Chapter 18: Interleaved Practice in Classrooms

Jogymol K. Alex[1]
Angel Mukuka[2]

AFFILIATIONS
[1] United Arab Emirates University, United Arab Emirates
[2] Walter Sisulu University, South Africa

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18.1. Concept Map

Interleaved practice is a teaching method that involves mixing or alternating between different types of problems or topics during a single study session. It is based on the idea that varied practice can enhance learning outcomes by challenging learners to recall information from previous sessions and apply different strategies or rules based on the problem at hand. This chapter aims to provide a guide for teachers (both preservice and in-service) at all levels of education on how to select and implement interleaved practice in their classrooms. Figure 1 illustrates the conceptualisation of interleaved practice in this chapter.

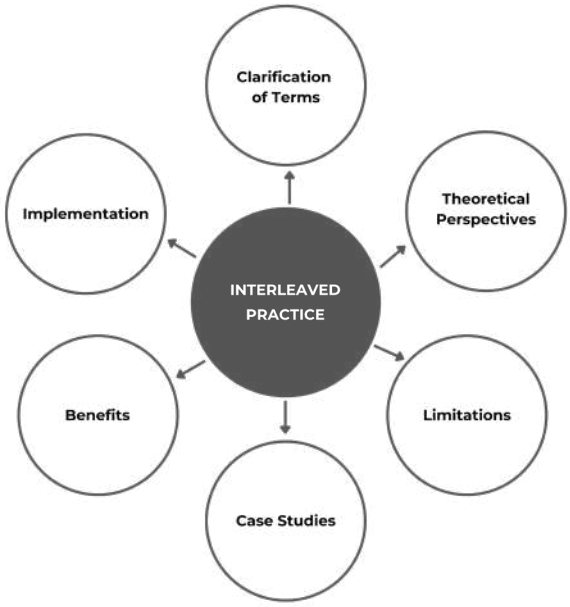

Figure 1. Chapter Map on Interleaved Practice in Classrooms

This chapter concludes by highlighting the importance, future directions, and emerging trends of interleaved practice in classrooms. It also provides reflective questions and references for further reading.

18.2 Learning Outcomes

- By the end of this chapter, readers should be able to:
- Define interleaved practice and differentiate it from blocked practice.
- Explain the theories that underpin interleaved practice in classrooms.
- Describe how to implement interleaved practice in a classroom setting.
- Identify the benefits of interleaved practice in classrooms.
- Understand the limitations of interleaved practice in classrooms.
- Apply interleaved practice in one's subject area of specialisation.
- Analyse case studies for successful implementations of interleaved practice.
- Discuss potential areas for further research and emerging trends.

These learning outcomes provide a roadmap for what the readers should know or be able to do by the end of the chapter.

18.3 Clarification of Key Terms: Blocked versus Interleaved Practice

Interleaved practice is a learning technique that involves mixing different topics or forms of practice, which can play a crucial role in developing holistic and adaptable learners in the 21st century. According to The Learning Agency Lab (2019), interleaved practice is the opposite of blocked practice, where students focus on one concept, one problem type, or one physical movement for a while. For example, after learning about the circumference of a circle, students would solve several problems on the same concept in blocked practice.

In contrast, interleaved practice involves cycling through multiple topics or subjects to learn each one. For example, students would solve problems on different concepts, such as volume, area, and perimeter, simultaneously in interleaved practice. Research shows that interleaving is generally more effective for long-term learning and application (Carvalho & Goldstone, 2019; Schorn & Knowlton, 2021).

Table 1 provides a sequence in which three mathematical concepts—circumference of a circle, area of a circle, and volume of a cylinder—could be presented, comparing both the blocked and interleaved practice approaches.
Table 1. Matrix representing the three geometric concepts taught in three blocked and interleaved sessions.

	Blocked Practice	Interleaved Practice
Session I	Students focus on calculating the circumference of a circle for an entire session.	The concept of circumference is mixed with other topics such as area and volume. Students solve a variety of problems in one session.
Session II	Students concentrate on calculating the area of a circle for a whole session.	The concept of area is interspersed with other topics. In one session, students might solve a problem related to circumference, the area, and the volume.
Session III	Students spend an entire session on calculating the volume of a cylinder.	The concept of volume is combined with other topics. Students might work on a problem related to circumference, the area, and then the volume in one session.

