

## Daily quiz – for engagement ... and learning

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### ABSTRACT

Advances in neuroscience technology have allowed brain scientists to learn more about what occurs in the brain when a person engages in – and learns – something. And the findings in neuroscience have tremendous value to us educators in our efforts to foster engagement and learning among students in our classes.

Following up on a previously published paper on daily quizzes as an assessment tool, this paper now focuses on how and why the daily quiz could work well in getting students to engage and learn.

The author relates what neuroscientists have found when the human brain is exposed to, and processes, information. One of their major findings is the so-called ‘testing effect’. He then connects the neuroscience findings with his own experiences with daily quizzes, of both the ungraded and the graded sorts, in his classes. He gathered students’ feedback and reflections on the quizzes. The quizzes are very short – about 5 to 8 minutes at a time. But he and his students have found them to be effective tools that foster deep learning. In this paper, he makes the connections between what neuroscientists are finding and what his students are revealing about how and why the daily quiz works.

Keywords: daily quiz, engagement, learning, neuroscience, assessment

## INTRODUCTION

In my research for a previously published paper on daily quizzes (“Formative Assessment: The One-Minute Paper vs. the Daily Quiz”, Kwan 2011), I first got exposed to the literature on brain-based teaching & learning. In particular, I was pulled into the neuroscience aspect of teaching/learning by James E. Zull’s *The Art of Changing the Brain: Enriching the Practice of Teaching by Exploring the Biology of Learning* (Zull 2002). Moreover, the empirical results from actual classrooms in a study on the testing effect done by Prof. Henry Roediger III and others, as reported in the *Chronicle of Higher Education* (Glenn 2007), inspired me to dig deeper into understanding this “testing effect” and how it applies in my own classes.

Subsequent to my earlier paper, I have increased the frequency of my short quizzes, and I now give daily (as in every class-period) graded homework assignments, multiple ungraded in-class quizzes, and graded in-class quizzes. I have also studied more of the brain-based literature, and have participated in workshops devoted to the topic.

In this paper, I will focus on my experiences with the daily in-class quizzes, both ungraded and graded. And I will try to relate these experiences with what I have learned about their effects on the brain, to understand how and why these quizzes work in strengthening the engagement and learning of students.

## THE DAILY QUIZZES

On average, I give a couple of short ungraded quizzes every session, oftentimes at the start (covering the previous period’s topics) and in the middle (after discussing a new major concept) of the session. Students also call these “practice quizzes”. These are done in a “think / pair / share” format where students work on the problems individually for a few minutes, then pair up with a classmate and briefly share their thinking (how they arrived at an answer) with each other. Sometimes, if I sense a general uncertainty among students, I present a way of analyzing/solving the problem at the end of the exercise before moving on to a new topic.

The graded quizzes are given in the last 5-8 minutes of each period, on past topics. These are mostly “open-notes”, though I emphasize to students that the idea is for them to study their notes before coming to class because the time constraint precludes their studying their notes on top of doing the quiz. Besides, I only allow them to open their notes for a few seconds at a time – time enough to recall a difficult formula or term, but not enough to study the notes. Indeed, by the third week of quizzing, many of them won’t even open their notes anymore.

## MOTIVATION FOR THIS RESEARCH

Towards the end of the Fall 2015 semester, I asked students in my three sections of Principles of Macroeconomics to reflect on the various learning tools that we have used in class and identify the three that they found to be most helpful. The range of tools they could choose from included: basic concept-examples, conceptual similarities-&-differences, book problems, frequent homework assignments, class note-sheets, real-world data sets, real-world applications, graded daily quizzes, ungraded quizzes, and long exams.

I was expecting them to not pick the graded activities – homework assignment, daily quizzes, and long exams. But they surprised me tremendously, leading me to dig deeper into student engagement and learning.

