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NEURO PEDAGOGY

Module 3

Engagement

Neuropedagogy

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Erasmus + Strategic Partnership for Higher Education

ENGAGEMENT

HOW DO YOU ENGAGE YOUR STUDENTS?

> *To learn, we need to engage.*
>
> - prof. dr. Paul Howard-Jones, Bristol University, UK

Engagement is an essential aspect of learning. However, we all know from experience that engaging students is sometimes a tricky part of teaching.

In this module, you discover what educational neuroscience can teach us about students' engagement with learning.

OVERVIEW

1. LEARNING OBJECTIVES

In this module, you learn:

- ❑ the neural mechanisms involved in the process of engagement
- ❑ that students all differ in what engages them
- ❑ that approach responses can engage us in learning
- ❑ that avoidance responses prevent us from learning
- ❑ that if you want to increase your students' engagement, you need to increase their activity
- ❑ strategies you can try in your classroom to engage your students

2. SELF-SCAN: QUESTIONS AND REFLECTION

Think of (one of) the classes you teach, and answer the questions below:

- What does an engaged student look like to you?
  - Paying attention?
  - Taking notes?
  - Listening?
  - Asking questions?
  - Responding to your questions?
  - Discussing the content of your class?
  - Other characteristics?
- How do you know your students are engaged?
- How long do you think your students can stay engaged and interested?
- How do you keep your students engaged and interested in your class(es)?
- What do you do when you notice your students are not engaged anymore?
- What factors motivate your students to work hard in your class(es)?
- What factors distract your students?
- How do you react to or deal with these distractions?

If you want to read more about engagement:

- *Schmoker, M. (2006). Results now: How we can achieve unprecedented improvements in teaching and learning. ASCD.*
- *Yarborough, C. B., & Fedesco, H. N. (2020). Motivating students. Vanderbilt University Center for Teaching. Retrieved 18/11/2021 from https://cft.vanderbilt.edu//cft/guides-sub-pages/motivating-students/*
- *Shirley, D., & Hargreaves, A. (2021). Five paths of student engagement: Blazing the trail to learning and success. Bloomington, IN: Solution Tree Press.*

3. WHAT DOES EDUCATIONAL NEUROSCIENCE SAY?

3.1. INTRODUCTION

Activating your prior knowledge …

- How do you think engagement works in the brain?
- What do you already know about engaging your students?

Z komentarzem [DS1]: https://www.shutterstock.com/nl/image-photo/involved-interested-happy-smiling-mixed-race-1443732986

> *The scientific study of engagement with educational contexts is in its infancy.*
>
> - Howard-Jones (2019)

Learning starts with engagement. But what does educational neuroscience already know about the neural mechanisms of engagement in our brains?

For this general introduction to neuroscience and engagement, you have the choice between two options:

(1) You can **watch a video** in which prof. dr. Paul Howard-Jones (Bristol University, UK) explains the neural mechanisms of engagement and why it is essential for learning.
(2) You can **read the summary** of the video.

At the end, there will be a short quiz. We encourage you to take some notes while watching or reading.

3.1.1. OPTION 1: WATCH THE VIDEO

Embedded YouTube video: https://youtu.be/kaeD7YZFsAI

3.1.2. OPTION2: READ THE SUMMARY

"To learn, we need to engage", states prof. dr. Paul Howard-Jones (Bristol University, UK). Being engaged is thus crucial for learning. It means that we are **caught and held in something**. If we want to learn something from a learning opportunity, we need to be ready and open to it. Engagement is therefore strongly related to and influenced by our emotions and motivation.

Communication between subcortex and cortex

To understand how engagement works in our brain, we must look at the **connections** between the **subcortex** and the **cortex**. The cortex is a thin sheet of neurons forming the outer bark of the brain. The subcortex consists of multiple structures lying deeper in the brain (see Figure 1).

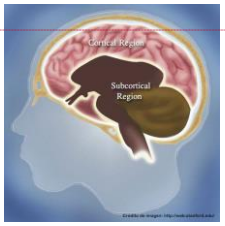


Figure 1: subcortex and cortex

Z komentarzem [DS2]: https://infotiti.com/wp-content/uploads/Cotical-y-subcortical.jpg

The **communication** between the subcortex and the cortex is **bi-directional**:

Some **subcortical structures**, like the amygdala and the nucleus accumbens, impact the prefrontal cortex, the part of the frontal cortex responsible for cognitive control, reasoning, problem-solving etc. Our emotions thus impact our reasoning.