In blocked practice, students focus on one type of problem at a time, which can lead to better performance during practice but often results in poorer long-term retention and transfer of skills. In contrast, interleaved practice involves switching between different types of problems within a single study session. While this approach can be more challenging during practice, it typically leads to better long-term learning outcomes.

18.4 Historical Background and Theoretical Perspectives

Interleaved practice has a long history of research and development, dating back to the early 20th century. One of the pioneers of interleaved practice was William Battig, who conducted a series of experiments on verbal learning in the 1960s and 1970s. He found that learners who studied different categories of words in a random order performed better on a final test than those who studied the same categories in a blocked order (Battig, 1972). He coined the term "contextual interference" to describe the phenomenon whereby interleaving creates more interference and difficulty during practice than blocking but leads to better retention and transfer of learning. Since then, many researchers have investigated the effects of interleaved practice in various domains, including mathematics, science, art, sports, and music (Chen et al., 2021; Koh et al., 2018; Schorn & Knowlton, 2021; Wong et al., 2020). Different theoretical explanations for why interleaving works have also been established, such as the discriminative-contrast hypothesis (Birnbaum et al., 2013), the retrieval practice hypothesis (Kang & Pashler, 2012), the elaboration hypothesis (Reigeluth, 1999), and the reconstruction hypothesis (Lee & Magill, 1983).

The discriminative-contrast hypothesis posits that interleaving helps learners notice and compare the similarities and differences between concepts or skills, thus forming more accurate and generalisable representations of them. Based on their review of literature, Chen et al. (2021) established that the discriminative-contrast hypothesis explains interleaved practice by suggesting that interleaving assists learners in discriminating between topic areas. The retrieval practice hypothesis suggests that interleaving enhances learning by requiring learners to frequently retrieve and use prior knowledge in different contexts, which strengthens their memory and understanding (Kang & Pashler, 2012). In a classroom setting, retrieval and interleaved practices can be combined to enhance learning outcomes. For instance, teachers can structure their lessons so that different topics are covered in each session (interleaving), while students are regularly asked to recall and apply what they have learned in previous sessions (retrieval practice). This approach not only helps students form stronger and more flexible memory representations of the material but also enables them to transfer their knowledge and skills to new contexts (Ruitenburg et al., 2021). This aligns with the principles of constructivism, which assert that learners construct new knowledge based on their existing knowledge.

The contextual interference effect is a phenomenon in which interleaving practice, rather than blocking practice, results in greater difficulty and more errors during the learning process. However, in the long term, interleaved practice leads to improved performance and better retention. Chen et al. (2021) explain that interleaved practice is based on the contextual interference hypothesis originally proposed by Battig (1972). This hypothesis, which aligns with the discriminative-contrast hypothesis, suggests that introducing higher contextual interference during practice can encourage learners to engage in more distinctive and elaborate cognitive processes, enabling them to differentiate between similar categories of information (Chen et al., 2021). This effect can also be explained through the elaboration hypothesis (Reigeluth, 1999), which asserts that interleaving fosters more comprehensive processing and encoding of information. Additionally, the reconstruction hypothesis (Lee & Magill, 1983) posits that interleaving compels learners to reconstruct their knowledge each time they switch between different topics or skills.

This suggests that the reconstruction hypothesis bears some resemblance to Bruner's (1960) notion of the spiral curriculum, an educational approach involving the repeated revisitation of the same concepts throughout a student's education. In both the reconstruction hypothesis and the spiral curriculum, the act of revisiting and reconstructing knowledge plays a vital role in enhancing learning. Both concepts acknowledge that learning is not a linear process but rather a cyclical one, necessitating continuous building and refinement of understanding. These hypotheses indicate that interleaving promotes more distinctive, elaborative, and reconstructive cognitive processes that help learners form more accurate and generalisable representations of the material. Interleaving is now widely recognised as a powerful learning strategy that can deepen learners' understanding, enhance their problem-solving skills, and facilitate their knowledge transfer (Abel, 2023; Carvalho & Goldstone, 2019; Foster et al., 2019; Nemeth et al., 2021; van Peppen et al., 2021). However, interleaving is not a panacea for all learning situations. Some factors may influence the effectiveness of interleaving, such as the characteristics of the learners,

the tasks, and the learning context. Therefore, teachers need to carefully consider how to implement interleaving in their classrooms in a way that maximises its benefits and minimises its drawbacks.

