiments are important for education. Very few studies have occurred in a classroom with actual students. As mentioned by Rohrer (2012), more studies in a real classroom are needed.

There is a clear message across the research that practice shouldn't just be looked at as a blocked vs. interleaved dichotomy (Carvalho & Goldstone, 2020). There are situations where blocking is of highest utility and other situations where interleaving is more impactful for learning outcomes. Researchers should examine the mechanisms of learning instead of “one-size-fits-all” approaches (Carvalho & Goldstone, 2017). Sorensen & Woltz (2016) suggest that future studies should contrast degrees of blocked and interleaved comparisons. Eglington & Kang (2017) suggested testing out interleaved presentations with more complex tasks, such as balancing chemical equations.

Chemistry involves visual, mathematical and conceptual understanding of material. There is no known action research on interleaved practice with high school chemistry students. Very few studies have experimented with actual students in a classroom. This research could provide clarity to the context in which is most effective.

### **Summary and The Need for Research**

The sequence in which skills are practiced influences the rate of learning. Studies suggest that there are conditions in which interleaved practice is more effective than blocked practice and vice versa. The sequential attention theory and the COCAT principle provide valuable insight for educational implementation of effective practice sequencing strategies. However, minimal research has been conducted in actual educational settings (Rohrer, 2012).

## **Methods**

### **Action Research Design**

The purpose of this action research is to determine the effect interleaved practice has on delayed assessment performance of closely related chemistry concepts in a high school setting. This action research is quantitative in nature. The independent variable is the practice question sequence under the two conditions of blocked or interleaved. The dependent variables are delayed interleaved assessment performance with a three-day delay, assignment completion time, and perceived assignment difficulty. The variables held constant include the notes given prior to the assignment and questions.

### **Participants**

Participants are 11th and 12th grade students enrolled in chemistry class. Chemistry is a non-required class typically taken by students that are more academically motivated than the average student. Treynor High School is a rural district in southwest Iowa located ten miles east



of the Council Bluffs/Omaha metropolitan area. Treynor has roughly 250 students enrolled in the high school.

### **Data Collection**

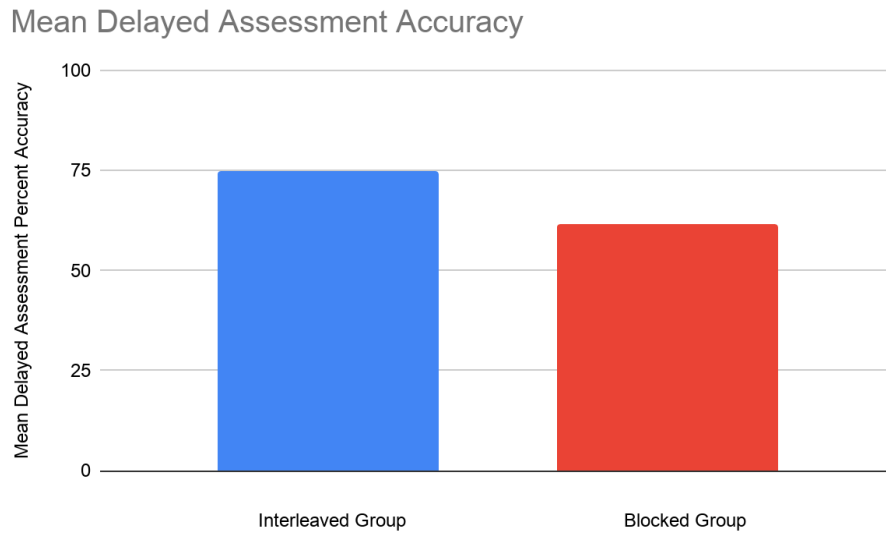
Participants completed mole-to-mass and mass-to-mole problems on a practice assignment. The practice assignment was constructed using textbook problems in Pearson Chemistry by Wilbraham, Staley, Matta and Waterman (2017). These questions were transferred to a physical worksheet. Prior to the completion of the assignment, students received direct instruction with guided practice questions for mole-to-mass and mass-to-mole conversions. Following this direct instruction, students independently completed their practice assignments.