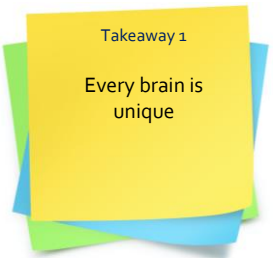
Communication also works in the opposite direction. The **prefrontal cortex** can provide top-down control of these subcortical structures, regulating how stimuli are processed. Our reasoning impacts the interpretation of emotional stimuli.

Because of this intensive connectivity between emotions (subcortex) and reasoning (prefrontal cortex), some scientists even suggest not considering them separately. Both are important for learning and engaging students to learn.

Four takeaways concerning engaging students

- Every brain is unique
- Approach responses can engage us in learning
- Avoidance responses prevent us from learning
- The plasticity of our brain

Brains engage differently



The relationship between engagement and learning is not a simple one. Engagement can lead to learning, but learning itself can also lead to more positive emotional responses and further engagement with learning (Supekar et al., 2015). Recent MRI studies (Howard-Jones et al., 2016a and 2016b) have shown increased activation in the brain's reward system, i.e. nucleus accumbens (see Figure 2), when students could win points while learning. The gamified learning environment increased the activity of the reward system, increased students' engagement, and increased their learning. Another recent study (DiMenichi et al., 2019) shows that when receiving feedback, the rewards system's activation correlates to how much the student learned from the feedback.

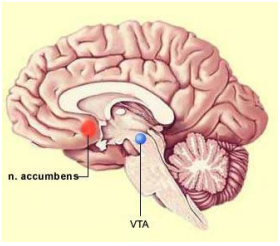
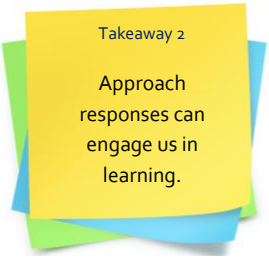


Figure 2: nucleus accumbens (reward systems)

However, not every brain is the same. Not every student responds in the same way to rewards and emotions. Not every student learns in the same way. Therefore, it is essential to consider interpersonal differences between students and understand that there is no one size fits all to engage your students to learn. Your students all differ in what engages them. As a teacher, you must consider these differences when designing your classes and selecting strategies to engage your students.

Different experiences can stimulate engagement and the reward system



When something holds a prospect of reward, we are more eager to engage in it. An approach response in the brain (see: 3.2.2) can be stimulated by rewards such as praise and tokens, acknowledging achievements, novelty, provision of choice and sharing attention.

Rewards

Rewards are one of the main stimulations to approach a learning opportunity. Rewards and acknowledging achievement are immensely important for engagement and learning.

Novelty

New or unexplored things can drive curiosity which impacts learning.

Uncertain rewards and choice

Uncertain rewards have a more significant impact on the reward system than predictable ones. Offering choice can also stimulate the reward system.

Sharing attention

Working together with others is also rewarding and stimulates learning.

In sections 2.2 and 2.3, we further detail these strategies.

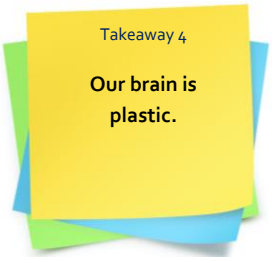
Fear and anxiety prevent us from learning

Fear and anxiety can cause us to avert our attention away from learning. Our only concern is dealing with the situation causing fear or anxiety. This reaction is connected to an evolutionary mechanism that helps us avoid threats, the so-called fight-flight response. In the classroom, feeling unsafe causes disengagement from a learning opportunity.

A subcortical structure called the amygdala is responsible for detecting threats. When a threat or an unsafe situation is detected, the amygdala impacts our prefrontal cortex. In particular, the amygdala affects our working memory in the prefrontal cortex, thereby reducing our ability to hold or process new information or even recall and use previously learned information. Fear and anxiety also avert our attention from the learning opportunity because our total attention is focused on the source of the fear or the anxiety, thereby reducing our ability to engage with something else.

