



White Paper

Productive Struggle for Deeper Learning

MARCELLA L. BULLMASTER-DAY, ED.D.

“Making mistakes and correcting them builds the bridges to advanced learning.”

— BROWN, ROEDIGER & MCDANIEL, 2014, P. 7



Significant, durable academic learning is difficult. When students expend effort to grapple with perplexing problems or make sense of challenging ideas, they engage in a process of **productive struggle**—effortful practice that goes beyond passive reading, listening, or watching—that builds useful, lasting understanding and skill.¹ This white paper will explain the concept of productive struggle, identify learning strategies that promote productive struggle, and discuss ways in which Waggle engages students in productive struggle to build critical thinking and increase school achievement in meeting more rigorous state standards.

PRODUCTIVE STRUGGLE: WHAT IS IT AND WHY IS IT IMPORTANT?

Many teachers and students intuitively believe that new material can best be mastered through familiar activities that have been widely used for decades. These include repeatedly reading and highlighting texts, intensively practicing one skill or problem type to “burn it into memory” before moving on to the next, or “cramming” in long study sessions right before a test. And, indeed, these methods do work in the short run when the only goal is to display the new information or skill on an immediate assessment. Studying by rereading, cramming, and massed practice produce an “illusion of knowing,”² yet the learning quickly dissipates and can’t be retrieved for future application to a new situation.³

On the other hand, durable mastery of the academic skills and content set forth in more rigorous state standards, including the Common Core State Standards, is evidenced by deep conceptual understanding and procedural fluency that transfers to new situations and persists over time.⁴ Empirical cognitive and neuroscience research shows that this kind of learning is achieved only through productive struggle.⁵

Effort and persistence matter so much because we encounter new information through our limited short-term

working memory system, which focuses attention by filtering out most environmental stimuli. Working memory holds the attended-to information for only a few seconds, seeking meaning through associations between the new material and what we already know. Then, the more we actively work with the new material over time to strengthen those associations, the better organized and integrated into our existing knowledge via interconnected neural networks or **schemas** of long-term memory, meaning, and understanding it becomes. Building robust, lasting connections between new and old information requires conscious effort to repeatedly pull the newer information from memory, including making mistakes along the way and correcting them through feedback and further practice.⁶

Productive struggle also enhances students’ metacognitive self-regulation – the ability to set learning goals, plan strategies to meet those goals, monitor progress, and know when and how to ask for help along the way.⁷ Critical thinking requires these types of self-regulation and thought processes.

KEY ELEMENTS OF PRODUCTIVE STRUGGLE

Motivation, persistence, and scaffolded support through targeted explanatory feedback are key elements of productive struggle.



Motivation and persistence: When a learning goal is clear and the level of challenge is not too low or too high, students are more likely to be internally motivated to engage in productive struggle to achieve the goal.

Opportunities for choice, collaboration, use of interesting texts, and hands-on activities bolster student motivation, while too many competing demands for attention can diminish student resolve to persist toward an academic goal.⁸

Furthermore, motivation for productive struggle requires a “growth mindset;” the understanding that success is a result of effort more than of raw ability. A growth mindset makes students eager for new challenges, and enthusiastic rather than fearful about learning from mistakes. Students who believe that their ability levels are inherent and “fixed” are less motivated to engage in productive struggle because they fear failure, resist risks, and worry about the judgments of others, thwarting their own learning.⁹



Support and feedback: The durability of students’ motivation to persist in struggling to achieve an academic goal is mediated by the quality of the teacher-student relationship and the scaffolding provided through feedback. Struggle in academic learning contexts is **not** productive when students become frustrated because the goal is unclear or far out of reach, they do not feel

safe to fail, or they do not receive adequate, appropriate support.¹⁰ Struggle can be destructive in this situation, and teachers need to intervene after finding that students are not making any progress and feeling that their efforts are pointless.

