

Recent cognitive psychology research shows strongly that quizzes help retain learning. What does this mean for CAA?

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Abstract

Recent research in cognitive psychology has deepened understanding of the positive effect of retrieval practice on retention of learning. Studies clearly show that practicing retrieval, including taking formative quizzes and tests, is an efficient way of retaining learning for the long term, more efficient than spending the same time restudying. Quizzes and tests do not just measure learning: the very act of taking them gives recall practice and strengthens retention of what has been learned.

This paper is a position paper that draws on new results from elsewhere rather than producing new data itself. The paper introduces research on the retrieval effect, its findings and then considers what the findings mean for the application of computer assisted assessment in higher education and corporate training. The paper suggests that the logical consequences of the psychological research are that it would be efficient to give learners more opportunities for retrieval practice and that computer-assisted formative assessments are a good route for doing this.

Implications for design of formative Computer Assisted Assessment (CAA) are given, including use where possible of more short-answer or fill-in-blank questions and use of feedback showing the

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correct answer. Advice for organizations is also considered, including enabling easy access to quiz authoring software for instructors.

The paper considers various likely objections to the principles proposed and gives some counter-arguments. It also suggests some further directions for research into how CAA could take more advantage of findings in retrieval practice.

Introduction

Cognitive psychology research provides evidence about how we are able to learn things that we can easily retrieve later on. Imprinting something in the brain is of little value if it cannot be retrieved via the appropriate cue when needed. Since we forget so much, there is a huge difference between learning something in a lesson and being able to retrieve it reliably in the future. So ways to improve retrieval ability are critical to learning success. Cognitive science has shown that practicing retrieval of something reinforces a memory and makes it less likely to be forgotten.

To quote the Distinguished Professor of Psychology at UCLA, Robert Bjork (Bjork 2011):

"The act of retrieving information from our memories does much more than simply reveal that the information in question exists in our memories. In fact, retrieving information modifies our memories: The retrieved information becomes more recallable than it would have been otherwise"

Intuitively we might think that studying something repeatedly is a good way to get it to "stick" in memory, and countless students read and re-read their notes thinking that this is a good study strategy. But psychological research shows that retrieval practice -- practicing recalling something -- aids long term retention much more than restudying.

There are many ways of practicing retrieval – for instance writing something down, saying it in your head, using it in practice or being quizzed by a peer. But a very effective means of practicing recall is to take a quiz or test. By answering questions in a quiz or test, you practice retrieval, and that process helps you retain the information in memory, so that if you need to retrieve it in the future, you are more likely to.

To quote another eminent psychologist, Distinguished University Professor at Washington University in St. Louis, Roddy Roediger (2011b):

Making people actually think about material, to reconstruct it, to say it in their own words is much more effective than simply restudying it, yet many students don't seem to appreciate this. If you ask students how they study to remember, their study strategy is typically rereading and reviewing. That's good up to a point, but it would be much better if they actively practiced retrieval, which is what a test requires them to do.

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Assessment professionals are familiar with many of the indirect benefits of low-stakes quizzes and tests in learning. Here are just a few (see Shepherd, 2010 and Thalheimer, 2003 for a wider treatment):

- Giving learners information on how much they know and which topics they need to direct their further learning
- Giving feedback to correct misconceptions
- Motivating learners to study for the assessment and so giving them spaced repetition
- Helping instructors know how their students are learning directing future instruction
- Providing intrigue to interest and focus learners

This paper describes an additional direct benefit – that actually taking a quiz or test gives you retrieval practice which makes you more likely to be able to retrieve it in future, and so directly helps retention of learning. It then suggests how this research can help CAA practitioners use assessments more wisely to help the learning process.

Evidence from cognitive psychology experiments

In a much-cited paper, Roediger (2006b) had students study a prose passage with one group studying it for two periods and one group studying it for one period and being tested on it (by free recall) for a second period.

The results were striking and shown in Figure 1: those who just studied knew more immediately after the learning (recalled 81% vs 75%) but a week later, the ones who had been tested recalled more (56% vs 42%). The students who had been tested forgot much less than those who had just studied.