In section 2.3, we will go into further detail.

Brain plasticity



Our brain does not provide a biological limit to what we can achieve. When we learn, the connections between neurons strengthen. Intensive study changes not only the brain's function but also the structure of specific parts. What we decide to do significantly impacts how our brain develops and our learning capacity. Promoting the message of brain plasticity to students positively affects their achievement. Knowing that the brain is plastic and can be altered by learning might incite students to engage more with a learning opportunity. It encourages students to believe in their own potential, not to give up and try their hardest.

Checking for understanding

@HP5: single choice@

1. Which part(s) of the brain is/are involved in engagement?

   A. Prefrontal cortex
   B. Amygdala
   C. Thalamus
   D. Nucleus accumbens

2. Which statement is true?

   A. Emotions impact our reasoning.
   B. Our reasoning impacts our emotions.
   C. Emotions and reasoning are intertwined and impact each other in both directions.
   D. None of the above

3. Which strategies can be used to stimulate engagement and learning?

   A. Tests
   B. Novelty
   C. Rewards
   D. Choice

4. How is the concept *engagement* defined?

   A. Enthusiasm and interest for a learning opportunity
   B. Being caught and held in a learning opportunity
   C. Liking school and learning
   D. None of the above

3.2. APPROACH RESPONSES AND AVOIDANCE RESPONSES

As mentioned in the previous section, two **subcortical structures,** in particular, are important for your students' engagement. The activation of these structures triggers a different response: the **amygdala** produces an **avoidance** response, and the **nucleus accumbens** an **approach** response.

3.2.1. THE AMYGDALA AND AN AVOIDANCE RESPONSE

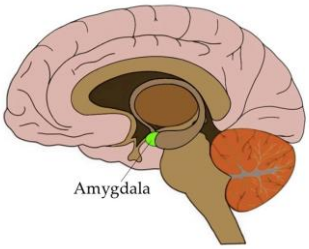
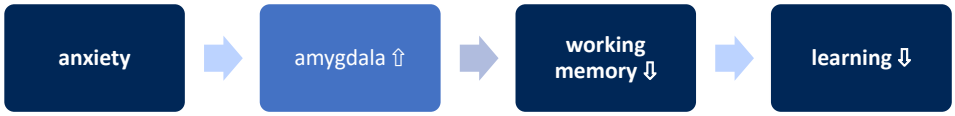


Figure 3: amygdala

Fear or **anxiety** activates the **amygdala**, an almond-shaped subcortical structure involved in detecting (negative) emotional stimuli (Kolb 2019:53; Dumontheil & Mareschal 2020:30; Ward 2020:31). The amygdala, for instance, is responsible for initiating the fight or flight response. When a threatening situation or event is detected, the neurons in the amygdala start firing, activating a chain reaction that results in the release of norepinephrine, a neurotransmitter and stress hormone. Norepinephrine activates the sympathetic division of the autonomic nervous system, which arouses the body for action: fight or flight. This reaction allocates all attentional resources to the threat and dealing with the situation. This phenomenon is also called amygdala hijacking because the amygdala takes over, leaving no mental space to engage with something other than the threatening situation. From an evolutionary perspective, this amygdala hijacking mechanism is vital for our survival.

The same can happen in classroom situations (Blakemore & Frith 2005:177; Churches 2017:104). When a student is - for some reason - fearful or anxious, he or she will not be able to engage optimally with the learning opportunities in your classes. The student cannot attend to the learning opportunity because the amygdala affects the working memory system, located in the lateral prefrontal cortex (LPFC). The fear or anxiety limits the access to working memory, and the student will have difficulty holding or manipulating information. As we will see in the module on attention/concentration, working memory is also a component of the attention network in the brain. The student will also struggle to maintain his or her attentional focus. As such, these negative emotions and feelings prevent the student from engaging in learning. In addition, a study by Luria et al. (2021) has shown that punishment also activates the amygdala, resulting in avoiding a learning opportunity.

Finally, research has shown that the amygdala shows heightened sensitivity to emotional stimuli during adolescence and emerging adulthood (Sato et al. 2008). Therefore, fostering a positive learning climate in your class in which students feel safe is crucial.