Following the assignment, students had their papers checked for accuracy. Students completed a survey indicating the relative difficulty of the assignment on a 1-10 scale using a google form. Additionally, students documented the time it took to complete the assignment on this form. There was a timer projected in the front of the class in order for students to accurately measure the time to complete the assignment. Three days after the completion of the practice assignment, an unannounced assessment was administered. This assessment had questions randomly organized in an interleaved fashion.

## Findings

### Data Analysis

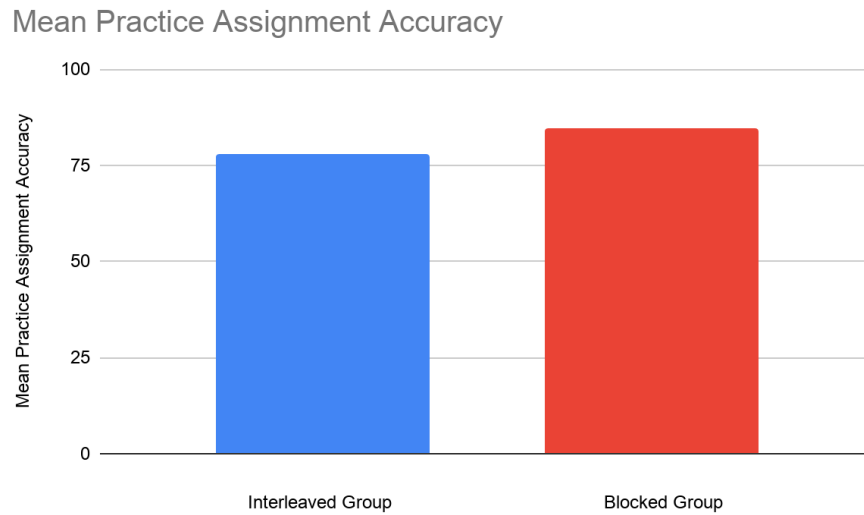
#### Delayed Assessment Score



**Fig. 1** The mean assessment score for the delayed assessment.

The mean delayed assessment percent accuracy is represented on Fig. 1. The interleaved group performed 13% better on the delayed assessment than the blocked group. The average interleaved assessment had 75% accuracy compared to the 61.7% accuracy of the blocked group. Sixty-nine percent of the interleaved group performed the same or better on the assessment compared to their practice assignment. For the blocked practice group, 40% of students performed the same or better on the practice assignment compared to their assessment.

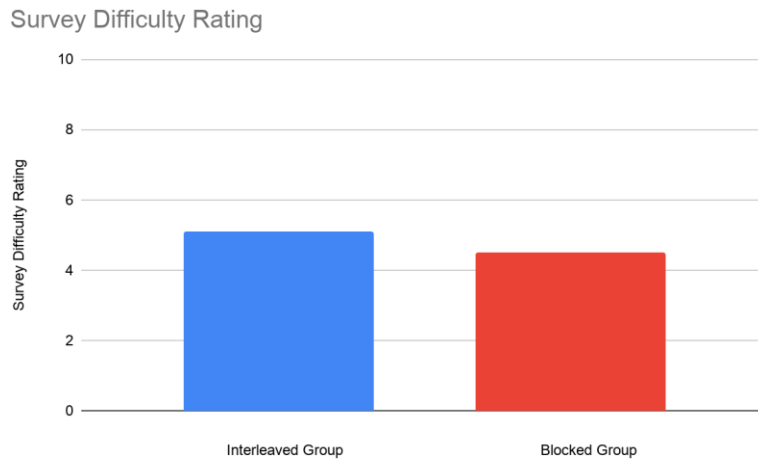
## Practice Assignment Accuracy



**Fig. 2** The mean score for the practice assignment.

The mean score for the practice assignment is displayed on Fig. 2. The blocked group performed 8% better on the practice assignment compared to the interleaved group. The average score for the interleaved practice assignment was 78%. The average score for the blocked assignment was 85%.

