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Context and Implications Document for: A systematic review of interleaving as a concept learning strategy

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Authors' Introduction

Interleaving is a technique which involves modifying the order of practice tasks or examples such that items of different types appear together, rather than in 'blocks' of similar items. For example, interleaved examples of artworks might feature the work of several different artists mixed together, in contrast to a 'block' of several paintings by the same artist. The latter example formed the basis of a research study by Kornell and Bjork (2008) which suggested that not only is interleaving highly beneficial for learning, learners tend to lack insight into its benefits and are therefore unlikely to adopt the technique spontaneously.

Subsequent studies extended this effect to a number of topic areas, including the learning of concepts in chemistry, biology, statistics and psychology, and there is also a body of work on the interleaved practice of maths problems. Thanks to this research, interleaving has begun to be cited as an 'evidence-based' approach to learning, and recommended to educators and to students who are pursuing independent study.

However, there remain a number of issues and unanswered questions about the technique. How strong is the interleaving benefit, and how widely does it apply in terms of both learners and materials? What kind of issues might educators wish to keep in mind, for example in terms of the type of items that they interleave, the number of examples given, or the duration of the process? How similar should the examples be, and would—as argued by Carvalho and Goldstone (2015)—the effect cease to hold if the studied items are too different from one another? Are interleaving benefits primarily a matter of improved memory for previously studied items, or does the

technique also improve the ability to transfer learning to novel examples? In our systematic review and meta-analysis for *Review of Education* we aimed to review and synthesise the evidence from the past decade in order to shed light on these issues, and to provide recommendations for classroom practice.

Implications for Practice

Our findings suggest that interleaving has a consistent benefit with a large effect size, and as such it is reasonable to consider the technique to be evidence-based. Furthermore, the benefit to transfer (novel items) was just as strong as the benefit to memory (previously studied items). This suggests that in contrast to other techniques that focus largely on retention, interleaving could play a valuable role in learning new concepts on a more abstract level, helping learners to generalise from a classroom task to new material that they later encounter.

While all of the studies we reviewed were lab-based and most were very brief in their time scale, the ones which did include a delay (varying from 24 hours to 10 days) supported the idea that the benefit of interleaving is durable. It can also be distinguished from the spacing effect; that is, the benefit does not occur just because practice is delayed.

However, educators should note that the findings related to procedures using individual items such as images or very short texts. These were (in the interleaving conditions) immediately contrasted with different items. The interleaving of longer blocks of study (for example, spending several minutes or more on one topic and then moving on to a different topic) was not supported, and would conflict with the main theoretical explanations of interleaving that have been advanced, and which are discussed in our review.

Educators and administrators can directly apply interleaving to classroom teaching or to review activities, and the existing evidence suggests that doing so would boost concept learning. There remains a shortage of classroom-based experimentation on the effect, however. In addition, due to the importance of contrasting items which are potentially confusable, the precise details of which items should be interleaved and which should not may rely on teachers' professional judgement. It will also depend on the learners themselves; subtly different, easily confused items are most productively interleaved, and what differences appear subtle will depend on learners' prior knowledge.

Resources for Teaching & Learning in Higher Education

Author Recommends

Carvalho, P. F., & Goldstone, R. L. (2015). What you learn is more than what you see: What can sequencing effects tell us about inductive category learning? Frontiers in Psychology, 6, *505. https://doi.org/10.3389/fpsyg.2015.00505*

This review of the state of the literature came at a time that the concept of interleaving was first clearly distinguished from spacing, and it helped to shape some of the key research questions going forward. It explores theoretical questions in a historical context, and presents the authors' attentional bias theory of interleaving.

Firth, J. (2019). *The teacher's guide to research: Engaging with, applying and conducting research in the classroom*. Routledge.

Chapter 5 of this work, 'Using a research-based intervention in your classroom', provides guidance on how teachers can implement interleaving, spacing and other evidence-based techniques to classroom practice.

Firth, J. (2021). Boosting learning by changing the order and timing of classroom tasks: Implications for professional practice. *Journal of Education for Teaching, 47*(1), 32–46. https://doi.org/10.1080/02607476.2020.1829965

This article addresses the intricacies of applying interleaving and spacing to the classroom, including the need to navigate interactions between learner knowledge and item difficulty, and the potential barrier of metacognitive beliefs.

Kang, S. H. (2016). The benefits of interleaved practice for learning. In Horvath, J. C., Lodge, J. M. & Hattie, J. (Eds.) *From the laboratory to the classroom: Translating the science of learning for teachers* (pp. 79–93). Routledge.

This very accessible review chapter features a useful section on the interleaving of motor learning, and benefits from thoughtful consideration of students' metacognitive judgements of interleaved practice.

Kornell, N. & Bjork, R. A. (2008). Learning concepts and categories: Is spacing the 'enemy of induction'? *Psychological Science, 19*, 585–592. https://doi.org/10.1111/j.1467-9280.2008.02127.x

This is in many ways the 'classic' study of interleaving in recent decades. The paradigm of interleaved painting styles provided the basis for most of the later work that we reviewed in our article. Although the title refers to spacing, it is better seen as a study of interleaving.

Sana, F., Yan, V. X., Kim, J. A., Bjork, E. L., & Bjork, R. A. (2018). Does working memory capacity moderate the interleaving benefit? *Journal of Applied Research in Memory and Cognition, 7*, 361–369. https://doi.org/10.1016/j.jarmac.2018.05.005

This study helped to tackle an emerging question around the cognitive mechanisms involved in interleaving. The authors' empirical finding that the interleaving effect did not depend on working memory capacity raises important questions with regard to cognitive load theory as well as interleaving itself.

Vlach, H. A., Sandhofer, C. M., & Kornell, N. (2008). The spacing effect in children's memory and category induction. *Cognition, 109*, 163–167. https://doi.org/10.1016/j.cognition.2008.07.013

This study extended the interleaving effect to young children. Although again the title refers to spacing, it is better seen as a study of interleaving.

> Zulkiply, N., McLean, J., Burt, J. S., & Bath, D. (2012). Spacing and induction: Application to exemplars presented as auditory and visual text. *Learning and Instruction, 22*, 215–221. https://doi.org/10.1016/j.learninstruc.2011.11.002

This study showed that interleaving can generalise to short texts (clinical case studies of psychological disorders) rather than images, and applies whether material is presented aurally (lecture-style) or on screen. Although again the title refers to spacing, it is better seen as a study of interleaving.

Useful Links

The following guide is excellent and evidence-based, though it should be noted that it focuses on interleaving of practice questions/review rather than initial learning, and on mathematics practice in particular:

https://www.retrievalpractice.org/strategies/2017/interleaving

The following blog post provides guidance on implementing interleaving into classroom teaching:

https://www.jonathanfirth.co.uk/blog/interleaving-using-it-in-the-classroom

Focus Questions

What is the key difference between interleaving and the spacing effect?

If interleaving depends on contrasting easily confusable examples, what are the implications for preparing teaching materials such as worksheets?

What planning implications relate to implementing interleaving across a school year?

How would an educator adjust an interleaved task if learners were initially finding it too difficult or confusing?

How different is interleaving from the broader issue of variable practice?

Seminar/Project Idea

Undergraduate or graduate students might wish to explore the concept of interleaving by working with teachers or other educational professionals to identify curriculum areas where learners easily mix up two or more concepts, and then preparing interleaved and blocked versions of teaching and homework tasks relating to these concepts. If ethical permission and consent could be obtained, the effects of these versions on learning could be compared empirically. Alternatively, students could seek to gather data on teachers' beliefs about the two versions, to test whether intuitions are in line with the evidence.