- Explain in your own words what an avoidance response is.
- How and why does an avoidance response effect learning?
- What actions might have caused an avoidance response during your classes?

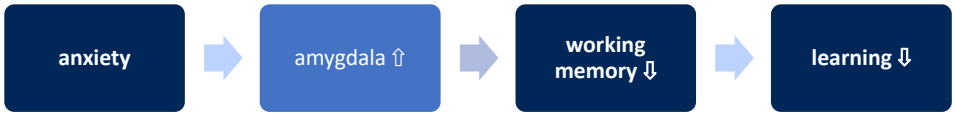
Checking for understanding

@HP5: drag the words@

1. Fear or <<**anxiety>>** activates the <<**amygdala>>**, an almond-shaped <<**subcortical**>> structure involved in detecting (negative) <<**emotional stimuli**>>.

@HP5: sorting choice@

2. Avoidance response:



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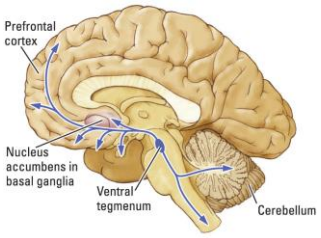
3. When a student is - for some reason - <<**fearful or anxious**>>, he or she will not be able to <<**engage**>> optimally with the <<**learning opportunities**>> in your classes. The student cannot attend to the learning opportunity because the <<**amygdala**>> affects the <<**working memory system**>>, located in the lateral prefrontal cortex (LPFC). The fear or anxiety limits the access to working memory, and the student will have difficulty <<**holding or manipulating information**>>.

3.2.2. THE REWARD SYSTEM AND AN APPROACH RESPONSE

Reward, or better the **anticipation of reward**, activates the **nucleus accumbens**, a subcortical structure that is part of the brain's reward system (Galvan, 2018:151-178; Kolb et al., 2019:431-434; Gazzaniga et al., 2019:50; Ward, 2020:432-433). The reward system is essential for our desire to approach and experience the world around us and the opportunities it offers us. When something is rewarding, we are more eager to undertake it or walk the extra mile. The concept 'reward' should be interpreted here in a broad sense: receiving money, earning points, tasty food, but also achieving a goal, mastering something, praise, gratification, etc.



Kolb et al., *An Introduction to Brain and Behavior*, 6e, © 2019 Worth Publishers

Figure 4: mesolimbic and mesocoritcal pathways of dopamine neurons

> *Animals engage in a wide range of voluntary behaviors because those behaviors are rewarding That is, these behaviors increase the activity in neural circuits that function to maintain an animal's contact with certain environmental stimuli, either in the present or in the future. Presumably, the animal perceives the activity of these circuits as pleasant. This conclusion would explain why reward can help maintain not only adaptive behaviors (…), but also potentially non adaptive behaviors.*
>
> - Kolb et al. (2019:431)

An important neurotransmitter in the reward system circuitry is **dopamine**. The axons of the dopaminergic neurons located in the brainstem (ventral tegmental area) spread throughout the entire brain (see Figure 4), thereby modulating multiple brain functions such as movement, addiction, reward, mood and memory. More specific, dopamine seems to intensify the activity in a neural network (Gazzaniga et al., 2019:533-537). However, recent research shows that dopamine responses vary among people, and different students will react differently to rewards. So, there is no one size fits all.

The reward system and learning

When a learning opportunity is rewarding or is expected to be, it is more likely that students will remember it later. An fMRI study with adults (Adcock et al., 2006) has shown that the amount of activation in the reward system (ventral tegmental area and nucleus accumbens) and the hippocampus, a subcortical structure involved with the formation of new memories, positively correlates to memory performance (see Figure 5). A more recent fMRI study by Howard-Jones (2016) has shown that when a learning opportunity is made engaging, it causes increased activation in the reward system network in response to the expectation of some kind of reward, e.g. earning points, social praise, etc.

