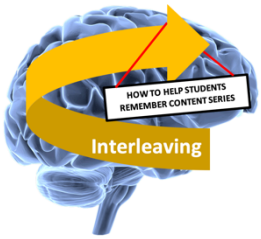
How to Help Students Remember Content Series:



Interleaving

I think it goes without saying that every teacher wants their students to remember the material that they teach...otherwise, why teach it. Of course, we all want our students to leave our classes being able to recall, apply and grow from what we've taught. This series is dedicated to helping classroom teachers know what the science of learning has discovered that really helps students retain the valuable information that you've taught them.

Today's topic: Interleaving

The concept of interleaving—as the definition suggests—is the action of inserting or interspersing something at regular intervals between parts of something else. The example

interleave | ɪntəˈliːv |

verb *[with object]*

1 insert pages, typically blank ones, between the pages of (a book): *books of maps* ***interleaved with*** *tracing paper*.
- place something between the layers of (something): *pasta* ***interleaved with*** *strips of courgette*.

2 *Telecommunications & Computing* mix (digital signals) by alternating between them.
- *Computing* divide (memory or processing power) between a number of tasks by allocating segments of it to each task in turn: *memory is automatically interleaved as additional memory cards are added.*

used in the definition is to insert blank pieces of paper between pages of a book, or to layer something like Zucchini between your strips of fettuccini when making a delicious dish of Zucchini Ribbon Pasta. Although not specified within the definition, the inserted elements are related in nature...that is to say that you wouldn't insert a car tire amongst the pages of a book and call that interleaving. ☺

So what does this have to do with the science of learning and teaching?

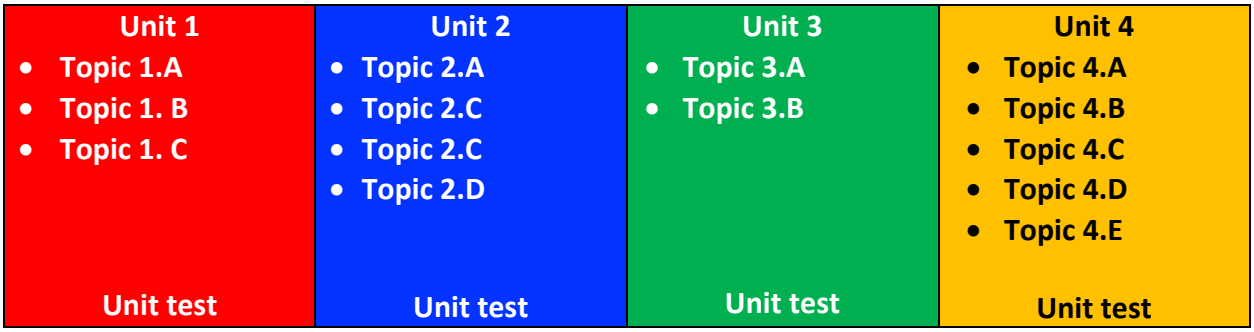
Interleaving is the teacher's action of intentionally mixing-in or interspersing more than one **related** skill or topic area at a time while teaching or assessing students (Roediger et al., 2018). In other words, it is a form of mixing up the practice and study of the skills you want your students to remember. A simple example of this is when a teacher includes a mixture of addition and subtraction questions on a worksheet for a student to solve, instead of simply

having one type of question on the sheet. Of course, it is understandable that teachers think in terms of first mastering one skill before moving on to another, often more difficult skill. We sometimes believe that we should get students to master lower-level foundational skills and then build upon these skills. That seems to make sense, right? Shouldn't a teacher ensure that students can show mastery of one set of skills before moving on to more difficult skills? As it turns out, no, that may not be the better way.