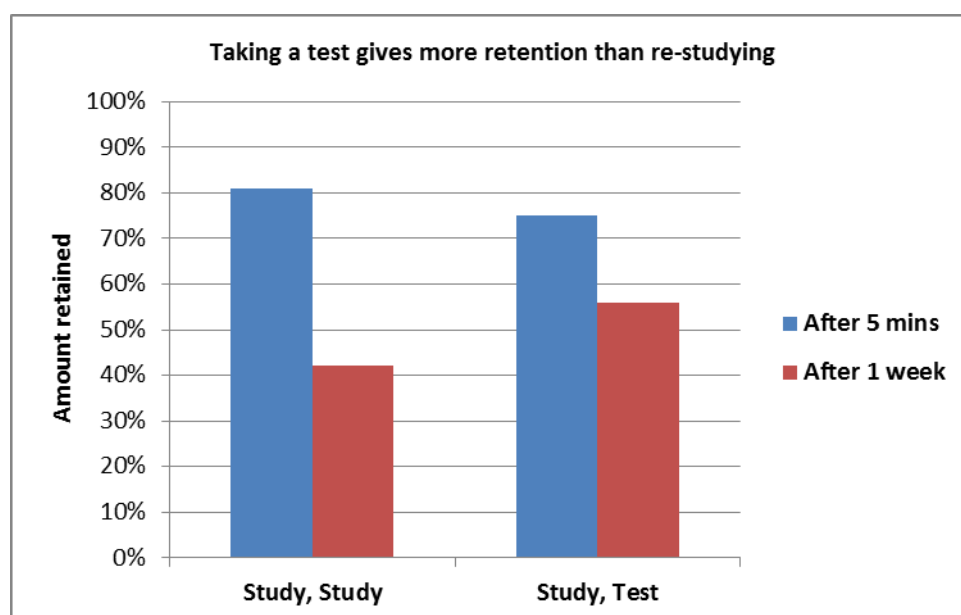


Figure 1, Data from Roediger 2006b, Experiment 1

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Other experiments have produced similar results using multiple-choice questions. Since retrieval reinforces what is answered, there is a risk with multiple-choice questions (see for instance Roediger, 2005) that learners might choose a distractor as the answer and reinforce wrong information. When using multiple-choice questions, the evidence suggests that giving feedback for wrong answers removes this risk and makes the quizzing process positive (Butler, 2008 and Roediger, 2011a).

Figure 2 below (redrawn from Roediger, 2011a) shows an experiment where 4 groups of students studied some history factual material. 3 groups were given a multiple-choice quiz, one with no feedback, one with immediate feedback and one with feedback delayed a bit. Students were tested a week later to see how much they'd retained, and the results are impressive. Retention significantly improved both by taking the quiz vs. not taking it (33% vs. 11%) and for receiving feedback (43% for feedback after each question and 54% for feedback at the end of a quiz).

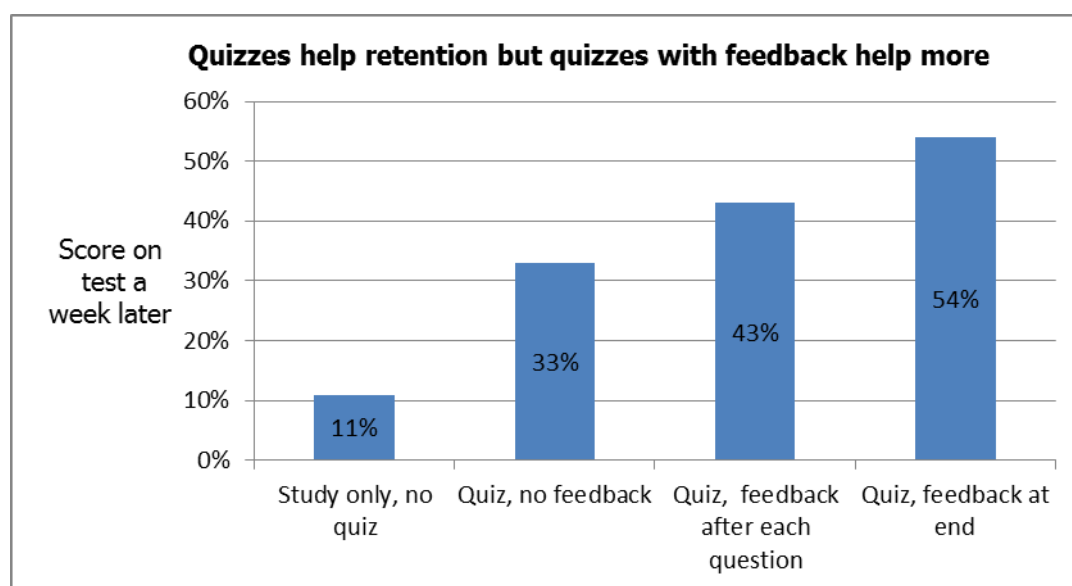


Figure 2. Chart from Roediger 2011a (Figure 3) redrawn

There are many other similar experiments that show the benefits of tests and quizzes to retain learning. See Roediger, 2006a and 2011a, and Thalheimer 2003 and 2008 for review papers. Some particular experiments of note:

