Life Long Learning
at Work and at Home

25 Learning Principles to Guide Pedagogy and the Design of Learning Environments

Applying the Science of Learning: What We Know About Learning and How We Can Improve the Teaching-Learning Interaction

1. Contiguity Effects.

Ideas that need to be associated should be presented contiguously in space and time in the multimedia learning environment. For example, the verbal label for a picture needs to be placed spatially near the picture on the display, not on the other side of the screen. An explanation of an event should be given when the event is depicted rather than many minutes, hours, or days later.

- **Implications**

Design the learning materials and lesson plans so that elements and ideas that need to be related are presented near each other in space and time.

- **References**

Mayer, R. E. (2001). *Multimedia learning.* NY: Cambridge University Press.

2. Perceptual-motor Grounding.

Whenever a concept is first introduced, it is important to ground it in a concrete perceptual-motor experience. The learner will ideally visualize a picture of the concept, will be able to manipulate its parts and aspects, and will observe how it functions over time. The teacher and learner will also gain a common ground (shared knowledge) of the learning material. Perceptual-motor experience is particularly important when there is a need for precision, such as getting directions to find a spatial location. For example, a course in statistics is not grounded in perceptual-motor experience when the teacher presents symbols and formulae that have no meaning to the student and cannot be visualized.

- **Implications**

Teachers should ground new concepts in perceptual-motor experiences when concepts are first introduced and when the content needs to be tracked with a high level of precision. This practice facilitates comprehension, learning, and later use of the information.

- **References**

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3. Dual Code and Multimedia Effects.

Information is encoded and remembered better when it is delivered in multiple modes (verbal and pictorial), sensory modalities (auditory and visual), or media (computers and lectures) than when delivered in only a singe mode, modality, or medium. Dual codes provide richer and more varied representations that allow more memory retrieval routes. However, the amount of information should not overwhelm the learner because attention is split or cognitive capacities are overloaded.

- **Implications**

Design the learning materials so that information gets delivered in multiple modes, modalities, and media, but do not overwhelm the learner with too much to learn or too much to attend to, two primary causes of cognitive overload.

- **References**

Mayer, R. E. (2001). Multimedia learning. NY: Cambridge University Press.

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4. Testing Effect.

There are direct and indirect effects of taking frequent tests. One indirect benefit is that frequent testing keeps students constantly engaged in the material. Although students will learn from testing without receiving feedback, there is less forgetting if students receive informative feedback about their performance. Multiple tests slow forgetting better than a single test. Formative assessment refers to the use of testing results to guide teachers in making decisions about what to teach. Learners also benefit if they use test results as a guide for their own learning.

- **Implications**

Use frequent testing to enhance learning and memory. This practice will encourage learners to study continuously throughout the semester. Use testing results to guide teaching and learning.

- **References:**

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Wheeler, M. A., & Roediger, H. L. III., (1992).Disparate effects of repeated testing: Reconciling Ballard's (1913) and Bartlett's (1932) results. *Psychological Science, 3*, 240-245.

5. Spaced Effects.

Spaced schedules of testing (like spaced schedules of studying) produce better long-term retention than a single test. When a single test is administered immediately after learning, students obtain high scores, but long-term retention is reduced with a single immediate test relative to spaced testing. When a test is given immediately after learning has occurred, learners still have the newly-learned information in a primary memory system and therefore obtain high test scores. Both teachers and learners often misjudge their high scores on a test given immediately after learning as evidence of good retention, when, in fact, long-term retention suffers with this practice**.**

- **Implications**

Teachers should give frequent tests so that the high scores on tests that are immediately given after learning can be maintained over time. If a single test is given soon after learning, both teachers and students fall prey to the "illusion of competence" or belief that the learners have information available in long-term memory, when in fact they do not.

- **References**

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Cull, W. L. (2000). Untangling the benefits of multiple study opportunities and repeated testing for cured recall. *Applied Cognitive Psychology, 14*, 215-235.

6. Exam Expectations.

Students benefit more from repeated testing when they expect a final exam that will include additional information than when they do not expect a final exam. It seems that learners will keep material more accessible in memory when they expect to need it later than when they do not.

- **Implications**

Teachers should create the expectation that there will be a final or comprehensive examination that will be administered at some future date. Learners will use knowledge of future testing to keep information in memory in a way that allows it to be recalled in the future.

- **References**

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7. Generation Effect.