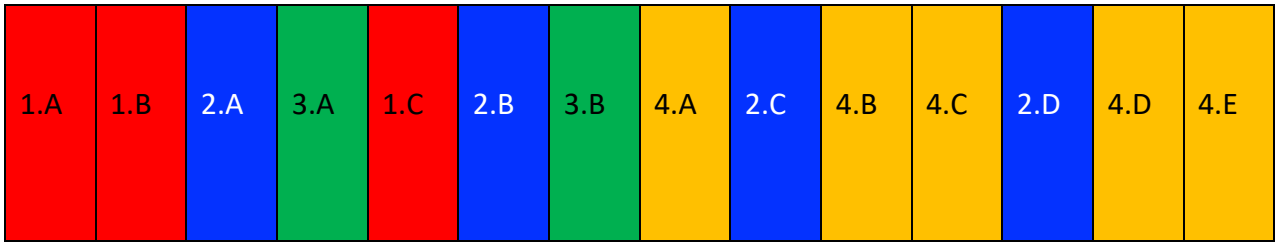
Below I've illustrated the difference between the concept of blocked units of teaching; that is, teach an entire unit, quiz students on that unit, and then move on to the next unit, and interleaved units. Interleaving would involve teaching part of a unit, pre-teaching a related unit yet to come, or mixing in an older unit.

Figure 1: Simplified Example

BLOCKED Units in a Subject Area (e.g. mathematics)



INTERLEAVED Units in that Subject Area



Interleaving content and problems while teaching is a better method than blocking. Blocking involves teaching or solving one type of problem at a time before moving on to the next type of problem (Kirschner & Hendrick, 2020). I don't know about you, but I remember as a young student receiving math sheets with 40 to 50 examples of the same type of math problem on them (e.g. factor the trinomial). The thinking must have been, solve a great number of these problems until it becomes almost automatic. Interleaving, by contrast, involves mixing in multiple types of problems, often already learned skills, amongst newly to-be mastered content. "This approach helps the learner choose the correct strategy to solve a problem and

helps them see the links, similarities, and differences between problem states. It also leads to increased transfer(p.18)."

For a few wonderful examples of interleaving within subject areas visit learningscientists.org and check out their section on Interleaving.

Why is this so Important? What does the science say?

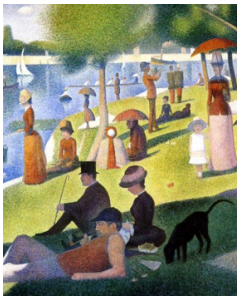
I am going to introduce you to two non-teaching examples first as a way to introduce the benefits of mixed-up practice and study. Oh, and before we get confused about terminology and usage of terms here, please let me clarify. Students are always learning. So, AS YOU ARE teaching a new unit, students ARE beginning to learn it....so, from the very introduction of content the learning is underway and remains ongoing. This is why I prefer to mix the terms teaching, learning, practice and studying all occurring simultaneously.

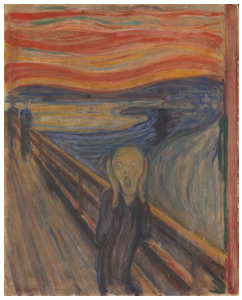
A study of artists illustration

In their excellent book *Make it Stick* (2014) Brown, Roediger, and McDaniel make the point on interleaving in a chapter about mixing up your teaching and practice. Compared to mass practice or mass teaching, "a significant advantage of interleaving is that it can help us learn better how to assess context and discriminate between problems, selecting and applying the correct solution from a range of possibilities" (p.53).

Several studies have shown that interleaving improves students' ability to discriminate differences between and recognize similarities, an important cognitive skill that aids in comprehension.


Dutch Golden Age
Vermeer, 1665


Post-Impressionism
Seurat, 1884


Expressionism
Munch, 1893


Realism
Whistler, 1871

One study involved learning to attribute paintings to the artists who painted them. Researchers initially thought that those students who massed-practiced or mass-studied the works of one artist before moving on to another artist would better be able to discriminate between random works when quizzed on them. I'll let the authors of *Make it Stick* describe the study (emphasis in the original):

> Researchers initially predicted that massed practice in identifying painters works, that is, studying many examples of one painter's works before moving on to study many examples of another's works, would best help students learn the defining characteristics of each artists style. Massed practice of each artist's works, one artist at a time, would better enable students to match artworks to artists later, compared to interleaved exposure to the works of different artists. The idea was that interleaving would be too hard and confusing; Students would never be able to sort out the relevant dimensions. The researchers were wrong. The *commonalities* among one painters works that the students learned through mass practice proved less useful than the *differences* between the works of multiple painters that the students learned through interleaving. Interleaving enabled better discrimination and produced better scores on a later test that required matching the works with their painters. The interleaving group was also better able to match painters names correctly to new examples of their work that the group had never viewed during the learning phase. (p.54)