- Marsh (2007) shows the effect does not just apply to facts but also to higher levels of the Blooms Taxonomy. Students quizzed with multiple-choice questions retained learning better both at the Bloom Definition level and also at the Bloom Application level
- Jacoby (2010) experimented with learners looking at pictures of birds and classifying them into families, and showed that people who had been quizzed were better at classifying birds in future over those who had studied for the same amount of time. This included bird examples that had not been included in the quizzes, and so demonstrates that the effect applies to concepts and not just facts.
- Karpicke (2011) experimented with students in science education, and achieved similar effects, both with facts that had been quizzed on earlier and with inference questions that had not been directly asked before.

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Evidence of practical benefit within learning

Real-life education and training is more complex than the laboratory, and it's natural to wonder how this effect applies in practice within a university or within corporate training. Do the results generalize to show that an instructor who quizzes his/her students frequently gets better results than someone who uses the time for other learning activities?

There are challenges in proving such results, as it's hard to provide a fair control group and also hard to isolate the retrieval practice effect from motivational and other benefits of testing. Here are three recent peer-reviewed studies where retrieval practice has been shown to produce practical benefit in real-life.

McDaniel (2007) shows an experiment where the retrieval effect was proved in a university course, with each student having a few facts after a lecture reinforced by restudying, a few by multiple-choice quizzes and a few by short answer quizzes. He and colleagues then measured performance on a final examination and determined if there was a difference in item performance depending on whether quizzes had been used to help retain the information. In this experiment, multiple-choice questions provided no significant long-term benefit over restudying, but using short answer questions for retrieval practice was significantly helpful on the final exam: 56% vs. 47%

Lyle (2011) also showed the effect in practice in a university course on statistics. He delivered the same course in two consecutive years, and introduced retrieval practice exercises (using recall questions) after each lecture in the second year. All other factors including student demographics were the same. Using retrieval practice after every lecture produced significantly higher exam results (average 86% vs 78%).

In another real-world study, Larsen (2009) performed an experiment with medical residents where doctors in training were given a training session on two topics. One group took a series of three spaced, practice short answer quizzes on one topic, and studied similarly spaced topic sheets on the second topic; the other group took quizzes on the second topic, and restudied the first topic. Results were then evaluated 6 months later with a final exam. There were statistically significant benefits for the topics that had been quizzed (42% vs 31%, and 36% vs 19%) and strong evidence that the retrieval practice effect applies in medical education.

Key messages for Computer Assisted Assessment

The key messages coming out of retrieval practice research that seem particularly relevant to CAA seem to be the following (see Roediger 2011b):

- Students are less likely to forget material if they have had retrieval practice, a chance to recall it after learning it.
- This applies both to knowledge of facts and also to application and to knowledge of concepts.
- There are other kinds of retrieval practice, but quizzes and tests are an excellent form of retrieval practice.
- Retrieval practice is most useful if it is effortful, for instance after a gap following learning.

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- Question types that prompt recall (e.g. short answer, fill in blanks) are the best questions for retrieval practice purposes.
- Question types that prompt recognition (e.g. multiple choice) give retrieval practice, but less effectively than recall questions.
- Quizzes and tests give retrieval practice and aid learning whether or not feedback is used. But corrective feedback that tells the right answer will improve the learning benefit (and is usually easy to deliver with CAA).
- If the quiz/test is difficult so that learners cannot get many right answers, then feedback is more important to provide learning benefit (Kang, 2007).
- There is a risk when using multiple-choice questions that if people choose a distractor and answer wrongly that the wrong answer could become more "imprinted" on their memory; giving feedback removes this risk (Butler, 2008).
- Feedback that gives the correct answer to incorrect questions is usually the most effective type of feedback (Fazio, 2010 and Shute, 2007).
- In order to retain something well, students need multiple attempts at retrieval.
- Learners are generally not good at predicting their own likelihood to forget; they typically overestimate their likelihood to retain learning (Karpicke, 2009 and 2011).