18.5 Implementation of Interleaved Practice in Classrooms

Research has shown that interleaving can encourage students to adopt intelligent and adaptable learning approaches, rather than relying excessively on memorisation and repetitive actions (Nguyen, 2021). The following are some methods to integrate interleaved practice into the classroom:

Varied Problem Sets: Instead of providing problem sets centred around one specific concept or topic, educators can design sets that incorporate a blend of problems covering various topics. In the context of mathematics, learners could engage in exercises that involve calculating the volumes of cubes, cuboids, and cylinders concurrently, rather than focusing solely on one type of prism at a time. This method compels the mind to engage in robust retrieval of prior knowledge and to decide which techniques or strategies to apply in their solutions. Based on the illustration provided, learners can understand that the formula for calculating the volume of any prism remains the same, with the only variation being the cross-sectional area specific to different types of prisms. For instance, a cube is characterised by a square cross-section, a cuboid by a rectangular one, and a cylinder is distinguished by its circular base. This highlights the beautiful uniformity underlying the diversity in geometric shapes.

Interleaved Schedule: This approach entails the strategic structuring of lesson plans to facilitate a dynamic interchange between various concepts or topics. It diverges from the conventional method of exhaustively exploring one topic before transitioning to the next, promoting a more integrated and diverse learning experience. This can be achieved by combining different concepts. In the context of life sciences, for example, the teacher may focus on identifying the most suitable conditions for specific types of plants rather than teaching about various plant types first and then exploring different growth conditions in another session. This approach encourages students to actively apply their knowledge rather than passively absorb it.

Cumulative Assessments: The practice of consistently evaluating students on previously covered content, rather than focusing solely on the most recent material, can significantly enhance their understanding and long-term retention of earlier concepts. This approach is particularly effective in subjects like mathematics, where knowledge is cumulative. Students may begin with fundamental topics such as basic arithmetic and progressively advance to more complex areas like algebra, geometry, and calculus. Each new topic reinforces previously learned knowledge while providing context for the introduction of new information. This method aligns with the concept of the spiral curriculum proposed by Bruner (1960). The spiral curriculum emphasises that revisiting learned material can lead to a deeper understanding of the concept. Each time learners revisit past material, they gain a more profound understanding, thereby solidifying their grasp of the subject matter.

Station Rotation Approach: The station rotation method offers an interactive structure for experimenting with interleaved learning, enabling students to move swiftly among various interconnected concepts in small groups (Fulbeck et al., 2020). This is facilitated by a combination of teacher-led instruction, online learning, and collaborative activities. In the classroom, teachers can implement the station rotation model by creating different learning stations, each dedicated to a specific concept or topic. Students rotate through these stations at timed intervals, engaging in activities such as group discussions, online quizzes, and hands-on experiments at each station (Larsari et al., 2023; Skolastika, 2020). This approach ensures that students encounter a mix of subjects and encourages them to actively apply their knowledge as they transition between stations.

Using Interleaving with Other Learning Strategies: To maximise the benefits of interleaving, it is advisable to combine it with other proven learning strategies such as repeated retrieval practice, regular testing, and varying study environments.

18.6 Benefits of Interleaved Practice in Classrooms

Interleaved practice is a teaching method that contrasts with traditional blocked practice. This approach has been gaining attention due to its numerous benefits in classroom settings. Consequently, several researchers and educators (e.g., Chen et al., 2021; Morkunas, 2020; Nguyen, 2021) have highlighted key advantages associated with interleaved classroom practices.

One of the primary benefits of interleaved practice is the "Interleaving Effect." This psychological phenomenon suggests that students learn more effectively when their study materials are interleaved rather than blocked (Yan & Sana, 2021). Other benefits of interleaved practice include the following:

Improved Retention: Interleaved practice has proven to be an effective method for enhancing long-term retention, allowing students to retain information over extended periods. This beneficial outcome can be attributed to the varied practice approach, which requires learners to repeatedly recall information from prior sessions. Consequently, this process strengthens their memory and ultimately contributes to the prolonged retention of the material.

Faster Acquisition of New Skills: When learners blend various types of problems or subjects, they are prompted to employ a variety of strategies and principles. This, in turn, can lead to a more rapid acquisition of new skills due to the challenges it presents.