Learning is enhanced when learners produce answers compared to having them recognize answers. Free recall or essay tests which require the test taker to generate answers with minimal cues produce better learning than multiple choice tests in which the learner only needs to be able to recognize correct answers. In fact, free recall tests produce as much learning as restudying the material.

- **Implications**

When possible, teachers should give recall tests and provide other opportunities for learners to recall information with minimal cues. (We do not know the conditions under which learners will gain comparable benefits from well written multiple choice or other recognition tests.)

- **References**

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Tulving E. (1967). The effects of presentation and recall of material in free-recall learning. *Journal of Verbal Learning and Verbal Behavior*, *6*, 175-184.

8. Organization Effects.

Outlining, integrating, and synthesizing information produces better learning than rereading materials or other more passive strategies. Students frequently report that when they study they reread materials they already read once. Strategies that require learners to be actively engaged with the material to-be-learned produce better long-term retention than the passive act of reading. Learners should develop their own mini-testing situations as they review, such as stating the information in their own words (without viewing the text) and synthesizing information from multiple sources, such as from class and textbooks.

- **Implications**

Provide learners with meaningful strategies for retaining information when they study. These strategies should require effort because there is a long-term retention advantage for effortful processing (assuming that the effort is within a reasonable level).

- **References**

Bjork, R. A.. (1994). Memory and metamemory considerations in the training of human beings. In J. Metcalfe & A. Simamura (Eds.). Metacognition: Knowing about knowing. (pp. 185-205.) Cambridge, MA: MIT Press.

Bransford, J. D., Brown, A. L., & Cocking, R. R. (Eds.). (2000). *How People Learn* (expanded ed.). Washington, D.C.: National Academy Press.

9. Coherence Effect.

The learner needs to get a coherent, well connected representation of the main ideas to be learned. It is important to remove distracting, irrelevant material, even when the added information is artistically appealing. Seductive details that do not address the main points to be conveyed run the risk of consuming the learner's attention and effort at the expense of their missing the main points.

- **Implications**

Design the learning materials so that the main points are prominent and that removes distracting, irrelevant materials.

- **References**

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10. Stories and Example Cases.

Stories and other forms of narrative are easier to read, comprehend, and remember than other types of learning materials. For many millennia, the primary way of passing wisdom down from generation to generation was through stories. Stories have concrete characters, objects, locations, plot, themes, emotions, and actions that bear some similarity to everyday experiences. Many stories also convey a point or moral that can be generalized to many situations. Example cases in a story-like format are persuasive, easy to comprehend, and very memorable.

- **Implications**

Teachers and learning environments should capture the important content in stories and example cases, which are comparatively easy to comprehend and remember.

- **References**

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Haberlandt, K., & Graesser, A. C. (1985). Component processes in text comprehension and some of their interactions. *Journal of Experimental Psychology: General*, *114*, 357-374.

11. Multiple Examples.

An understanding of an abstract concept improves with multiple and varied examples.

- **Implications**

Provide learners with examples of concepts, especially examples that are selected from different academic disciplines (e.g., correlations in historical events and medicine) and different domains of knowledge (applied and abstract).

- **References**

Hakel, M., & Halpern, D. F. (2005). How far can transfer go? Making transfer happen across physical, temporal, and conceptual space. In J. Mestre (Ed.), *Transfer of learning: From a modern multidisciplinary perspective* (pp.357-370). Greenwich, CT: Information Age Publishing.

12. Feedback Effects.

Students benefit from feedback on their performance in a learning task, but the timing of the feedback depends on the task.

- **Implications**

Provide feedback to learners according to schedules that allow them to recognize correct responses without the aid of feedback.

- **References**

Pahler, H., Cepeda, J.T., Wixted, J.T., & Rohrer, D. (2005). When does feedback facilitate learning of words? *Journal of Experimental Psychology: Learning, Memory, & Cognition, 31,* 3-8.

13. Negative Suggestion Effects.

Just as people learn correct information with frequent testing, they also can learn wrong information this way. For example, when incorrect alternatives on multiple choice tests are presented, the wrong answers can be learned instead of the correct answers. This effect is also found on short answer essay questions when students do not know the answers and use their general knowledge about the field to construct a response that seems reasonable to them. In this situation, learners recall their incorrect, but logically consistent response as being correct. These effects can be reduced when learners receive feedback immediately after taking a test which allows them to revise their memory and understanding without delay.

- **Implications**

Provide immediate feedback after testing to correct errors and overcome negative suggestions created by recalling incorrect responses. Teachers should provide feedback about correct responses as soon as the testing is completed. It is easier to achieve this goal when multiple short tests are given than when fewer, longer tests are given.