Advantages of CAA for retrieval practice

There are many possible strategies for encouraging retrieval practice, including getting students to understand its importance and having them practice recall or self-assessment. But clearly, use of computerized quizzes as assessments to help reinforce learning is one of the most obvious strategies for getting students to do retrieval practice. Here are some advantages of computer delivered assessments:

- The computer can help encourage or force retrieval practice. Learners often are over-confident about what they will remember and prefer an easier route than practicing retrieval (e.g. see Karpicke, 2009 and Karpicke, 2011). If you are taking a computer quiz, you usually cannot "cheat yourself" by looking ahead to the right answer, and you are forced to practice retrieval. Whereas for instance if you have a paper quiz with the right answers available, some learners will peek ahead and not gain the benefit of retrieval practice.
- The computer can record whether the quiz is taken or not, allowing reporting on and measuring of the retrieval practice
- There is some evidence (e.g. Jelfs, 2000) that people learn better in a situation with "presence" and that they ascribe such presence to a computer
- The computer can provide automated feedback, which helps reinforce the learning effect and remove any side effects of retrieving wrong answers
- The computer can randomly vary the questions, making it easier to repeat the quiz and give repetition of retrieval practice without using exactly the same questions
- As a side effect of delivering quizzes, it's easily possible to perform item analysis on questions and identify areas of student weakness, so a report back to the

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instructor on what areas students find puzzling will be a useful side-effect of the quizzes

- Increasing prevalence of mobile devices, including tablets like the iPad and smartphones, makes it practical to deliver quizzes on mobile devices that are available to students at any time
- Well-designed computer assessments can be more accessible for those with disabilities than paper assessments

There are other reasons to do assessments in the learning process, but this additional and significant benefit of retrieval practice should encourage use of computer assisted quizzes to directly aid retention of learning.

Implications for design of formative assessments

Here are some potential implications for the design of formative assessments, both those used directly for retrieval practice and also that, although they offer the benefits of retrieval practice, also have other purposes:

1. Where possible, use recall questions (e.g. short answer or fill-in-blanks questions) rather than recognition questions (e.g. multiple choice). However, multiple-choice questions will still help.
2. Encourage answering questions to give the retrieval practice. Don't, for instance allow people to "peek ahead" to see the right answer.
3. Focus your questions on the learning objectives and information that you want learned. Identify the key things that you want your learners to retain and ask questions about them. Do not test trivial facts or things that are not important to retain.
4. Consider using quizzes embedded on the page (Kleeman, 2010)
5. Give feedback for each question, particularly those that people get wrong. Ensure that the feedback includes the right answer (Fazio, 2010)
6. Consider repeating questions and assessments to give repeated retrieval practice.

Implications for a teaching or training organization

I would suggest these implications of this research for the central learning or assessment officers of an academic institution and for training managers in companies and government or other forms of adult learning:

1. Consider communicating the concept of retrieval practice to help people understand and use it. The more your learners and instructors understand that retaining learning requires retrieval practice, the more they are likely to

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use it and so retain learning longer. Restudying is not as efficient a learning strategy as retrieval practice.

2. Provide tools and infrastructure that allow your instructors to give your learners formative quizzes to help them practice retrieval. Given that almost any learning will benefit from retrieval practice, it will not be practical for all formative assessments to be centrally directed; empower all instructors to have the technology to create and deliver quizzes. The more you can make it easy for instructors to create and deliver retrieval practice quizzes easily, the more they will do it.
3. Train your instructors about the benefit of retrieval practice to increase take-up.
4. Make it easy for your learners to take quizzes by making them available on devices that learners have easy access to. The more channels of delivery there are, the more likely it is that people will use them. So consider making assessments available on all learner workstations and also consider how quizzes could be taken on mobile devices (smartphones, tablets, etc.) that many learners will have.
5. Since there is a significant benefit to giving feedback in such quizzes, particularly feedback in the form of correct answers to questions people got wrong, ensure that this is enabled in your system and communicated as good practice.
6. Consider in the light of your organization's culture whether to capture names of people taking retrieval quizzes; some people fear to be seen as wrong and in some cultures, it could be beneficial to allow quizzes to be taken anonymously. You may even want to label the quizzes as "memory aids".
7. Record the aggregate results of assessments so you can measure how much retrieval practice is being done and track trends over time. This will also help diagnose misconceptions by identifying where people are making mistakes.