Effective feedback makes clear to students what the goal is, what progress they are making toward that goal, and what they need to do next to make better progress. Instead of merely correcting students’ errors, effective feedback guides students to develop better strategies for processing and understanding the material so that they gain mastery, confidence, and motivation to continue to invest effort in productive struggle.¹¹

LEARNING STRATEGIES THAT PROMOTE PRODUCTIVE STRUGGLE

Productive struggle is fostered through what psychologists have termed **desirable difficulties**; challenges that compel the learner to repeatedly retrieve information over time, thereby strengthening long-term memory for flexible transfer of the information to new contexts later.¹² Strategies for desirable difficulties include low-stakes quizzing and self-testing; mixing or “interleaving” different types of problems; and spacing study and practice over time and locations.¹³

Quizzing and self-testing: The retrieval-enhanced practice of low-stakes, ongoing quizzing or formative assessment requires students to express, from memory, what they understand about new material and allows them to pinpoint and correct their knowledge gaps or misconceptions. Productive low-stakes testing methods include creating flashcards; generating summaries, outlines, and questions; explaining the material to oneself (elaborate interrogation); explicitly relating new mate-

rial to other examples; and taking multiple-choice or constructed-response tests.¹⁴

Spaced (distributed) practice: Spreading study, quizzing, and practice sessions over time and locations has been shown to produce lasting learning because long-term memory of the material is strengthened each time



information is actively retrieved. Spaced practice involves productive struggle, as it entails some forgetting, mistakes, corrections, and re-learning.¹⁵

Mixed (interleaved) practice: On standardized tests and in real-world situations, questions and problems do not come to students with labels naming the type of problem and revealing which strategies, skills, or algorithms should be invoked to solve the problem or respond to the question. Therefore, practicing different kinds of questions and problems builds learning-for-transfer more effectively than the more common massed-practice approach of working on one type of problem at a time until it appears that students have mastered it before moving on to the next. Interleaving problem types requires students to ask themselves, “What kind of problem is this? What do I need to do? Where should I start?” They must engage in the productive struggle of retrieval to answer these questions.¹⁶

HOW WAGGLE EFFECTIVELY ENGAGES STUDENTS IN PRODUCTIVE STRUGGLE

Research shows that adaptive online instruction with practice is conducive to expanding student learning time, personalizing learning tasks, and engaging students in effective productive struggle.¹⁷ Waggle provides students with rich opportunities to gain confidence and competence in meeting more rigorous standards through productive struggle in a safe, positive environment with in-the-moment feedback, scaffolded instruction, and personalized pathways to retrieval practice.

Quizzing, testing, and feedback in Waggle: Waggle’s Smart Practice is the core of the Waggle solution, providing students with personalized practice and customized feedback. Waggle leverages Knewton’s adaptive learning technology, which continuously analyzes the activity of each student, such as how many hints were accessed, active time in the program, past performance on related items, and cohort activities. With Knewton, Waggle can recommend activities at the right level of challenge for each student and provide targeted feedback to help address specific weaknesses.

In every ELA or math practice item, Waggle offers students up to five hints that they can choose to access if they need help. In addition, when they get the practice

item wrong, instead of revealing the answer immediately, Waggle offers feedback that corrects misperceptions and helps students to be more successful in their next attempt. There can be 12 or more different pieces of feedback for any item. The student can then reset the problem and tackle it again.

Smart Practice also serves as ongoing formative assessment, with real-time reporting on how students are doing while they are practicing. Teachers do not need to wait for students to take a full-length summative exam to pinpoint students’ strengths and weaknesses on a particular skill or standard.

As students are practicing in Waggle, they are rewarded for their effort, not merely for their correct or incorrect responses. Students are never penalized for accessing hints or resetting the item to try it again. They will see their points continue to rise the more that they practice, which creates a sense of safety to take risks and to persist when they initially miss a correct response to an item.