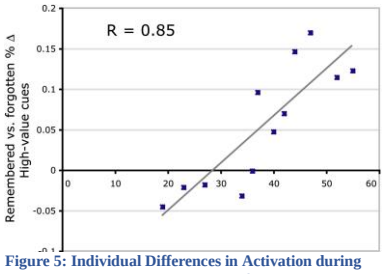
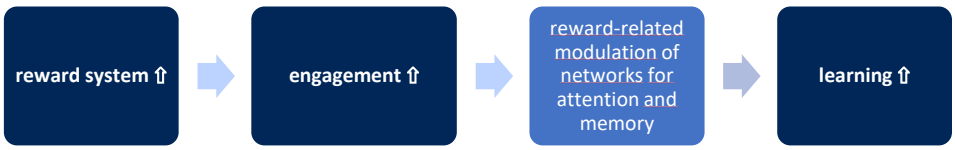


Figure 5: Individual Differences in Activation during the Cue Interval Correlate with Performance (Adcock et al., 2006:512)

What exactly happens in our brain? When a learning opportunity is expected to be rewarding or beneficial in some way, it activates the dopaminergic neurons in the reward system network. As a consequence, we become more engaged in the learning experience. The dopamine released by the dopaminergic neurons intensifies activity in neural networks, thereby reinforcing the learning in which we are engaged. The activation of the reward system also boosts our attentional networks. When we are interested in and engaged with a learning experience, we are more eager to pay attention to this experience. As we will see in the next module, directing our attention is also important for learning and facilitates better memory formation.

The expectation of reward thus creates an approach response and motivates us to engage more with the learning opportunity. Therefore, teachers need to elicit approach responses.



- Explain in your own words why rewards are important and produce an approach response.
- Why and how is the reward system important for learning?
- What actions might have caused an approach response or activation of the reward system during your classes?

Checking for understanding

@H5P: True/false question

1. The anticipation of reward activates the nucleus accumbens.

- **True**
- False

@H5P: True/false question

2. The reward system's activation negatively correlates to memory performance. So, the more activation in the reward system, the worse the memory formation.

- True
- **False**

@H5P: Fill in the blanks

3. An important neurotransmitter in the reward system circuitry is <<**dopamine>>**. This neurotransmitter intensifies activity in neural networks, thereby reinforcing the learning in which a student is engaged.

@H5P: single choice

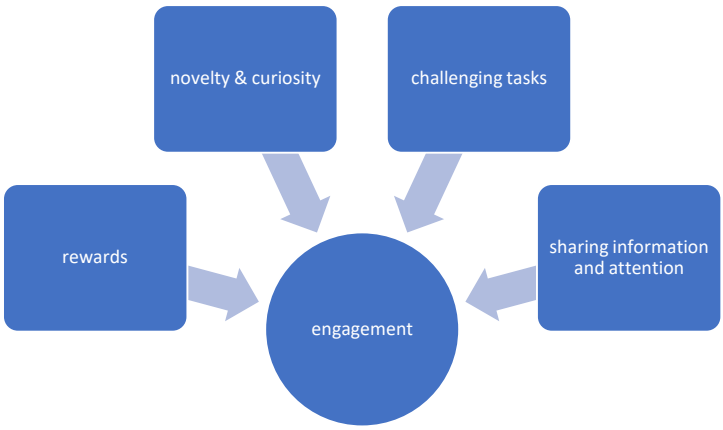
4. Which answer is correct?

A. **reward system ⇧ ➞ engagement ⇧ ➞ approach response ➞ modulation of networks for attention and memory ➞ learning ⇧**
B. modulation of networks for attention and memory ➞ reward system ⇧ ➞ approach response ➞ engagement ⇧ ➞ learning ⇧
C. reward system ⇧ ➞ engagement ⇧ ➞ modulation of networks for attention and memory ➞ approach response ➞ learning ⇧
D. reward system ⇧ ➞ approach response ➞ modulation of networks for attention and memory ➞ engagement ⇧ ➞ learning ⇧

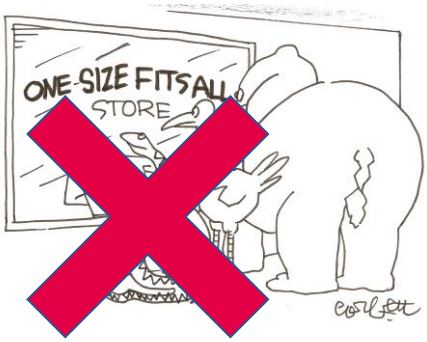
3.3. STRATEGIES THAT TRIGGER THE REWARD SYSTEM AND ENGAGEMENT

> *There is a large range of strategies used routinely by teachers to engage their students in this sense (Guilloteaux & Duornyei, 2008). Very few of these strategies have themselves been the subject of focused scientific investigation in terms of their underlying neurocognitive processes.*
>
> - Howard-Jones et al. (2020: 450)

This section discusses four research-based strategies that can influence the brain's reward system and engage students in learning (Howard-Jones et al., 2020:449-452). These four strategies are:



Please remember that different students will react differently to these strategies. Therefore, it is important to experiment and determine which techniques might produce an approach response in your students.