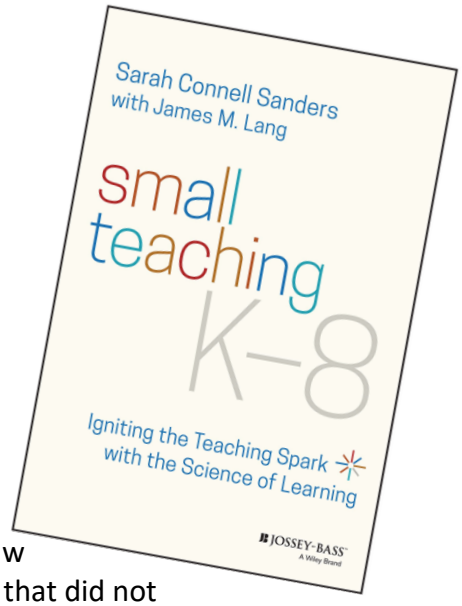
Of particular importance here is what researchers concluded about higher level learning. Conceptual understanding requires a grasp of the interrelationships of the basic elements within a larger structure that enable them to function together. Being able to discriminate and compare and contrast is useful in seeing the interrelationships within content, and this may be better enabled through interleaving of concepts across a unit of study.

There are many examples of the acceptance and necessity of interleaving in skill learning and development of athletes across many sports.

Undoubtedly, when most of us go to hit some golf balls at the local driving range we normally only take a driver and plan to smack out a bucket of balls, one drive after another. That's mass practice using one club. But golf pros tell us that we shouldn't really do that. Instead, we need to use all of the clubs when we hit a bucket of balls and simulate different types of shots if we want to replicate what a real game is like. Likewise, golf instructors won't teach you just one swing, wait until you master it, and then teach you another swing. Instead, they will teach you the movements and functions of several related swings so you can discern differences and similarities in club position, stance, clubhead speed and follow through.

Basketball players don't just practice one shot hundreds of times in a row and then move on to another type of shot and practice it hundreds of times. Experienced basketball players know that they need to mix up their practice and take shots from many areas of the floor to improve their shooting. Similarly, basketball coaches—or any coach for that matter—won't give their players one move or one skill until it's mastered before teaching another move. Coaches mix in several skills and movements and expect their players to learn and improve over time (and with further coaching) to implement a full array of skills into play.

In the same way, it doesn't make sense to mass practice or mass teach one academic or cognitive skills at a time, mass practice it, assess it and then move on to another skill.



In a new book by educator Sarah Connell Sanders and Dr. James M. Lang, called *Small Teaching K-8: Igniting the Teaching Spark with the Science of Learning* (2023), Sanders and Lang highlight the work of middle-school math teacher Anne Agostinelli. Agostinelli was frustrated that math textbooks introduced large blocks of problem sets focused solely on new skills, without also tying in previous work to apply within the newer material. She saw students falling into the same repetitive and predictable routines that did not produce deep processing, so she decided to interleave a range of problems that spanned a cumulative viewpoint of mathematics and included work across the entire term up to that point.

Let me lift a quote from page 13:

> Agostinelli grew especially fond of applying interleaving to her middle schoolers' homework assignments. Each week, she assigned five problems for homework, two of which referred directly to her current instruction and three that referred back to earlier content.

It's easy to see how interleaving can be used in some subjects or skill areas, such as history, writing, mathematics, chemistry, art, music and physical education to name a few. It can be used, as Agostinelli uses it, to support homework and review, but it also can be used in our teaching to make comparing and contrasting more explicit, to preteach new concepts, to situate new learning in relation to previous information, and so on.

The concept is fairly straight forward, mix up your teaching to include material that allows students to see how your current material relates to what you've already taught and to foreshadow what is yet to come. Students make better connections across the curriculum this way and interleaving assists in the development of breadth and depth of understanding.