There was a total of 85 students in my three classes that term; 84 of them turned in their reflection papers. Out of 84 students, 31 picked both graded and ungraded quizzes, 22 picked graded quizzes (but not the ungraded ones), while 25 picked ungraded quizzes (but not the graded ones). Six students even picked the long exams, of which there were three in the semester. The first group – those who picked both types of daily quizzes – made me wonder about the distinction between these quizzes from the students' viewpoint. In particular, what make these quizzes separately beneficial to students' learning? My research into this question made me realize that these quizzes have important effects on students' learning, which is known as the "testing effect" in the literature, and also on students' engagement or motivation.

To learn more about the brain-science aspect of motivation, I participated in the weeklong Learning & the Brain Summer Institute on "Neuroscience and Classroom Engagement" facilitated by Dr. Judy Willis in July 2017. The discussions at the institute led me to explore additional literature on the topic.

In this paper, I relate what neuroscience says about classroom engagement and student learning to what my students said about their experiences with daily quizzing. My goal is to help teachers understand what about daily quizzes works – and why.

## **DAILY QUIZZES, CLASS ENGAGEMENT, AND LEARNING**

In my simplistic non-technical understanding and terminology of the human brain, I discuss below what I learned from the neuroscience research literature about student learning and engagement.

The human brain is constantly bombarded with bits of information from all the body's senses. But only a tiny fraction of these sensory input gets through the attention or intake filter (the reticular activating system) of the brain, which it attends to at the moment. The rest is filtered out – ignored. "Awareness is the attention of the moment" (Willis 2006, p.39). Dr. Robert Desimone, director of MIT's McGovern Institute for Brain research describes consciousness as "just a vague word for the mental experience of attending ..." (Lightman 2014).

Only when the brain pays conscious attention to some information does the info become encoded as part of one's experience. But attention – the filtering of information: focusing on some, discarding the rest – comes at a cost to the brain. Neurons (brain cells) use up oxygen and glucose, and when the brain processes information, it tires the body (Levitin 2014). Hence attention is a strictly finite mental resource. Moreover, when the brain pays continued attention in concentrating on a task, neuroscientists in several studies have found that the brain is actually doing two things actively – focusing on some stimuli while actively suppressing other signals to avoid distraction (Gaspar & McDonald 2014).

The info that gets into conscious awareness quickly passes through the emotional switch (amygdala) which forwards it to either the lower reactive brain or to the upper reflective brain (hippocampus and prefrontal cortex). The lower brain's response to information that reaches it is mostly instinctive – fight, flight, or freeze. The upper brain is where further processing of information to become part of learning or long-term memory occurs – or not, depending on whether or not the new information can be connected to existing knowledge already stored in the brain (Willis 2017).

These are the two stages most relevant to understanding and managing our students' engagement.

## Filtering of Information

Neuroscientists have found that information tends to grab the brain's attention if (a) it is related to survival or bodily needs, (b) it presents a choice to be made, or (c) it involves novelty, the unexpected – a change in pattern (Willis 2006). Frequent short quizzes may encompass all three – grades for the students' academic survival, deciding on an answer to quiz questions, and breaking up the flow of a lecture or other class activity.

That my students viewed the quizzes as important is reflected in their comments. The quizzes, they wrote, *“helped for their grade incentive”*, *“made me pay more attention in class and take careful notes”*, *“helped me learn better, prepare for the big exams, cut down on test anxiety”*, *“force us to review every day, keep us on track”*, *“required that I come to class, and come prepared.”* One student even wrote, *“even though I dreaded these at the beginning, they kept me on top of things.”*

One quick note about the last comment. Willis (2017) notes that while some amount of stress may get the mind to focus, too much stress can impair memory and learning. Excessive stress felt by students in the classroom can show up as boredom, diffidence, or outright hostility. Breaking up tests into small and frequent quizzes (each counting for only a few points, if graded) helps bring down the stress level that comes with testing – and allows the beneficial impact on engagement and learning to work. One student noted about my short daily quizzes, *“they are a good indicator of our understanding ... even if you do not do well in a few quizzes, it will not destroy your grade.”* while another wrote, *“they tested my understanding and since I wouldn't use my notes, I really had to think through them ... getting them back and seeing what I got right help boost my confidence, or spurred me to study more on what I got wrong.”*

Indeed, one student even described the graded quiz as *“time-constrained, like a mini test; the pressure helps me stay engaged.”*

The quizzes make students think and decide, the second factor that engages their brain. Willis (2017) identifies ‘making predictions’ and ‘achieving challenges’ as two high-power dopamine releasers. Dopamine is not just a neurotransmitter, but also a source of intrinsic satisfaction – which fosters attention and motivation. Thus, it is important to design an appropriate level of challenge in the quizzes, and also to equip the students to succeed in them.