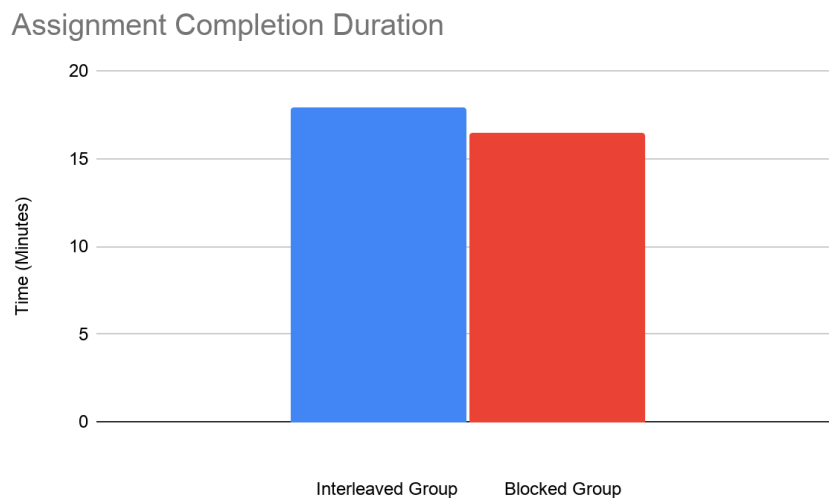
## Practice Difficulty



**Fig. 3** The mean difficulty rating from the practice assignment.

The mean difficulty rating for the practice assignment is displayed in Fig. 3. The interleaved group perceived the assignment to be 12% more difficult than the blocked group. The average practice difficulty was rated 5.1 out of 10 for the interleaved group and 4.5 out of 10 for the blocked practice group. The range of values for the interleaved group was 3-8 and the range of the interleaved group was 2-8.

### Assignment Completion Duration



**Fig. 4** The mean duration of time needed to complete the practice assignment.

The mean assignment completion duration is represented on Fig. 4. On average, the interleaved group took longer to complete. The average completion time was 17.9 minutes for the interleaved group and 16.5 minutes for the blocked group. The interleaved group took an average of 7.8% longer to complete.

## Discussion

### Summary of Major Findings

Interleaved practice produced superior results compared with blocked practice on a delayed, interleaved chemistry assessment. The content assessed, mole to mass conversions, was primarily computational in nature. The results of this action research were consistent with previous experiments in mathematics (Taylor & Rohrer, 2010; Rohrer et al., 2015; Rohrer et al., 2020; Barzagar Nazari & Ebersbach, 2019; Sana et al., 2017, Foster et al., 2019). However, it is

important to note that the practice wasn't solely computational. It also incorporated visual tasks and a conceptual understanding of components on the periodic table.

The discriminative contrast hypothesis suggests that the juxtaposition of problem types in practice causes learners to identify similarities and differences between the problems (Carvalho & Goldstone, 2014). There were two separate categories of problems in this action research. According to this hypothesis, interleaved practice should be more effective because it allows learners to consider the differences between these two categories. The results of this experiment support the discriminative contrast hypothesis. The degree of difference between problems within one category was relatively small. The degree of similarities between one type of problem was so low that blocked practice was ineffective according to the discriminative contrast hypothesis.

The distributed practice hypothesis suggests that the interleaving effect occurs as a result of temporal spacing between practicing a particular type of item (Rohrer et al., 2014). The results of this action research agree with the distributed practice hypothesis. Interleaved practice items had a delay between problems of one type to another. However, this action research wasn't designed with the intention to determine the mechanism of the interleaving effect.