Spaced practice in Waggle: Knewton’s adaptive learning technology introduces new material incrementally and weaves it into familiar content over an extended period of time. The Knewton system also accounts for changes in memory and skill, reintroducing items on topics to which students have not had recent exposure. This helps to counter the loss, and students benefit from more durable learning with active retrieval of material.

Mixed practice in Waggle: Waggle provides students with mixed practice on a variety of dimensions. First, there are 11 different item types such as drag-and-drop and sorting as well as educational games. These items are not labeled as specific types of problems, and they come up “mixed” so that students cannot predict what type of item will come next.

Second, practice items vary in content and subject matter. Based upon students’ responses to items and their learning histories, Knewton’s adaptive system ascertains which underlying or related skills need further practice and offers the most appropriate practice to meet each student’s need.



Reporting in Waggle: Waggle offers a full suite of reporting in real-time that gives teachers the help they need in planning and adjusting instruction. Teachers can keep track of students' productive struggle through a "grit level" that takes into consideration the following variables:

1. Amount of time a student has spent working on a skill (active time)
2. Number of hints accessed across all practice items and games
3. Number of attempts a student has made working on the practice items or games
4. How often a student works on additional practice items after completing that skill

Waggle also reports on students' "proficiency" at the skill level. Knewton calculates proficiency by taking account student behavior in the system, including factors like their activity history, goals, and time remaining. If a student is getting the items correct without making multiple attempts, then their proficiency level is likely to be higher. If a student needs customized feedback and multiple tries to get the answer, then their proficiency level is likely to be lower. As students engage in productive struggle, their proficiency level is expected to increase. In the instances where grit level is high but proficiency level is low, intervention by a teacher is required. Waggle's reports identify the students who are struggling so that the teacher is alerted to the situation.


PRODUCTIVE STRUGGLE IN ACTION, —MATH EXAMPLE

Below is a line-plot math item at the sixth grade level. **There are four hints at the bottom** that the student can access if they need help.


The first hint helps the student think about taking the first step in solving the problem by asking the student to locate Shawna's score from the first round of the game.

Shawna is playing a board game with her brother. She scored -3 points in the first round. How many points does she need to score in the second round so that her overall score is 0?

Plot a point to show the score Shawna needs in the next round.
Click or tap the point. Click or tap the Reset button to start over.



Hint 1: What was Shawna's score after the first round? Try locating that on the number line.



Tools Hints: 1 2 3 4  Check My Answer




If a student working on this problem chooses '-6' on the number line, and then checks their answer, Waggle will not simply reveal the correct answer. Rather, Waggle will direct the student to take another look, providing specific feedback about the answer choice and how to approach the item again by thinking about the "opposite direction."

Shawna is playing a board game with her brother. She scored -3 points in the first round. How many points does she need to score in the second round so that her overall score is 0?

Plot a point to show the score Shawna needs in the next round.
Click or tap the point. Click or tap the Reset button to start over.



Take another look The number you selected, -6 , is 3 units away from -3 on a number line, but is it in the same direction from 0 or the opposite direction from 0 as -3 ? Do -6 and -3 have a sum of 0?


Tools Hints: 1 2 3 4  Check My Answer


The student can now "reset" the problem to try it again.

Shawna is playing a board game with her brother. She scored -3 points in the first round. How many points does she need to score in the second round so that her overall score is 0?

Plot a point to show the score Shawna needs in the next round.
Click or tap the point. Click or tap the Reset button to start over.

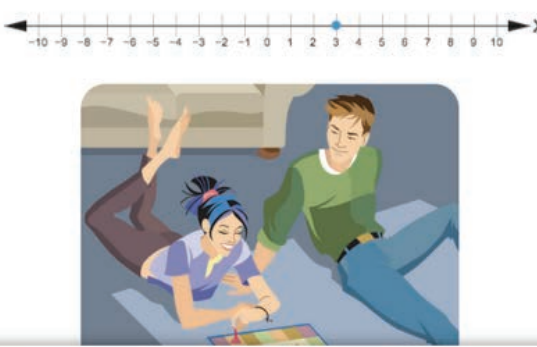
 Reset

Tools Hints: 1 2 3 4  Check My Answer

This time, the student chooses 3, the correct answer. Waggle provides **affirmative feedback**, reinforcing why the solution chosen is correct, and the student can move on to the next question.