My students wrote that the practice quizzes *“made us think, write, and talk about our answers with a classmate”*, *“gave me a chance to work concepts out on my own”*, *“help me think and process concepts, and explain things to another.”*

One student wrote that in the ungraded quizzes, *“I try and apply what we learned on my own, then collaborate with a classmate for a possible different viewpoint that will make it click,”* and that *“with people being actively engaged and asking questions, the practice quizzes help a lot.”*

This last part of the statement above points to the ‘change in pattern’ that elicits the mind's attention. Along this same theme, other students wrote that the ungraded quiz *“is another style of teaching that switches up the traditional lecture,”* and *“makes me stop and think about what I'm learning.”*

Furthermore, Willis (2017) identifies ‘Interaction with peers’ and ‘movement’ as among the dopamine-boosters that help sustain engagement. A student commented that *“when I compare my thinking with that of my classmate, there is oftentimes another part of the concept or the problem that becomes clearer to me. This makes me think further about it.”*

In their popular book *How Learning Works*, Ambrose et al. (2010) discuss “seven research-based principles of smart teaching.” Principle #3 pertains to motivation among learners, and they define goals as “the basic organizing feature of motivated behavior.” The authors additionally identify two elements of motivation or goal-directed behavior: (a) the subjective value of a goal, or how important the goal is to the learner and (b) the expectancies of success, or how probable the learner’s effort is to attain the goal. I believe that having the daily small quizzes help bolster the expectancies of students in that they get a regular reading of where they are in their understanding.

Moreover, Ambrose et al. (2010) cite practice and feedback as Principle #5 of smart teaching, stating that goal-directed practice coupled with targeted feedback are critical to learning. I believe that the daily quizzes – both graded and ungraded – fostered my students’ engagement and learning, as evidenced in the following comments:

The ungraded quizzes “*give us frequent practice*”, while the graded ones “*force us to review, keep us on track, and feedback on my answers helped me learn more*”;

“*The practice quiz gave me a chance to attempt on my own, and then have an ‘on-the-spot correction’ when discussing with a classmate; the graded quiz challenged me on what I learned, identifying my errors.*”

One student made the following contrast: “*The practice quiz tests my understanding of a new concept on the spot; the daily graded quizzes assess my knowledge, after time passes.*”

That the daily graded quizzes helped in managing students “expectancies of success” are reflected in the following comments: “*the quizzes gave us a measure of what we already learned and what to spend more time on*” and “*a great indicator of how well I’m learning or not.*” And from one who decided to not use notes during the quiz: “*they helped me see what I learned in my memory – wrong answers raised a red flag for me to spend more time on.*”

James Lang, in his popular book *Small Teaching*, discusses two types of learning motivators frequently identified in the research literature: extrinsic and intrinsic. Examples of extrinsic motivators he cites are prizes, praise, some broader scale like personal, social or spiritual development (Lang 2016). Intrinsic motivation, however – when learners value learning itself or the item to be learned – is what ultimately drives true learning. Zull (2002) even describes extrinsic rewards as ‘deceptions’ which the brain easily sees through and thus does not foster true learning. Nevertheless, Zull continues, extrinsic rewards can have two positive effects that could lead to learning. One is that “they can get a learner started on something,” and they “can also sustain a learner at times of pressure and difficulty” (Zull 2002, p.52-53).