3.3.1. REWARDS

In education, rewards such as points, praise, badges, smileys, etc., are commonly used as positive reinforcement strategies to promote learning (Dufrene, Lestremau & Zoder-Martell 2014; Wehby & Copeland 2000). However, the effects and benefits of these social rewards on learning have been called into question by several educational researchers (Deci, Koestner & Ryan 1999). More recently, neuroscience studies (Farooqi et al. 2007; Izuma, Saito & Sadato 2008; Howard-Jones, Jay, Mason & Jones 2016; Schultz 2016) have shown that social rewards have a similar effect on the brain as material rewards such as receiving money or eating your favourite food. Both types of rewards - and even the expectation of the reward - influence the release of the neurotransmitter dopamine. The neurons responsible for the release of dopamine are located in Ventral Tegmental Area, a region in the brainstem, and project their axons to a wide range of brain structures, such as the nucleus accumbens, the prefrontal cortex and the hippocampus. The release of dopamine enhances the learning experience in three ways:

(1) Dopamine activates the reward system via the mesolimbic pathway, making us more eager to engage in the learning opportunity and motivating us to work hard to obtain the reward.
(2) Dopamine boosts the neural activity in the prefrontal cortex via the mesocortical pathway. Rewarding stimuli draw and focus the attention of individuals.
(3) Dopamine also seems to play an essential role in the hippocampus for successfully encoding and storing information (Lisman, Grace & Duzel 2011).

> *DA* [=dopamine] *release from the midbrain is thought to play an important role in learning to associate rewards and actions in reinforcement learning and reward learning, and such release can also enhance declarative memory formation.*
>
> - Howard-Jones & Jay (2016:70)

Using rewards thus engages and encourages to learn, raises attention, and facilitates the formation of new memories, thereby increasing the chance that a learning experience will be remembered better (Howard-Jones & Demetriou, 2009; Puig, Antzoulatos & Miller, 2014).

Reward uncertainty

Research has shown that adding an element of **reward uncertainty** may increase the release of dopamine (Fiorillo et al., 2003). As Howard-Jones & Jay, (2016:68) explain: *current understanding suggests that, when there is uncertainty about an upcoming reward, there is a slow and sustained ramping of dopamine (DA) neuron activity between the cue predicting that a reward may (or may not) arrive and the revealing of outcome*. (…) *Ramping of DA neuron activity in response to uncertain reward during responding (which may be 'scaffolded' by the teacher or by access to learning resources) should support learning.*

In case of reward uncertainty, a correct answer or a successfully completed task does not automatically lead to the promised reward. A chance factor (dices, coin tossing, wheel of fortune) determines whether a student 'wins' the reward or not or how much the actual reward is. Chance-meditated rewards increase students' engagement because it motivates them to seek opportunities to have a shot at winning a reward. Ozcelik et al. (2013) have shown that reward uncertainty positively impacts meaningful learning and motivation. Finally, reward uncertainty has also the benefit that the received rewards do not reflect how much a student actually knows, only how lucky he or she was in the learning game. In this way, it might also contribute to a positive learning climate in your classes.

> *Findings suggest a games-based approach to learning that increases the emotional and/or motivational response by disrupting the learning-reward relationship with chance, in order to encourage greater reward activity without endangering self- and social esteem.*
>
> - Howard-Jones & Holmes (2017:262)

Rewarding individual progress

An important caveat is that rewards should focus on individual progress and achievements and not on a student's progress or achievements in relation to other students. If rewards focus on the individual student, it might raise their self-esteem, which is beneficial to learning and might motivate a student to learn more. Comparison with others might cause anxiety, fear or a feeling of unsafety, thereby triggering an avoidance response. In this case, a student will disengage from the learning opportunity.