A student may attempt the problem several times and use both hints and the constructive feedback to learn what is the best way to tackle the problem. Going through practice items with productive struggle takes time and persistence, but engages students in active learning.

Shawna is playing a board game with her brother. She scored -3 points in the first round. How many points does she need to score in the second round so that her overall score is 0?



Plot a point to show the score Shawna needs in the next round.
Click or tap the point. Click or tap the Reset button to start over.

Yes! Well done! Shawna will have a score of 0 after the second round by getting the opposite number of points, 3, that she scored in the first round.

Tools Hints: 1 2 3 4  Next question

CONCLUSION

The case for productive struggle, especially with the current increase in the rigor of state standards, is compelling—if not critical—to helping students attain college and career readiness. Waggle offers an excellent opportunity for students to work through desirable difficulties through spaced and mixed practice with immediate feedback in a personalized, smart-practice solution.



ABOUT THE AUTHOR

Marcella L. Bullmaster-Day is the Director of the Touro College Lander Center for Educational Research in New York City. She has worked as a teacher, principal, researcher, university professor, corporate executive, curriculum and program designer, and professional development consultant in urban educational contexts for over three decades. Dr. Bullmaster-Day holds a doctorate in Curriculum and Teaching from Columbia University Teachers College.



ENDNOTES:

- ¹ Hiebert, J., & Grouws, D. (2007). The effects of classroom mathematics teaching on students' learning. In F. K. Lester (Ed.), *Second Handbook of research on mathematics teaching and learning* (pp. 371 – 404). Greenwich, CT: Information Age.
- Dr. James Stigler on productive struggle:
<http://www.npr.org/blogs/health/2012/11/12/164793058/struggle-for-smarts-how-eastern-and-western-cultures-tackle-learning>
- ² Bjork, R. A., Dunlosky, J., & Kornell, N. (2013). Self-regulated learning: Beliefs, techniques, and illusions. *Annual Review of Psychology*, 64, 417–444.
- Karpicke, J.D. (2009). Metacognitive control and strategy selection: Deciding to practice retrieval during learning. *Journal of Experimental Psychology*, 138(4), 469 – 486.
- Kornell N., & Bjork, R. A. (2007). The promise and perils of self-regulated study. *Psychonomic Bulletin and Review*, 6, 219–224.
- ³ Callender, A. A., & McDaniel, M. A. (2009). The limited benefits of rereading educational texts. *Contemporary Educational Psychology*, 34(1), 30–41.
