ADAPTIVE LEARNING TUTORIAL PROGRAMS – LESSONS FROM BRAIN SCIENCE

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Abstract - Neuroscientists and game experts are helping us educators to understand better how to engage our students' minds in our classes. Their collaboration in research have identified some factors that we in education can use as guides to enhance the effectiveness of adaptive-learning tutorial programs which are now often packaged together with our textbooks.

Key Terms - Adaptive learning tutorial, engagement, frequent quizzes, games neuroscience

I. WHAT BRAIN SCIENCE SAYS ABOUT STUDENT ENGAGEMENT &LEARNING

In my research for a previous 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 and the effectiveness of frequent testing. 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". But what would make students persevere in doing the frequent tests? Several years ago I got involved in a project writing and editing questions for a major publisher's adaptive tutorial package to go with their popular economics textbook. I joined the projectalong with a couple of other professors, without fully understanding the philosophy and science behind the adaptive learning system. It was during my participation some years later in the Learning & the Brain Summer Institute on "Neuroscience and Classroom Engagement" facilitated by Dr. Judy Willis in July 2017 (Willis 2017) that the 'lightbulb moment' occurred for me. I learned that neuroscientists having been studying one common activity where young people exhibit strong active engagement in: playing games, particularly computer games. The scientists are thus working with gamers and game designers to acquire a better understanding of what makes an activity fully engaging and what goes on when a person is truly engaged in an activity (Bavelier, Green, Pouget, and Schrater 2012). In my simplistic non-technical understanding of the human brain, I discuss below what I learned from the neuroscience research literature about student engagement and learning. 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 information 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 students' engagement.

II. 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). The second and third factors are in play in engaging games: the player is

constantly required to make decisions and take action, and the scenario in the game keeps on changing from one round to the next, from one level to the next.

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 can show up as boredom, diffidence, or outright hostility. Breaking up tests into small and frequent questioning, as in the tutorial packages – along with the tutorial not counting too heavily towards the students' final grade – helps bring down the stress level of doing the tutorial. And this could allow the beneficial impact on engagement and learning to work.

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 tutorials, and also to equip the students to succeed in them. If the learner finds the tutorial questions too simple, boredom will quickly set in and the learners would disengage. On the other hand, if the learner finds the tutorial too complicated and challenging, with little hope for success, the learner would also disengage. Challenging, with reasonable expectations of success, is what would elicit enduring engagement, and thence learning (Dale, Sampers, Loo, and Green 2018).

III. HOW ADAPTIVE TUTORIAL PROGRAMS ARE DEVELOPED

Tutorial-Question Writers & Quality of Questions

My experience taught me that the questions included in tutorial packages that come with textbooks may be written by the textbook authors, or by other experienced professors with doctorates in the field, or by college instructors with master's degrees. Thus, in the case of economics some writers might write mostly theoretical questions, while others might focus more on real-world applications.

The quality of the questions could therefore vary quite a bit. The relative emphasis on various concepts or topics would also differ, depending on the biases of the question writers. For example in economics, some writers might consider the mathematics and computations of elasticities to be very important, while other writers may put more stress on the application of the elasticity concept. Even two writers stressing application may still differ in which application they focus on – simple theoretical cases, or more-complex business management-related applications.

There may even be variance in how the question writers understand and apply aspecific concept. For example, some economics professors might refer to G (in C, I, G, NX) as government spending whereas some others may distinguish between government purchases (G) and government spending (G + transfers).

Another major source of variance among tutorial writers is the level of difficulty or challenge they decide to assign each question. Level of difficulty is programmed into the tutorial packages, and this determines the sequence in which the questions would be posed to the learner. And, while there may be general agreement about the challenge level of basic definitional questions, this is not true for more advanced questions such as application or analytical ones.

Finally, one major element for a tutorial package to be effective is the accuracy of the prescribed answers. This is the "guide" that the program uses to either accept or reject a learner's answers. This depends on the carefulness of the question-writer and the accuracy-checker employed by the publisher.

Question Types& the Prescribed Answers

This section discusses some of the common question-types in adaptive tutorial programs, and corresponding characteristics that affect their ability to engage learners and their effectiveness as learning tools.

True/False–True/false questions heavily rely on the clarity and simplicity of the given statements, to elicit appropriate answers. Compound statements significantly weaken the usefulness of these questions to foster learning. But the major problem with true/false questions is their blindness to the reasoning or logic that underlies a student's answers. Unless the program requires true/false answers to be explained, these questions are minimally useful as formative assessment tools.

In the future, when the tutorial programs will have the ability to evaluate short explanations or discussions of true/false answers, then the educational power of these questions would improve.

Multiple Choice – The clarity of the "stem" or root statement, and of the alternative answers offered, is important to the effectiveness of these questions as learning tools. The quality of distractorsin each question is a vital element. Poorly written multiple-choice questions either contain distractors that are so obviously wrong, or the correct answer can be arrived at by guessing (based, for example, on the relative lengths of the correct answer versus the distractors) – making them devoid of learning.

Fill-in-the-blanks – The effectiveness of these questions relies on the uniqueness of the answers or the scope of alternative answers – and whether all possible correct answers have been inputted into the program. Students, for example, get extremely frustrated if a simple typo makes the program reject an otherwise correct answer.

