GENERATION EFFECT

Definition and Background

Learners are more likely to retain information when asked to produce (generate) an answer, compared to having that same information provided. (Slameka & Graf, 1978). However, students are unlikely to engage in generative learning on their own (King, 1992; Wittrock, 1989); they need to be prompted and guided to do so through providing learning activities that are consistent with generative learning (see Bertsch & Pesta, 2014) for a review.

Generating answers increases the likelihood a learner will recall or recognize information later (Bertsch, Pesta, Wiscott, & McDaniel, 2007; McNamara & Healy, 1995, 2000). When compared to passive activities such as reading, generative activities encourage learners to use methods during learning (or encoding) that can be evoked during retrieval of the learned information (McNamara & Healy, 2000). The learning benefits of actively constructing knowledge have been noted in several areas, including mathematics (Lawson & Chinnappan, 1994; McNamara & Healy, 2000; Pesta, Sanders, & Murphy, 1999), reading comprehension (Doctorow, Wittrock, & Marks, 1978; Wittrock, 1990), and trivia questions (deWinstanley, 1995).

Generation activities can vary in form, resulting in differing levels of cognitive processing:

- Surface processing:
  - Rearranging letters or filling in missing letters in a word
  - Recognition tests
- Deep processing:
  - Relating two concepts to one another
  - Creating a hierarchy of relationships between items
  - Creating and answering questions on the material
  - Summarizing a reading passage

Self-questioning during a lecture is somewhat more beneficial than generating summaries where learners use their own words to connect their prior knowledge to the material they are learning (King, 1992). Both strategies, however, are more beneficial than more passive strategies such as taking notes during lecture and reviewing them for a test. Although students report that generation methods are helpful, when comparing generation techniques to retrieval (testing), retrieval appears to offer more benefits for later retention (Karpicke & Zaromb, 2009).

Limitations and considerations:

Learning objectives and learning activities

- Generation activities during learning are optimal when the activities students engage in during learning resemble the retrieval or product that will be required during learning assessments. This is referred to as *transfer-appropriate processing* (deWinstanley, Bjork, & Bjork, 1996; Foos, Mora, & Tkacz, 1994; McDaniel, Waddill, & Einstein, 1988; McNamara & Healy, 2000; Morris, Bransford, & Franks, 1977; Thomas & McDaniel, 2007).
    - Reading with general instruction allows the learner to focus more broadly on all aspects of the material. Deep generative activities, however, may be indicated when assessments require students to:
        - make connections between concepts
        - work to provide specific solutions
- Placing minimal constraints on the generating activity, such as a free-recall exercise, will yield better learning than placing constraints to what the students generate (McCurdy, Leach, & Leshikar, 2017).

Low-skill versus high-skill learners:

- Learners who are low in comprehension skills might benefit more from instruction on generative activities, such as self-questioning, than high-skill learners, (King, 1992).

Novice versus expert learners:

- Generative activities, such as fill-in-the-blank questions, for material that is unfamiliar to learners (such as vocabulary words) may not be beneficial for students who have no pre-existing mental representation of the topic (Lutz, Briggs, & Cain, 2003).
- As expertise in an area increases, the benefits of generation decreases; those with high prior domain knowledge may not benefit from generation to the extent that those with low prior knowledge (Lutz, Briggs, & Cain, 2003; Rittle-Johnson & Kmicikewycz, 2008).
- Generating an incorrect answer in a problem-solving activity may not yield the benefits of the generation effect described above. This is true when the activity requires the construction of knowledge, rather than the retrieval of existing knowledge (Kizilirmak, Wiegmann, & Richardson-Klavehn, 2016).
    - However, generation can be beneficial when an incorrect response is accompanied by corrective feedback (Metcalfe and Kornell, 2007).
- As the cognitive load necessary to complete a learning task increases, the efficacy of the generation effect decreases.
    - Providing worked worked-examples may prove to be more beneficial (Chen, Kalyuga, & Sweller, 2016).

Educational Implications

- Preparing for exams
  - students first generate potential exam items and then answer them
  - students generate study outlines from course materials
- Transfer appropriate processing
  - Assign generative activities that focus on the elements important to future testing
  - Ensure that the generative practice resembles the actual testing situation. For example:
    - Essay exam questions: short essay generative-study activities
    - Multiple-choice exam questions: quizzing activities, matching future testing, that align with Bloom's Taxonomy generative-learning activities
- Provide corrective feedback, when indicated, to generative activities
- Finally, Metcalfe and Kornell (2007) suggest, ". . . pause from time to time, asking questions that encourage the students to generate the answers themselves, Socratic style. It would seem important not to immediately jump to the answer. A short pause or, even better, a seemingly interminable pause of several seconds may greatly enhance learning. It may also be beneficial for the whole class, and not just for the students who answer, if the instructor asks individuals to answer aloud, but without saying in advance who the victim will be" (p. 228).