Enhanced Proficiency in existing Skills: Interleaved practice enhances the mastery of existing skills by requiring learners to apply their knowledge across diverse situations and scenarios.

Deeper Learning: Interleaving promotes long-term skill development and retention, as well as a smoother transfer to other contexts.

Enhanced Problem-Solving Skills: Interleaved practice helps learners identify distinctions among similar materials, ultimately enhancing their problem-solving capabilities. It encourages learners to identify, recognise, and differentiate between various problem types or concepts before engaging in problem-solving tasks.

Improved Knowledge Transfer Capability: The diverse practice inherent in interleaving can enhance one's ability to transfer acquired knowledge to new and unfamiliar contexts.

18.6.1 Limitations of Interleaved Practice in Classrooms

Although interleaved practice has demonstrated its capacity to enhance learning outcomes, it is not without challenges. The following are some potential limitations:

Slower Initial Learning: Interleaved practice may result in a slower rate of initial learning compared to blocked practice. This discrepancy arises from the need for students to switch between different types of problems or topics, which can impose greater cognitive demands.

Increased Cognitive Load: Interleaved practice increases the cognitive load on students, requiring frequent transitions between different problems or subjects. This heightened cognitive load can be particularly challenging for students who may already be struggling with the material.

Requires Careful Implementation: The effective application of interleaved practice requires careful consideration and execution. It is crucial to curate a thoughtful selection of interleaved practice problems for students, allowing them to engage deeply rather than hastily.

Not Universally Applicable: Interleaved practice may not be universally suitable for all topics or subjects. Its efficacy is more pronounced in disciplines that emphasise problem-solving, such as mathematics or science, compared to subjects that primarily involve rote memorisation.

Demands Greater Teacher Planning: Implementing interleaved practice requires a higher level of planning from educators. Teachers must carefully select and sequence the problems or topics to be interleaved, ensuring that the instructional design aligns with pedagogical objectives.

Notwithstanding these challenges, many educators and researchers (e.g., Chen et al., 2021; Morkunas, 2020; Nguyen, 2021) maintain that the advantages of interleaved practice outweigh its potential drawbacks. As a teaching methodology that fosters profound comprehension and superior retention, interleaved practice is a valuable and effective tool within the educational realm.

18.7 Case Studies in Interleaved Learning

In the contemporary educational landscape, characterised by heightened complexity, interleaved practice presents an innovative and effective alternative to the conventional blocked practice paradigm, in which learners typically focus on mastering a single skill or concept in isolation. Embracing interleaved practice can thus be seen as a promising strategy to meet the evolving demands of 21st-century education, capitalising on its inherent capacity to enhance the breadth and depth of knowledge acquisition. Here are a few case studies in different subjects that demonstrate the effectiveness of interleaved practice in learning:

Mathematics Learning: In research conducted by Rohrer et al. (2014), published in the Psychonomic Bulletin & Review, it was discovered that interleaved practice had a significant impact on student performance compared to blocked practice. The study involved 140 seventh-grade students who were subjected to either blocked or interleaved practice over a span of nine weeks. An unexpected test was administered two weeks after the practice period. The findings revealed that students who engaged in interleaved practice scored higher (72%) on the test compared to those who used blocked practice (38%), indicating a large effect size of d = 1.05. Interestingly, this interleaving effect was observed even when the problems presented were not similar to each other, unlike previous studies on interleaved mathematics, where the problems were almost identical. The study concluded that interleaved practice enhances mathematics learning not only by aiding in distinguishing between different types of problems but also by reinforcing the link between each problem type and its respective solution strategy.

Language Learning: A study published in the Journal of Educational Psychology by Pan et al. (2019) provides evidence that interleaved practice can significantly enhance language learning. The research involved four experiments in which college students employed either interleaved or blocked practice to learn verb conjugation in the Spanish preterite and imperfect past tenses. The results indicated that interleaved practice led to superior verb conjugation skills compared to blocked practice when utilised across multiple training sessions. In a separate study by Schneider et al. (2002), it was found that interleaved practice improved relearning, particularly when the initial learning involved the more challenging English-French translation direction. The study also demonstrated that interleaving reduced forgetting over a one-week delay when learning involved the more challenging English-French translation direction or mixed pairs. These findings suggest that interleaved practice may serve as a powerful tool for foreign language acquisition.