One student bore this out by writing: “*Before this class, I had no idea what economics is about. It’s not part of my major. But the quizzes and assignments etc. helped me learn a lot, and now it is one of my favorite subjects.*”

Another one wrote: “*At first I was upset that we would be taking quizzes every day and have HW due each class, but now I am so thankful for them... I feel like I’m not just memorizing and dumping it out after the test ...*”

When many students surprisingly identified both ungraded and graded quizzes separately as very helpful in their learning, it drove me to ponder the factors that drive students’ motivation to learn. In the terminology cited in the preceding paragraph, grades are the easiest example of extrinsic motivation. But other factors, extrinsic and intrinsic, are reflected in my students’ comments below.

Some students stated that “*the ungraded quizzes gave us a chance to practice without the grade pressure*”; some called them “knowledge checks”. But some students delved deeper into this notion of practice. One stated that the quizzes “*help me think and process concepts, and then explain things to another.*” Another one wrote “*discussing our thinking with someone ‘feeds back to our memory and strengthen it at the same time’, if we couldn’t agree we turn to someone else and ask about it. Knowledge is thus advanced.*”

Regarding the graded quizzes, one student stated “*even though I dreaded them at times, they were good practice for the test, I also used my quizzes for review.*” Another wrote, “*they solidify my understanding, also helped me break up my studying and not just cram before big exams.*” And one wrote, quite insightfully, “*the quizzes made sure that we can combine old concepts with new info, and kept all info fresh in our minds.*”

Finally, one student addressing me directly, wrote, “*with your quizzes and other tools, you opened my eyes to a new way of learning, and what true understanding of a concept means and feels like.*” I now thus turn to the “testing effect” – how daily quizzes foster learning.

### **Connecting to Prior Knowledge, and Enhancing Understanding**

Describing how information that gets through the brain’s attention filter is then processed into learning, Dr. Willis writes: “When there is connection to prior knowledge or positive emotional experience, new information passage through the limbic system will be enhanced. The thalamus will then ‘decide’ to pay attention to the information. If it is then interpreted as having rational meaning based on previous knowledge, it is linked to existing brain cell networks which, in turn, are enlarged, extended, and ultimately strengthened by their reactivation. If there are no emotional or intellectual connections to the new information ... it will be discarded and attention is withdrawn.” (Willis 2006, p.44)

The insightful student’s comment quoted earlier bears this out: “*the quizzes made sure that we can combine old concepts with new info, and kept all info fresh in our minds.*”

In schools, testing has traditionally been used as a dipstick of knowledge used to assign grades. But testing has another, even more important, use – as a learning tool. The “testing effect”, also known as the “retrieval-practice effect”, makes learning stick far better than does a simple review of the original material. This has long been known. Aristotle had written, “exercise in repeatedly recalling a thing strengthens the memory” (quoted in Brown, Roediger III, McDaniel 2014, p29). What has been more recently discovered is why this happens. Neuroscientists have found that recalling from memory is not a process of mere reproduction, but rather of reconstruction or reconsolidation or rebuilding. And the act of rebuilding strengthens and broadens the memory even more, and is what we experience as increased learning (Brown, Roediger III, McDaniel 2014, p74).

A Washington University study reported in the Chronicle of Higher Education (Glenn 2007) concluded that the benefits of increased motivation and heightened effort to study are merely the nice side-effects of quizzing. Its more potent effect lies in what the scholars call “effortful retrieval”. Frequent quizzing triggers a process that enhances long-term retention of new knowledge. Two of the researchers offer great analogies for this effect. Prof. Henry Roediger III says that quizzes may be somewhat like dipstick devices, but not exactly. They actually do more than a dipstick, because “every time you test someone, you change what they know.” Similarly, Jeffrey Karpicke says people’s memory may be like a storage space, or a library, except that the act of retrieving from it “is not neutral; it affects the system” (both quoted

in Glenn 2007). There is something in the process of responding to a quiz that strengthens learning.