- **References**

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14. Desirable Difficulties.

Learning is enhanced when learners have to organize the information themselves or exert additional effort during acquisition or retrieval than in conditions in which the information to be learned or retrieved does not require effort. One possible explanation for this effect is that learners create multiple retrieval paths which make the information more accessible at retrieval. These practices slow initial learning, but promote long-term recall.

- **Implications**

Teachers should present the to-be-remembered information in formats that require effortful processing. For example, information presented in class should not follow in the same order as information in a related chapter so learners will be to integrate the two sources of information. Learners will remember information better when it requires effortful processing than information that is easy to learn.

- **References**

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15. Manageable Cognitive Load.

Multimedia learning environments should be compatible with what we know about how people learn. A common error in the design of multimedia learning materials is to “clutter” the learning environment with extraneous information that increases the cognitive load for learners who are in the process of discovery what is important and what is decorative and distracting. The demands on working memory can exceed capacity when there is auditory input that does not match written text and there is visual animation and other movement to monitor at the same time, especially early in learning. The *coherence principle* calls for the removal of extraneous materials. The *spatial contiguity* principle refers to the need to keep printed text next to the visual display that it describes.

- **Implications**

Keep multimedia learning materials free of clutter with text information and auditory input physically near the matching visual display and near in time to match animations or other movement.

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- **References**

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16. Segmentation Principle.

Information presented in text is necessarily linear because of the constraints of language. When multimedia materials are designed, it is possible to present information simultaneously in multiple modes—auditory, motor, visual, being the most common. The general principle of introducing new concepts in manageable segments becomes even more critical when there are multiple sensory systems involved.

- **Implications**

Plan the order and amount of new information that is to be presented in discrete units so as not to overwhelm new learners with too much new information at once.

- **References**

Mayer, R. E., & Moreno, R. (2003). Nine ways to reduce cognitive load in multimedia learning. *Educational Psychologist, 38,* 43-52.

17. Explanation Effects.

Explanations consist of causal analyses of events, logical justifications of claims, and functional rationales for actions. Explanations provide coherence to the material and justify *why* information is relevant and important. Students may be prompted to give self-explanations of the material through think aloud protocols or questioning tasks that elicit explanations that connect the material to what they already know. Self-explanations and the activity of studying good explanations facilitate deeper comprehension, learning, memory, and transfer.

- **Implications**

Teachers and learning environments should deliver good explanations of ideas and elicit self-explanations from the learner. These explanations promote deeper learning of complex mechanisms, causal and functional analyses, links between claims and evidence, and logical reasoning.

- **References**

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18. Deep Questions.

Deep explanations of material and reasoning are elicited by questions such as *why, how, what-if-*and *what-if not*, as opposed to shallow questions that require the learner to simply fill in missing words, such as *who, what, where,* and *when*. Training students to ask deep questions facilitates comprehension of material from text and classroom lectures. The learner gets into the mindset of having deeper standards of comprehension and the resulting representations are more elaborate.

- **Implications**

Good questions promote deeper comprehension of the material. Teachers and students need to be trained on good question asking skills because most questions that get asked are shallow questions. Deeper questions lead to improved comprehension and learning at deeper levels of mastery.

- **References**

Craig, S. D., Sullins, J., Witherspoon, A., & Gholson, B. (2006). The deep-level reasoning effect: The role of dialogue and deep-level-reasoning questions during vicarious learning. *Cognition and Instruction, 24*, 565-591.

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Rosenshine, B., Meister, C., & Chapman, S. (1996). Teaching students to generate questions: A review of the intervention studies. *Review of Educational Research, 66,* 181-221.

19. Cognitive Disequilibrium.

Cognitive disequilibrium stimulates inquiry, curiosity, thinking, and deep questions, which in turn lead to deeper learning. Cognitive disequilibrium occurs when there are obstacles to goals, contradictions, conflicts, anomalous events, breakdown scenarios, salient gaps in knowledge, uncertainty, equally attractive alternatives, and other types of impasses. When these impasses occur, the learner needs to engage in reasoning, thought, problem solving, and planning in route to restoring cognitive equilibrium. There is a higher incidence of deep questions, thought, reasoning, and study efforts when learners undergo cognitive disequilibrium.

- **Implications**

Learning environments and teachers should provide challenges that put the learner in cognitive disequilibrium if the learning objective is to promote deep learning of the material. These experiences can present confusion or frustration to some students, so there needs to be forms of scaffolding that help them get through the impasse.