Physics Learning: In a peer-reviewed article published in the Memory & Cognition Journal by Schorn and Knowlton (2021), the advantages of interleaved practice in the context of physics learning were demonstrated. The study revolved around a serial reaction time task in which participants practised three distinct eight-item sequences. These sequences were organised in either an interleaved or blocked manner on both Day 1 (during training) and Day 2 (during testing). Experiment 1 aimed to evaluate the participants' ability to retain the three training sequences on Day 2, while Experiment 2 involved the performance of three entirely new sequences on Day 2 to assess knowledge transfer. Furthermore, the researchers sought to gauge the participants' awareness of

the sequences, investigating whether the benefits of interleaved practice extended to sequences that were implicitly learned. This research revealed that despite exhibiting inferior initial acquisition performance, interleaved practice yielded superior long-term retention outcomes. Moreover, it was discovered that even among participants who reported no conscious awareness of the sequences, interleaving demonstrated advantages in both retention and transfer, compared to participants who practised sequences in a blocked manner.

Music Education: A recent study conducted by Wong et al. (2020) serves as an illustrative example of how interleaved practice can facilitate the acquisition of skills for playing new musical compositions. The motivation behind this study stemmed from the recognition that the ability to recognise and differentiate between diverse musical styles plays a pivotal role in the development of aural proficiency and musical competence. However, this task can be particularly challenging for music learners, especially those who lack extensive experience. To address this challenge and offer guidance for music education practices, the study leveraged cognitive psychological principles to explore the impact of presenting music compositions by various classical composers in an interleaved fashion. Participants with four or fewer years of musical experience were exposed to musical pieces from six composers in an interleaved manner, alternating between listening to works by different composers, while they encountered pieces from another six composers in a blocked format, which entailed listening to the compositions of one composer consecutively before moving on to the next. Subsequently, a test was administered in which participants were required to classify unfamiliar compositions created by the same 12 composers. The results demonstrated the superiority of interleaved presentation over blocked presentation, even though the majority of participants initially perceived blocking as the more effective method, highlighting the effectiveness of interleaved practice in the instruction of music composers' distinctive styles.

18.8 Conclusion

This chapter has illuminated the concept of interleaved practice as a potent learning strategy characterised by the mixing of diverse topics or problem types within a single study session. Its demonstrable effectiveness in enhancing learning outcomes across multiple domains, including mathematics, language, music, and science, among others, has been well established. Nevertheless, it is worth acknowledging that the field of interleaved practice is not without its challenges and areas of inquiry.

One noteworthy challenge lies in the need to differentiate between the theoretical underpinnings of spaced and interleaved practices, both of which are effective learning strategies but are occasionally conflated. A deeper understanding of the distinct mechanisms governing these practices could pave the way for more precise and efficacious implementation strategies. Moreover, we concur with the sentiments expressed by other scholars regarding the necessity for additional research aimed at elucidating how interleaved practice can be effectively applied within diverse learning contexts. For instance, investigating its impact on learning outcomes in online and blended learning environments remains an essential avenue of exploration.

Furthermore, we have identified emerging trends that have the potential to shape the trajectory of interleaved practice in 21st-century classrooms. These include the integration of digital technology to facilitate the seamless interleaving of various topics or problem types, the gamification of learning activities to enhance engagement among students, and the customisation of interleaved practice to align with each student's unique learning requirements.

Overall, interleaved practice unquestionably stands as a valuable and effective learning strategy, replete with numerous benefits. Nonetheless, its continued refinement and widespread adoption demand ongoing research and thoughtful implementation. As we navigate the educational landscape of the 21st century, interleaved practice emerges as a powerful tool for optimising learning outcomes in contemporary classrooms.

18.9 Reflective Questions

1. How do you think the implementation of interleaved practice could affect your students' long-term retention of the material?
2. What potential challenges do you anticipate when implementing interleaved practice in your classroom, and how might you address them?
3. How do you plan to integrate digital technology or gamification into your implementation of interleaved practice?
4. In what ways do you think the interleaved practice could influence the pace and depth of learning in your classroom?
5. How do you plan to tailor the selection and sequencing of topics or problems in interleaved practice to meet each student's unique learning needs?

18.10 Reference

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