- Karpicke, J. D., Butler, A. C., & Roediger, H. L. (2009). Metacognitive strategies in student learning: Do students practice retrieval when they study on their own? *Memory*, 17, 471–479.
- Storm, B.C., Bjork, E.L., Bjork, R.A. (2007). When intended remembering leads to unintended forgetting. *Quarterly Journal of Experimental Psychology*, 60(7), 909 – 915.
- ⁴ See: <http://www.corestandards.org/read-the-standards/>
- ⁵ Bransford, J.D., Brown, A.L., & Cocking, R.R. (Eds.) (2000). *How people learn: Brain, mind, experience, and school*. Washington, DC: National Academy Press.
- Bransford, J.D., Brown, A.L., & Cocking, R.R. (2008). Mind and brain. In *The Jossey-Bass reader on the brain and learning*. San Francisco: Jossey-Bass.
- Carey, B. (2014). *How we learn*. New York: Random House.
- Karpicke, J. D. (2012). Retrieval-based learning: Active retrieval promotes meaningful learning. *Current Directions in Psychological Science*, 21, 157–163.
- Rohrer, D., & Pashler, H. (2010). Recent research on human learning challenges conventional instructional strategies. *Educational Researcher*, 39(5), 406 – 412.
- Tokuhamma-Espinosa, T. (2010). *The new science of teaching and learning: Using the best of mind, brain, and education science in the classroom*. New York: Teachers College Press.
- Willingham, D.T. (2009). *Why don't students like school?* San Francisco: Jossey-Bass.
- ⁶ Brown, P.C., Roediger, H.L., & McDaniel, M.A. (2014). *Make it stick: The science of successful learning*. Cambridge, MA: Harvard University Press.
- For much more research about memory and learning, see the following:
<http://bjorklab.psych.ucla.edu/research.html>
<http://bjorklab.psych.ucla.edu/RABjorkPublications.php>
<http://bjorklab.psych.ucla.edu/ELBjorkPublications.php>
<http://psych.wustl.edu/memory/publications/>
- ⁷ Zimmerman, B. (2002). Becoming a self-regulated learner: An overview. *Theory into Practice*, 41(2), 64 – 70.
- Magno, Carlo (2010). The role of metacognitive skills in developing critical thinking. *Metacognition and Learning*, 5, 137–156
- ⁸ Carter, E. W., Lane, K. L., Crnabori, M. E., Bruhn, A. L., & Oakes, W. P. (2011). Self-determination interventions for students with and at risk for emotional and behavioral disorders: Mapping the knowledge base. *Behavioral Disorders*, 36(2), 100 – 116.
- Fredricks, J. A., Blumenfeld, P. C., & Paris, A. H. (2004). School engagement: Potential of the concept, state of the evidence. *Review of Educational Research*, 74, 59 – 109.
- Guthrie, J. T., Hoa, L. W., Wigfield, A., Tonks, S. M., Humenick, N. M., & Littles, E. (2006). Reading motivation and reading comprehension in later elementary years. *Contemporary Educational Psychology*, 32, 282 – 313.
- Heyman, G. D. (2008). Talking about success: Implications for achievement motivation. *Journal of Applied Developmental Psychology*, 29, 361 – 370.