Dr. Willis explains this more technically thus: With repeated practice and reactivation, the neuronal circuits of axons and dendrites (where knowledge or information is coded) become stronger and more developed ... “repeated practice stimulates cells in the memory circuit so that the circuit is reinforced and ... can be quickly switched on through a variety of cues coming in from the senses.” (Willis 2006, p.7)

These ideas are confirmed by the following comments from my students:

*“While I follow the class discussions well, this sometimes doesn’t translate to true learning. The regular quizzes force me to review the material and truly learn it.”*

*“The daily quizzes help fix class materials in our minds; they help you reflect on your notes.”*

*“Both the graded and the practice quizzes force us to use concepts from class and apply them in actual examples; they ingrain the topic we are learning into our memory by having us work on the topics three or more different days instead of just one.”*

In their book *Make It Stick*, Brown, Roediger III and McDaniel (2014) stress that quizzing must involve effort – effortful retrieval, they call it. This “makes for stronger learning and retention. We’re easily seduced into believing that learning is better when it’s easier, but research shows the opposite: when the mind has to work, learning sticks better.” (p.43)

Several of my students’ comment confirm this point:

*“The quizzes keep people on their feet .... Reviewing and applying something after learning it is the key.”*

*“Homework gives us immediate practice, the quizzes check our understanding afterwards. Both make the concepts stick – they reinforce our learning.”*

*“Quizzes are so constant in our class ... they help me learn; concepts don’t just go in one ear and out the other; and the quizzes are relatively short – not overwhelmingly long – but they still make us think.”*

*“The quizzes allowed me to apply my knowledge outside of my comfort zone, channeling my thinking into a specific mindset .... thus gaining a deeper understanding.”*

*“The quizzes keep me focused on the class ... frequent review & work help me learn.”*

*“As frustrating as it is sometimes to have a quiz every class, I honestly wouldn’t want you to take them away.”*

Another major point that *Make It Stick* makes regarding quizzes, which is also stressed in *Small Teaching* (Lang 2016), is the usefulness of “interleaving”. Researchers have found that practice, be it in sports or in math, produces deeper and more effective learning if interspersed and spaced out with other activities. Learners often believe that massed or repetitive practice is quicker and easier, and indeed it is. But is the resulting learning long-lasting?

To quote from *Make It Stick*: “If learning can be defined as picking up new knowledge or skills and being able to apply them later, then how *quickly* you pick something up is only part of the story. Is it *still there* when you need to use it out in the everyday world? ... [Interleaved practice] produces better mastery, longer retention, and more versatility.” But this solid gain in learning from interleaved practice has a cost – it requires more time and effort, it feels slower. Researchers have found that even in studies where the participants themselves got superior results from spaced learning, they still believed that they learned better with massed practice! (Brown, Roediger III and McDaniel 2014, p.47)

I am very pleased that at least several of my students actually addressed the benefits of interleaved quizzes:

One wrote, “... *having quizzes on topics after some other new topic is introduced made us then bring old info back into our brains, causing us to recall the info better.*”

A second stated, “*I enjoyed the scheduling of these quizzes: at the end of every class – allowing the passage of time and other topics, encouraged us to give thought to the material outside of class, and then checking our true understanding ... I gained from this ‘baby steps’ approach to teaching/learning.*”

A third wrote something similar: “*The quizzes assess my knowledge, after time passes along with new topics. Have to review my notes, and then revisit past topics every day in the quiz.*”

Yet another one (already quoted above) wrote, “*the quizzes made sure that we can combine old concepts with new info, and kept all info fresh in our minds.*”

I had been getting from some students, over the years, requests to have the graded quizzes at the start of class rather than at the end – before the class works on new topics. But I have resisted doing so, because it is easier to impose the time constraint on the quiz if it’s at the end of class. Furthermore, students who finish the quiz quickly don’t have to wait around for the rest of the class if the quiz is at the end. But now, I have an even more important reason to continue scheduling these quizzes at the end of class – interleaving.

### **Timely and Corrective Feedback**

The importance of timely feedback in order to engage students has already been covered in the section on “Filtering of Information”. Such feedback is also vital for the development of learning. *Make It Stick* states that timely informative feedback “enables you to see failure as a badge of effort and a source of useful information – the need to dig deeper or to try a different strategy... striving and setbacks [as in video games] are essential if you are to surpass your current level of performance, toward true expertise. Making mistakes and correcting them builds the bridges to advanced learning”. (Brown, Roediger III and McDaniel, 2014, p.7)

In my ungraded quizzes, students get feedback quickly from their classmates or me. With the graded quizzes, I always give these back to the students (with feedback) at the start of the next meeting.