- **References**

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20. Cognitive Flexibility.

Cognitive flexibility increases when there are multiple viewpoints, perspectives, and points of view about a phenomenon. It also increases when there multiple layers of knowledge that interconnect facts, rules, skills, procedures, plans, and deep conceptual principles. The cognitive complexity and multiple viewpoints are helpful when learners face tasks that have unique complexities that cannot be anticipated proactively. For example, mathematics has the layers of facts (2 + 3 = 5), algebraic procedures, and deep mathematical concepts that need to be linked and coordinated. Cognitive flexibility is achieved by trying to solve a large variety of problems and by training that links these different layers.

- **Implications**

Teachers and learning environments promote cognitive flexibility by having students work on problems that vary in content and complexity. In addition to multiple varied cases, there needs to be training that points out connections between the layers of facts, procedural knowledge, functional explanations, and deep principles.

- **References**

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21. Goldilocks Principle.

Assignments should not be too hard or two easy, but at the right level of difficulty for the student's level of skill or prior knowledge. The definition of the zone of proximal development (ZPD) is a bit more technical: the difference in learning that occurs with versus without a learning scaffold (e.g., tutor, teacher, text, and computer). Researchers have identified a number of zones that reflect how much learning, memory, mastery, or satisfaction occurs along a continuum of task difficulty and that is sensitive to individual differences among learners. When the material is too easy for the learner, the student is not challenged and may get bored. When it is too difficult, the student acquires very little and gets frustrated or tunes out.

- **Implications**

Learning environments and teachers should tailor the materials to characteristics of the learner, making sure that the material is not too difficult, or not to difficult, but just right.

- **References**

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VanLehn, K., Graesser, A.C., Jackson, G.T., Jordan, P., Olney, A., & Rose, C.P. (2007). When are tutorial dialogues more effective than reading? *Cognitive Science, 31*, 3-62.

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22. Imperfect Metacognition.

Both adults and children have very limited knowledge of how their mind works and how to learn, so they need explicit training on cognitive processes and optimal learning strategies. Metacognition is a person's knowledge or judgments of memory, learning, planning, problem solving, and decision processes. Students' metacognition can be mislead by folk wisdom of a culture about cognition and their making incorrect analyses of there personal mental experiences. The vast majority of adults are not good at planning, selecting, monitoring, and evaluating their strategies of self-regulated learning. Most students have trouble discovering important principles on their own, without guidance and scaffolding by teachers. Occasionally the learning materials have precisely the right characteristics and affordances to stimulate discovery by the student, but that is rare and difficult to engineer. As a consequence, there needs to be explicit training and practice before students acquire adequate metacognition, self-regulated learning, and discovery learning.

- **Implications**

Teachers and learning environments need to train students on characteristics of metacognition and strategies of self-regulated learning and discovery learning. These capacities and skills do not come naturally to most adults. Without such instructional mediation, students lack the ability to effectively read for particular purposes, search through hypertext/hypermedia, select actions in interactive simulation environments, and design systems that satisfy multiple constraints.

- **References**

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23. Discovery Learning.

Most students have trouble discovering important principles on their own, without careful guidance, scaffolding, or materials with well-crafted affordances.

- **Implications**

When designing learning materials, teachers need to provide guides and explicit instruction in the principles that are to be learned.

- **References**

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24. Self-regulated Learning.

Most students need training in how to self-regulate their own learning and other cognitive processes.

- **Implications**

Provide learners with frequent assessments so they can become aware of what they do not know because it is difficult to assess ones own understanding or learning without an external assessment.

- **References**

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25. Anchored Learning.

Anchored learning occurs when students work in teams for several hours or days trying to solve a challenging practical problem that matters to the student. The activity is linked to background knowledge of the learner on a topic that is interesting. The problem is challenging, so the learner needs to engage in problem solving and recruit multiple levels of knowledge and skills. These activities are coherently organized around solving the practical problem. Examples of anchored learning are *problem-based curricula* in medical schools where students work on genuine medical cases and *communities of practice* where students try to solve problems of pollution in their city.

- **Implications**

Anchored learning weaves together many principles of learning in a coherent activity that engages teams of students for many hours and days. It provides a context for learning that motivates many students and stimulates problem solving and organized social interactions.

- **References**

Bransford, J. D., Brown, A. L., & Cocking, R. R. (Eds.). (2000). *How People Learn* (expanded ed.). Washington, D.C.: National Academy Press.