What does this mean for summative assessments?

Summative assessments measure learner performance at the end of a course, or to determine who will receive a certificate or qualification as a result of assessment.

The main purpose of summative assessment is to measure learner knowledge, skills and abilities (KSA) and to provide a goal for learners to aim at. Although there will obviously be a small retrieval practice implication in summative assessments, this is outweighed by the measurement and goal-setting needs.

In general, summative assessments and certifications have an important place in society to measure people's KSA, and measurement issues should take priority over pedagogical ones. For instance, feedback is not given in some summative assessments and certifications in order to protect the content from exposure, and this will be a sensible balance for many organizations.

Where summative assessments are more granular, for instance where several summative assessments are given for a course, then the cumulative impact of the assessments is likely to have more impact on retention of learning, and so it may be worth considering the benefits of feedback in such assessments.

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Objections

Here are some potential objections to the thesis this paper presents, with some brief comments.

This just applies to facts, but my learners need to learn concepts and how to apply things.

See Marsh 2007 and Jacoby 2010 for evidence this is not the case.

Our course schedule is overloaded. We don't have time for learners to take more tests and quizzes.

The evidence suggests that taking a quiz or test is more efficient for retaining learning than spending time restudying. So if you want your learners to retain the information, it is worth using the time.

Our learners won't be willing to take tests.

As learners become educated on the benefit of tests for retrieval practice, this resistance is likely to reduce. Larsen (2009) reports: "Medical educators sometimes avoid tests because of fears that learners will be unwilling to take repeated tests (in addition to the fact that they have to be graded). This fear appears unfounded. In our study, the vast majority of residents expressed willingness to take regular tests."

We already have too many tests.

There is criticism that within some educational systems, there are too many standardized tests, which can test irrelevant facts or push teaching towards an inappropriate goal. The argument presented in this paper is not about standardized tests, it is about using relevant quizzes and tests to help people learn.

What matters is that our learners become creative – how does this help?

There are many facets to learning and clearly we need our learners to gain creativity, initiative, teamwork and many other skills for which retrieval practice may provide limited help. Creativity and other skills do need a foundation of knowledge on which to act.

Privacy rules or trade unions don't allow us to test learners.

Although it can be useful to capture identities of learners for analysis purposes, the benefits of retrieval practice do not require this. You can give anonymous quizzes or quizzes where results are not centrally recorded and still get the benefits.

We don't have the information technology to do more computer assessment.

It may be worth looking at technology innovations such as delivering assessments on smartphones or tablets/iPads, but if you don't have the IT, then give retrieval practice with paper quizzes.

More evidence would be helpful

The basic cognitive psychology evidence seems very strong, but it would be helpful to have more studies of the effect in practical, large-scale application within real-life courses, including those with CAA.

Cognitive psychology is not fashionable within education and training

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Huge sums are spent on education and training, and it's important that they are evidence-based. There seems considerable evidence that retrieval practice aids retention of learning. Education and training does not need to revert to drill and practice as its only style of learning, but the evidence suggests that using more formative assessments for retrieval practice is likely to help education and training produce better outcomes. Fashion may need to change!

Directions for further research

Research in this area is often directed from a cognitive psychology perspective rather than a CAA perspective. Here are three potential areas for further research:

1. The research has focused on the benefits of short-answer, fill-in-the-blank and multiple-choice questions. There has been less research on other question types – for instance matching questions or drag-and-drop questions. It would be useful to know how much benefit various question types provide for retrieval practice.
2. Research using computer-assisted assessment as retrieval practice within a real-world course (e.g., in a university or company) compared against a control group not using CAA would help validate the evidence.
3. More research on how many times it is helpful to retrieve something and what gaps between retrieval attempts to maximize learning benefit would be useful.

Conclusion

This paper has illustrated the substantial and significant benefits of retrieval practice in helping retain learning, and it has suggested how CAA practitioners can learn from the research.

For instructors and learners everywhere, the benefits of retrieval practice provide a promising pathway to more efficient learning. If we can reduce forgetting, then we can learn and retain more, faster. Students will come out of learning better equipped and instructors will be able to take them further in the same amount of time.

For computer assessment specialists, there is room to explore how we can use computer assessment to help with retrieval practice and allow our software to be used not just for measuring learning but also for directly helping it.