- Lens, W., Lacante, M., Vansteenkiste, M., & Herrera, D. (2005). Study persistence and academic achievement as a function of the type of competing tendencies. *European Journal of Psychology of Education*, 20(3), 275 – 287.
- Moreira, P.A.S., Dias, P., Vaz, F.M., & Vaz, J.M. (2013). Predictors of academic performance and school engagement – integrating persistence, motivation, and study skills perspectives using person-centered and variable-centered approaches. *Learning & Individual Differences*, 24(1), 117 – 125.
- Pintrich, P.R., & Schunk, D.H. (2002). *Motivation in education: Theory, research, and applications* (2nd edition). Upper Saddle River, NJ: Merrill-Prentice Hall.
- Turner, J., & Paris, S. G. (1995). How literacy tasks influence children's motivation for literacy. *The Reading Teacher*, 48(8), 662 – 673.
- ⁹ Corpus, J., Ogle, C., & Love-Geiger, K. The effects of social-comparison versus mastery praise on children's intrinsic motivation. *Motivation & Emotion*, 30(4), 333 – 343.
- Dickhauser, O., Reinhard, A., & Englert, C. "Of course I will...": The combined effect of certainty and level of expectancies on persistence and performance. *Social Psychology of Education*, 14(4), 519 – 528.
- Dweck, C. (2006). *Mindset: The new psychology of success*. New York: Random House.
- Henderlong, J., & Lepper, M. R. (2002). The effects of praise on children's intrinsic motivation: A review and synthesis. *Psychological Bulletin*, 128(5), 774 – 795.
- Stevenson, H.W., & Stigler, J.W. (1992). *The learning gap: Why our schools are failing and what we can learn from Japanese and Chinese Education*. New York: Summit Books.
- Wood, R., & Bandura, A. (1989). Impact of conceptions of ability on self-regulatory mechanisms and complex decision making. *Journal of Personality and Social Psychology*, 56, 407 – 415.
- Zentall, S. R., & Morris, B. J. (2010). "Good job, you're so smart": The effects of inconsistency of praise type on young children's motivation. *Journal of Experimental Child Psychology*, 107(2), 155 – 163.
- ¹⁰ Cimpian, A., Arce, H., Markman, E. M., & Dweck, C. S. (2007). Subtle linguistic cues impact children's motivation. *Psychological Science*, 18, 314–316.
- Fisher, D., Frey, N. (2014). Scaffolded reading instruction of content-area texts. *Reading Teacher*, 67(5), 347– 351.
- Henderlong, J., & Lepper, M.R. (2002). The effects of praise on children's intrinsic motivation: A review and synthesis. *Psychological Bulletin*, 128(5), 774 – 795.
- Jackson, R.R., & Lambert, C. (2010). *How to support struggling students*. Alexandria, VA: ASCD.
- Valiente, C., Lemery-Chalfant, K., Swanson, J., & Reiser, M. (2008). Prediction of children's academic competence from their effortful control, relationships, and classroom participation. *Journal of Educational Psychology*, 100(1), 67 – 77.
- ¹¹ Black, P., & Wiliam, D. (1998). Assessment and classroom learning. *Assessment in Education*, 5(1), 7 – 74.
- Hattie, J., & Timperley, H. (2007). The power of feedback. *Review of Educational Research*, 77(1), 81 – 112.
- ¹² Bjork, R. A. (1994). Memory and metamemory considerations in the training of human beings. In J. Metcalfe and A. Shimamura (Eds.), *Metacognition: Knowing about knowing* (pp.185 – 205). Cambridge, MA: MIT Press.
- ¹³ Blakemore, S., & Frith, U. (2008). Learning and remembering. In *The Jossey-Bass reader on the brain and learning*. San Francisco: Jossey-Bass.
- Bransford, J.D., Brown, A.L., & Cocking, R.R. (2008). Mind and brain. In *The Jossey-Bass reader on the brain and learning*. San Francisco: Jossey-Bass.
- Dunlosky, J., Rawson, K.A., Marsh, E.J., Nathan, M.J., & Willingham, D.T. (2013). Improving students' learning with effective learning techniques: Promising directions from cognitive and educational psychology. *Psychological Science in the Public Interest*, 14(1), 4 – 58.
- Rohrer, D., & Pashler, H. (2010). Recent research on human learning challenges conventional instructional strategies. *Educational Researcher*, 39(5), 406 – 412.
- Sweller, J., van Merriënboer, J., & Paas, F. (1998). Cognitive architecture and instructional design. *Educational Psychology Review*, 10(3), 251– 296.
- Willingham, D.T. (2014). Strategies that make learning last. *Educational Leadership*, 72(2), 10 – 15.
- ¹⁴ Agarwal, P. K., Bain, P. M., & Chamberlain, R. W. (2012). The value of applied research: Retrieval practice improves classroom learning and recommendations from a teacher, a principal, and a scientist. *Educational Psychology Review*, 24(3), 437–448.