The sequential attention theory states that different sequences of questions, blocked or interleaved, results in different attentional patterns (Carvalho & Goldstone, 2017). In this theory, blocking is more effective when there is a high degree of difference between problems of a particular category. Interleaved practice is more effective when there is discrimination between two concepts (Carvalho & Goldstone, 2021). In the case of this experiment, participants were assessed on two different concepts. The first was converting the mass of a substance to the moles

of that substance. The second was converting the moles of a substance to a mass of that substance. These results support the sequential attention theory. While more research is needed to clarify guidelines to optimize question sequencing on educational materials, the sequential attention theory should be utilized to design practice assignments.

Participants in the interleaved group performed worse on the practice assignment than the blocked group. Similar results occurred with Rohrer & Taylor (2007;2010). In those studies, participants in blocked practice groups performed better on the assignment but worse on the assessment. This implies that assignment performance doesn't necessarily transfer to assessment success. Additionally, the interleaved assignment was perceived to be slightly more difficult and time consuming than the blocked assignment.

These results suggest that effective sequencing in accordance with the sequential attention theory may create desirable difficulties for learning. Bjork (1994) coined the term desirable difficulties to represent situations in which challenges produce better long-term learning outcomes than predictable learning conditions. Bjork & Kroll (2015) noted that educators often use assignments that produce rapid improvements in performance but fail to optimize long-term retention. This is due to a lack of difficulty in these assignments. The action research results from this chemistry assignment seem to reflect this observation.

The sequential attention theory can be utilized by educational materials to produce better long-term learning outcomes with little to no additional cost. However, few educational materials seem to use the sequential attention theory in their design. Rohrer, Dedrick & Hartwig (2020) analyzed 13,505 problems from six mathematics textbooks and only identified 9.7% of problems as interleaved even though the interleaving effect has been consistently demonstrated in

mathematics. The educational materials could be improved by considering what is known about effective practice sequencing. For this reason, more studies should be conducted to provide clarity for guidelines related to interleaved and blocked practice in the classroom.

### **Limitations of the Study**

One limitation of this action research was the relatively small sample size ( $n=25$ ). Chemistry was selected because of the novel content and the computational connection to previous literature. However, there was a limited number of chemistry students. Replication of this experiment on a larger scale would provide stronger results.

The difficulty rating students completed after the practice assignment could have been improved with the addition of a rubric. The scale at which students evaluated the difficulty of the assignment was 1-10 without any descriptors by which to evaluate their judgements. Including descriptors would produce a more accurate judgment.

After the assessment was completed, it was evaluated privately. In a typical learning environment, immediate feedback would be provided by checking over the assignment as a class. This gives students the opportunity to determine if they accurately understand the material. The absence of this feedback could have influenced the assessment results.

### **Further Study**

This action research consisted of a single assignment and assessment pertaining to one skill. It would be beneficial to see more long-term studies in an authentic educational environment using blocked and interleaved groups. Rohrer et al. (2020) completed a large-scale trial of this nature with interleaved mathematics practice. Future studies could utilize this design in chemistry and other educational topics.



Blocked practice seems to be less difficult and more efficient than interleaved. However, it doesn't seem to produce the same long-term learning outcomes. Perhaps there is a blocked-to-interleaved ratio that is optimal for efficiency and effectiveness of long-term learning. Future studies could evaluate various blocked-to-interleaved schedules for time, perceived difficulty and long-term retention. Other researchers have mentioned that blocked-to-interleaving intervals may have value (Carpenter & Mueller, 2013; Dulosky et al., 2013; Rohrer et al., 2020).

The assignment in this action research only involved differentiating between two categories of problems. Future studies could analyze the categorical capacity in which interleaving is more effective. Experiments could change the number of categories that are interleaved for an assignment. This could provide clarity for instructional design of practice assignments.

## **Conclusion**

The results from this action research demonstrate that interleaved practice can be utilized in accordance with the sequential attention theory to improve delayed retention of instructional material in a high school chemistry class. Findings of this action research suggest that the sequential attention theory can be utilized by educators in designing problem sequences in practice assignments. Effective problem sequencing is a low-cost way to improve educational outcomes. However, research on interleaving and blocked practice is still in its early stages. Further research should be conducted to identify guidelines for interleaving applications in educational environments.

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