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References

- Bjork, R. A. (2011). On the symbiosis of learning, remembering, and forgetting. *A. S. Benjamin (Ed.), Successful remembering and successful forgetting: a Festschrift in honor of Robert A. Bjork. London, UK: Psychology Press*
- Butler, A.C., & Roediger, H.L. (2008). Feedback enhances the positive effects and reduces the negative effects of multiple-choice testing. *Memory & Cognition, 36, 604-616*
- Fazio, Lisa K. , Huelsner, Barbie J. , Johnson, Aaron and Marsh, Elizabeth J. (2010) Receiving right/wrong feedback: *Consequences for learning, Memory, 18: 3, 335 – 350*
- Jacoby, L. L., Wahlheim, C. N., & Coane, J. H. (2010, August 30). Test-Enhanced Learning of Natural Concepts: Effects on Recognition Memory, Classification, and Metacognition. *Journal of Experimental Psychology: Learning, Memory, and Cognition. Advance online publication. doi: 10.1037/a0020636*
- Jelfs, A. and Whitelock, D (2000). The notion of presence in virtual learning environments: what makes the environment "real". *British Journal of Educational Technology, 31(2), pp. 145–15*
- Kang, S. H. K., McDermott, K. B. and Roediger, H. L. (2007) Test format and corrective feedback modify the effect of testing on long-term retention. *European Journal of Cognitive Psychology, 19:4, 528 - 558*
- 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*
- Karpicke, J. D., & Blunt, J. R. (2011). Retrieval practice produces more learning than elaborative studying with concept mapping. *Science, 331, 772-775*
- Kleeman, J., Shepherd E. & Phaup J (2010). Embedded Assessments: Building Knowledge Checks, Surveys and Other Assessments into Learning Materials. *International Computer Assisted Assessment Conference 2010*
- Larsen, D.P., Butler, A.C., & Roediger, H.L. (2009). Repeated testing improves long-term retention relative to repeated study: a randomized controlled trial. *Medical Education, 43, 1174-1181.*
- Lyle, K.B & Crawford, N.L (2011). Retrieving Essential Material at the End of Lectures Improves Performance on Statistics Exams. *Teaching of Psychology 2011 38: 94*
- Marsh, E.J., Roediger, H.L., Bjork, R.A. & Bjork, E.L. (2007). The memorial consequences of multiple-choice testing. *Psychonomic Bulletin & Review, 14, 194-199*
- McDaniel, M. A., Roediger, H. L., & McDermott, K. B. (2007). Generalizing test-enhanced learning from the laboratory to the classroom. *Psychonomic Bulletin & Review, 14, 200-206*
- Roediger, H. L., III, & Marsh, E. J. (2005). The positive and negative consequences of multiple-choice testing. *Journal of Experimental Psychology: Learning, Memory, & Cognition, 31, 1155-1159*

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Roediger, H. L., III, & Karpicke, J. D. (2006a). The power of testing memory: Basic research and implications for educational practice. *Perspectives on Psychological Science, 1*, 181-210.

Roediger, H. L., III, & Karpicke, J. D. (2006b). Test-enhanced learning: Taking memory tests improves long-term retention. *Psychological Science, 17*, 249-255.

Roediger, H.L., & Butler, A.C. (2011a). The critical role of retrieval practice in long-term retention. *Trends in Cognitive Sciences, 15*, 20-27

Roediger, H.L., III (2011b). Private communication, *transcribed at*
<http://blog.questionmark.com/advice-from-cognitive-psychologist-roddy-roediger-on-using-retrieval-practice-to-aid-learning> and
<http://blog.questionmark.com/professor-roddy-roediger-on-applying-the-retrieval-practice-effect-to-creating-and-administering-assessments>, retrieved 30th March 2011

Shepherd, E & Godwin, J (2010). Assessments through the Learning Process
Retrieved March 30th, 2011, from
<http://www.questionmark.com/us/whitepapers/index.aspx>

Shute, V (2007) Focus on Formative Feedback, Retrieved March 30th 2011 from
<http://www.ets.org/Media/Research/pdf/RR-07-11.pdf>

Thalheimer, W. (2003). The Learning Benefits of Questions. Retrieved March 30th 2011, from <http://www.questionmark.com/us/whitepapers/index.aspx>

Thalheimer, W. (2008). Providing Learners with Feedback—Part 1: Research-based recommendations for training, education, and e-learning. Retrieved March 30th 2011, from <http://www.questionmark.com/us/whitepapers/index.aspx>

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