Another source of learner frustration – and thus disengagement – is when the program fails to recognize an alternative correct answer.
Again, once technology allows the program to recognize and disregard minor errors, and to consider all alternative correct answers, then fill-in-the-blank questions would also become more useful as a tutorial tool.

Computations – Matching theprecision and accuracy of the prescribed correct answers for computation questions is a major challenge that learners face in getting the tutorial program to accept their answers. Problems crop up when rounding-off is necessary, for example. These concerns, however, are already currently addressed by specifying as acceptable a range of values within which the student's answer should fall. But the other side of this accommodation is the potential for wrong answers to fortuitously fall within the accepted range.

IV. EFFECTIVENESS OF ADAPTIVE TUTORIAL PROGRAMS TO ENGAGE LEARNERS – LESSONS FROM GAMES

Why are some computer/video games addictive for many people? Neuroscientists have identified the following as some of the contributing factors:

Challenging but with reasonable chances of success – To be engaging, tutorial programs as with games need to hook the learner into a challenging situation, and keep the challenge throughout, but one where the learner believes that success can be attained with effort. If the learner finds no challenge in the activity, boredom would quickly set in. If, however, the learner keeps on failing in every attempt, engagement would cease also.

Variable entry and multiple levels of challenge – This is a characteristic that adaptive tutorial programs all aspire for. It allows the learners to pace themselves, and to develop incremental learning. Good tutorial programs accommodate both those who need to start from the basics and those who could jump on to more challenging questions.

Self mastery and development of self-confidence – Engaging tutorial programs, like addictive games, allow the learner/player to notice the development of mastery from going through the program/game repeatedly. And as the challenge level progresses, learning also develops.

Reward for success; consequence of failure is not too punitive – Neuroscientists have identified dopamine as a both a neurotransmitter and also a source of pleasure for the brain. A feeling of success triggers a dopamine-boost in the brain, which in turn leads to motivation and engagement. Thus, if a learner sees that doing the tutorial over progressively-rising challenge-levels improves performance in a class, then that would be a quite an effective reward system for continued engagement with the tutorial. Moreover, if the learner encounters failure in the adaptive tutorial, but is able to do another 'round' in order to improve mastery without too harsh a penalty, then that too would foster engagement.

CONCLUSIONS

Just like in engaging computer/video games, good design couple with good content are necessary elements for an adaptive tutorial program to be effective. The vehicle has to be able to attract and hold the attention of the learner, and the content has to be effective in promoting learning.

Some games are unrewarding – players give them a try but the attention doesn't last. There is no motivation to persevere. These games are either boring or too complicated to attain success.
Brain science has found that for a learner to engage in an activity, that activity has to be challenging yet provides a reasonable expectation of success with effort. The reward system must be designed to trigger a dopamine boost in the brain, in order to sustain engagement.
How closely the course instructor's pedagogical approach, and vocabulary, match those in the adaptive tutorial program is an important factor of engagement because it affects the learner's perception of challenge and his/her chances of success in the tutorial program. The design and type of the tutorial questions, and the flexibility/rigidity of the programmed answers, are also important factors.
If learners see an improvement in their class performance as a result of their engaging with the adaptive tutorial program connected to the class, then that would provide aboost of motivation to sustain engagement with the tutorial.

REFERENCES

[1] Bavelier, D., Green, C.S., Pouget, A., & Schrater, P. (2012). "Brain Plasticity Through the Life Span: Learning to Learn and Action Video Games," Annual Review of Neuroscience, 35, 391-412.

[2] Dale G., Sampers, D., Loo S., and Green C.S. (2018). "Individual Differences in Exploration and Persistence: Grit and Beliefs about Ability and Reward," PLOS ONE, Vol.13 No. 9, September 4.

[3] Gaspar J. M. & McDonald J. J. (2014). "Suppression of Salient Objects Prevents Distraction in Visual Search," Journal of Neuroscience, Vol.34 (16) pp.5658-5666.

[4] Glenn, David (2007). "You Will Be Tested On This," Chronicle of Higher Education, June 8, Vol. 53 Issue 40, pp.A15-A17.

[5] Kwan, Felix (2011)"Formative Assessment: The One-Minute Paper versus the Daily Quiz," Journal of Instructional Pedagogies, Volume 5, May 2011, (http://aabri.com/manuscripts/10717.pdf).

[6] Levitin, Daniel J. (2014). "Why It's So Hard to Pay Attention, Explained by Science," Fast Company

Newsletter, September 23. (Adapted from The Organized Mind: Thinking Straight in the Age of Information Overload,by Daniel J. Levitin. Plume/Penguin Random House, 2014).

[7] Lightman, Alan (2014). "Attention," The New Yorker, October 1. (https://www.newyorker.com/tech/elements/anatomy-attention).

[8] Willis, Judy (2006). Research-Based Strategies to IGNITE Student Learning. Alexandria, VA: Association for Supervision and Curriculum Development (ACSD).

[9] Willis, Judy (2017). "Neuroscience and Classroom Engagement: Strategies for Maximizing Students' Attention, Focus and Potential," Learning and the Brain Summer Institute, July 10-14, Santa Barbara CA.

[10] Zull, James E. (2002). The Art of Changing the Brain: Enriching the Practice of Teaching by Exploring the Biology of Learning. Sterling, VA: Stylus Publishing, LLC.

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