Here’s what my students wrote about feedback and their learning:

“*The quizzes help my understanding as I am always getting constant feedback through my results; allowing me to ask questions when needed.*”

“*Homework is a way of solidifying my understanding of the topics ... the quizzes basically test the effectiveness of my studying.*”

“*The frequent timely feedback on the quizzes helped me clear up a lot of my early mistakes in each topic.*”

“*The quick feedback is great for our learning, but also it really helps in staying engaged.*”

“*Discussing our thinking with someone feeds back to our memory and strengthen it at the same time, if we couldn’t agree we turn to someone else (ex, prof) and ask about it. Knowledge is thus advanced.*”

“*Explaining to one another gave us the ability to get a different way of thinking, to help my understanding at a higher level.*”



## IMPACT OF DAILY QUIZZES ON STUDENT PERFORMANCE

Besides the overwhelmingly positive feedback that students give me about the daily quizzes, I have also seen a significant positive effect on student grades. I have always been giving frequent short graded quizzes since I started teaching more than 30 years ago. But it was in the last six years that I intensified the use of this learning tool, when I gave them on a daily basis, plus ungraded quizzes too.

I dug up my gradebooks from when I started teaching at my current school (in 1996) and analyzed the average grades that students had earned in my Principles of Economics courses – both Macroeconomics and Microeconomics over the years. Besides the quizzes, I also give three long exams in each class – spread out over the semester, roughly 5-6 weeks apart. These exams tend to measure the students’ long-term understanding (or retention if you will) of concepts. In the table below, I compare the average student grades in the period 1996-99 when the quizzes were frequent but not quite daily against the last six years (2012-17) when the quizzes became a daily exercise.

	Macroeconomics		Microeconomics	
	1996-99	2012-17	1996-99	2012-17
Number of classes	10	18	9	20
Average Grade in Quizzes (%)	84.3	84.5	83.2	84.1
Average Grade in Exams (%)	81.7	83.9	81.6	84.3

The data indicate that in the earlier period, when the quizzes were not quite daily, the students’ performance in the long exams were not as good as in the quizzes. Average exam grade in exams was 2.6%-pts and 1.6%-pts below the average quiz grade in Macroeconomics and Microeconomics respectively. Both of these differences are statistically significant at the 10% level of significance. In the later period however, when the short quizzes became more frequent, the students’ average performance in quizzes and in exams came close to parity. This suggests that the daily quizzing helped solidify the students’ understanding of the concepts, so that they can still recall and apply them even after the passage of several weeks.

## CONCLUSION

The daily quiz is indeed a powerful tool not just for assessing students’ performance but also, even more important, for fostering student engagement and learning. Research in neuroscience is helping us understand how and why this is so.

One final feedback from a student regarding quizzes and engagement: *“You show to us students that you’ve put in a lot of effort into developing and implementing and grading these quizzes. This makes us students see a purpose in your class: ‘If my prof is willing to work so hard, I will work as hard as him as well.’”* And a final comment regarding quizzes and learning: *“Having a prof give homework and quizzes every class period does not mean he is ‘punishing us for being in college’ or ‘throwing work at us for fun,’ rather it could mean he*

wants us to learn the material beyond just the lecture. Watching someone else swim will not make us learn to swim, we have to get in the water and try it ourselves. Same concept here.”

For the quizzes to be effective, however, they must be properly designed and implemented. To hold the attention and the engagement of students, they must present an achievable challenge. Challenging enough to avoid boredom, yet not too daunting as to create excessive stress that shuts down engagement and learning. The quizzing must also be ‘interleaved’ - testing old information or skills in the midst of learning new ones - so that effort is needed to succeed in them, and also to avoid mistaking memorizing for learning. Lastly, to promote growth in learning, the frequent quizzing must come with timely and corrective feedback.

The overlap between brain science and education is indeed a fertile area in which our understanding of how students learn and how to get them engaged can grow – helping us educators to become more effective in our profession.

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