Bibliography

Bertsch, S. & Pesta, B. (2014). Generating Active Learning. In V. A. Benassi, C. E. Overson, & C. M. Hakala (Eds.). *Applying science of learning in education: Infusing psychological science into the curriculum.* Retrieved from the Society for the Teaching of Psychology web site:http://teachpsych.org/ebooks/asle2014/index.php

Bertsch, S., Pesta, B. J., Wiscott, R., & McDaniel, M. A. (2007). The generation effect: A meta-analytic review. *Memory & Cognition, 35*(2), 201-210.

Chen, O., Kalyuga, S., & Sweller, J. (2016). Relations between the worked example and generation effects on immediate and delayed tests. *Learning and Instruction*, 45, 20-30.

deWinstanley, P. A. (1995). A generation effect can be found during naturalistic learning. *Psychnomic Bulletin & Review, 2*(4), 538-541.

deWinstanley, P. A., & Bjork, E. L. (1997). Processing instructions and the generation effect: A test of the multifactor transfer-appropriate processing theory. *Memory, 5*, 401-421.

deWinstanley, P. A., Bjork, E. L., & Bjork, R. A. (1996). Generation effects and the lack thereof: The role of transfer-appropriate processing. *Memory, 4*(1), 31-48.
Doctorow, M., Wittrock, M. C., & Marks, C. (1978). Generative processes in reading comprehension. *Journal of Educational Psychology, 70*(2), 109-118.
Foos, P. W., Mora, J. J., & Tkacz, S. (1994). Student study techniques and the generation effect. *Journal of Educational Psychology, 86* (4), 567-576.
Johnson, D. I., & Mrowka, K. (2010). Generative learning, quizzing and cognitive learning: An experimental study in the communication classroom. *Communication Education*, *59*(2), 107-123. doi:10.1080/03634520903524739
Karpicke, J. D., & Zaromb, F. M. (2010). Retrieval mode distinguishes the testing effect from the generation effect. *Journal of Memory and Language, 62*, 227-239. doi: 10.1016/j.jml.2009.11.010
King, A. (1992). Comparison of self-questioning, summarizing, and notetaking-review as strategies for learning from lectures. *American Educational Computing Research Journal, 29*(2), 303-323.
King, A. (1992). Facilitating elaborative learning through guided student-generated questioning. *Educational Psychologist, 27*, 111126.
Kizilirmak, J.M., Wiegmann, B., & Richardson-Klavehn, A. (2016). Problem solving as an encoding task: A special case of the generation effect. *Journal of Problem Solving,* 9, 59-76.
Lawson, M. J., & Chinnappan, M. (1994). Generative activity during geometry problem solving: Comparison of the performance of high-achieving and low-achieving high school students. *Cognition and Instruction, 12*(1), 61-93.
Lovett, M. C. (1992). *Learning by problem solving versus by examples: the benefits of generating and receiving information*. In Proceedings of the Fourteenth Annual Conference of the Cognitive Science Society. (pp. 956–961). Hillsdale, NJ: Erlbaum.
Lutz, J., Briggs, A., & Cain, K. (2003). An examination of the value of the generation effect for learning new material. *The Journal of General Psychology, 130*(2), 171-188.
McCurdy, M.P., Leach, R.C., & Leshikar, E.D. (2017). The generation effect revisited: Fewer generation constraints enhances item and context memory. *Journal of Memory and Language,* 92, 202-216.
McDaniel, M. A., Waddill, P. J., & Einstein, G. O. (1988). A contextual account of the generation effect: A three-factor theory. *Journal of Memory & Language, 27*, 521-536.
McNamara, D. S., & Healy, A. F. (1995). A procedural explanation for the generation effect: The use of an operand retrieval strategy for multiplication and addition problems. *Journal of Memory and Language, 34*, 399-416.
McNamara, D. S., & Healy, A. F. (2000). A procedural explanation of the generation effect for simple and difficult multiplication problems and answers. *Journal of Memory and Language, 43*, 652-679.
Metcalf, J., & Kornell, N. (2007). Principles of cognitive science in education: The effects of generation, errors, and feedback. *Psychonomic Bulletin & Review, 14*(2), 225-229.
Morris, C. D., Bransford, J. D., & Franks, J. J. (1977). Levels of processing versus

transfer appropriate processing. *Journal of Verbal Learning & Verbal Behavior*, *16*, 519-533.

Pesta, B. J., Sanders, R. E., & Murphy, M. D. (1999). A beautiful day in the neighborhood: What factors determine the generation effect for simple multiplication problems? *Memory & Cognition, 27*(1), 106-115.

Rittle-Johnson, B., & Kmicikewycz, A. O. (2008). When generating answers benefits arithmetic skill: The importance of prior knowledge. *Journal of Experimental Child Psychology, 101*, 75-81

Slameka, N. J., & Graf, P. (1978). The generation effect: Delineation of a phenomenon. *Journal of Experimental Psychology: Human Learning and Memory, 4*(6), 592-604.

Thomas, A. K., & McDaniel, M. A. (2007). The negative cascade of incongruent generative study--test processing in memory and metacomprehension. *Memory & Cognition, 35*(4), 668-678. doi:10.3758/BF03193305

Wittrock, M. C. (1989). Generative processes of comprehension. *Educational Psychologist, 24*, 345-376.