- Butler, A. C. (2009). Repeated testing produces superior transfer compared to repeated studying. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 36, 1118–1133.
- McDermott, K. B., Agarwal, P. K., D’Antonio, L. D., Roediger, H. L., & McDaniel, M. A. (2014). Both multiple-choice and short-answer quizzes enhance later exam performance in middle and high school classes. *Journal of Experimental Psychology: Applied*, 20(1), 3 – 21.
- Roediger, H. L., Agarwal, P. K., McDaniel, M. A., & McDermott, K. B. (2011). Test-enhanced learning in the classroom: Long-term improvements from quizzing. *Journal of Experimental Psychology: Applied*, 17(4), 382 – 395.
- Roediger, H.L. & Karpicke, J.D. (2006). The power of testing memory: Basic research and implications for educational practice. *Perspectives on Psychological Science*, 1(3), 181 – 210.
- Roediger, H. L., Putnam, A. L., & Smith, M. A. (2011). Ten benefits of testing and their applications to educational practice. In J. Mestre & B. Ross (Eds.), *Psychology of learning and motivation: Cognition in education* (pp. 1–36). Oxford: Elsevier. [
- Rosenshine, B., Meister, C., & Chapman, S. (1996). Teaching students to generate questions: A review of the intervention studies. *Review of Educational Research*, 66(2), 181 – 221.
- ¹⁵ Benjamin, A. S., & Tullis, J. (2010). What makes distributed practice effective? *Cognitive Psychology*, 61(3), 228 – 247.
- Cepeda, N. J., Vul, E., Rohrer, D., Wixted, J. T., & Pashler, H. (2008). Spacing effects in learning: A temporal ridge of optimal retention. *Psychological Science*, 19(11), 1095 – 1102.
- Delaney, P. F., Verkoeijen, P. P. J. L., & Spiguel, A. (2010). Spacing and the testing effects: A deeply critical, lengthy, and at times discursive review of the literature. *Psychology of Learning and Motivation*, 53, 63 – 147.
- Kornell, N., & Bjork, R. A. (2008). Learning concepts and categories: Is spacing the “enemy of induction”? *Psychological Science*, 19(6), 585–592.
- Rawson, K., Dunlosky, J., Sciartelli, S. (2013). The power of successive relearning: Improving performance on course exams and long-term retention. *Educational Psychology Review*, 25(4), 523 – 548.
- Rohrer, D. (2009). The effects of spacing and mixing practice problems. *Journal for Research in Mathematics Education*, 40, 4–17.
- Rohrer, D., & Taylor, K. (2006). The effects of overlearning and distributed practice on the retention of mathematics knowledge. *Applied Cognitive Psychology*, 20(9), 1209–1224.
- Smith, S.M., & Glenberg, A., & Bjork, R.A. (1978). Environmental context and human memory. *Memory & Cognition*, 6(4), 342 – 353.
- Sobel, H.S., Cepeda, N.J., & Kapler, I.V. (2011). Spacing effects in real-world classroom vocabulary learning. *Applied Cognitive Psychology*, 25(5), 763 – 767.
- ¹⁶ Dunlosky, J., Rawson, K.A., Marsh, E.J., Nathan, M.J., & Willingham, D.T. (2013). What works, what doesn’t. *Scientific American Mind*, 24(4), 47 – 53.
- Roediger, H.L. (2014). The science of successful learning. *Educational Leadership*, 72(2), 42– 46.
- Rohrer, D., & Taylor, K. (2007). The shuffling of mathematics practice problems improves learning. *Instructional Science*, 35(6), 481 – 498.
- ¹⁷ Koedinger, K.R., & Aleven, V. (2007). Exploring the assistance dilemma in experiments with cognitive tutors. *Educational Psychology Review*, 19(3), 239 – 264.
- Means, B., Toyama, Y., Murphy, R., Bakia, M., & Jones, K. (2010). *Evaluation of evidence-based practices in online learning: A meta-analysis and review of online learning studies*. Washington, DC: U.S. Department of Education Office of Planning, Evaluation, and Policy Development.
- Roels, P., Van Roosmalen, G., & Van Soom, C. (2010). Adaptive feedback and student behavior in computer-assisted instruction. *Medical Education*, 44(12), 1185 – 1193.
- Vandewaetere, M., Vanercruysse, S., & Clarebout, G. (2012). Learners’ perceptions and illusions of adaptivity in computer-based learning environments. *Educational Technology Research & Development*, 60(2), 307 – 324.



info@wagglepractice.com
www.WagglePractice.com