Last but not least, more is not better. A recent study (Apitz & Bunzeck, 2013) shows that the release of a large amount of dopamine reduces learning performance, while the release of a small amount improves learning performance.

- Explain in your own words why we are more likely to remember a learning experience when it perceived as rewarding.
- What is the role of dopamine?
- Explain in your own words why reward uncertainty might improve learning and motivation?
- On what kind of progress and achievements should rewards focus? Why?

Checking for understanding

@H5P: Drag the words

1. Using rewards <<**engages**>> and encourages to learn, raises <<**attention**>>, and facilitates the <<**formation of new memories**>>, thereby increasing the chance that a <<**learning experience**>> will be <<**remembered**>> better.

@H5P: single choice

2. Which answer does NOT fit?

A. Rewards
B. Nucleus accumbens
C. Approach response
D. Amygdala

@H5P: single choice

3. Which answer does NOT fit?

A. Chance factor
B. Wheel of fortune
C. A point per correct answer
D. Reward uncertainty

@H5P: True/false

4. Rewards should focus on students' progress compared to other students, not on their individual progress and achievements.

A. True
B. False

3.3.2. NOVELTY AND CURIOSITY

> *Regardless the source, these curiosity "sparks" share one thing in common: the presence of an information gap – a space of missing content that spans directly between knowing and not knowing. It's an invisible cognitive barrier separating frustration and reward.*
>
> - Mussalam (2017:12)

New things attract our attention and interest. They spark our curiosity. We want to fill in the information gap between what we already know and the novel (learning) experience. Novelty and curiosity make us eager to approach a learning opportunity, and they motivate us to engage in it to satisfy our curiosity and not-knowing. However, the "missing" information in the novel learning experience should neither be too small nor too big. If the information gap is too small, students will quickly lose interest. If the gap is too big, students might get discouraged. The novelty and curiosity "sweet spot" lies somewhere in students' zone of proximal development. 'Wow'-moments, which quickly pass, should be avoided.

Novelty and curiosity are rewarding for our brain (Biederman & Vessel, 2006; Min Jeong Kang et al., 2009; Schomaker et al., 2015). The expectation of discovering something new or satisfying our curiosity triggers the release of dopamine which stimulates the reward system. The uncertainty associated with the novelty and curiosity "may influence tonic levels of dopamine, producing a sustained ramping between a cue that a reward may be arriving and delivery of the reward". (Howard-Jones & Jay 2016:66). This neural response increases engagement in the learning opportunity because students are intrigued and eager to fill in the information gap. Dopamine also modules the neural activity in reward-related brain networks, thereby promoting learning: (1) it boosts activity in prefrontal cortex regions related to attention networks, and (2) it plays an important role in the hippocampus for successful encoding and storage of information (Lisman, Grace & Duzel 2011; Howard-Jones et al. 2020).

You can create novelty and curiosity by:

- Starting with something new
- Offering interesting experiences
- Doing something unexpected

- Using a different approach
- Changing the location

- Explain in your own words why novelty and curiosity might produce an approach response and engage students in a learning opportunity.
- Give two strategies you can use to engage your students.
- In which ways do you make your students curious at the beginning of your classes?

Checking for understanding

@H5P: True/False@

1. The novelty and curiosity "sweet spot should be gauged to your student's zone of proximal development.

A. True
B. False

@H5P: Drag the words@

2. The expectation of discovering <<**something novel**>> or satisfying <<**our curiosity**>> triggers the release of <<**dopamine**>> which stimulates the <<**reward system**>>. This neural response increases <<**engagement**>> in the learning opportunity because students are intrigued and eager to <<**fill in the information gap**>>.

3.3.3. CHALLENGING TASKS

> *Challenging activities call attention to themselves and are more memorable as well as give the learner a sense of achievement.*
>
> - Tokuhama-Espinosa (2014:176-177)

You probably know from experience that when an assignment or task is (too) easy, it quickly becomes boring. When it is too hard, on the other hand, it might become frustrating, and you might give up. In both cases, you disengage with the learning opportunity because there is not enough challenge or there is too much challenge. The same holds for your students in your classes.

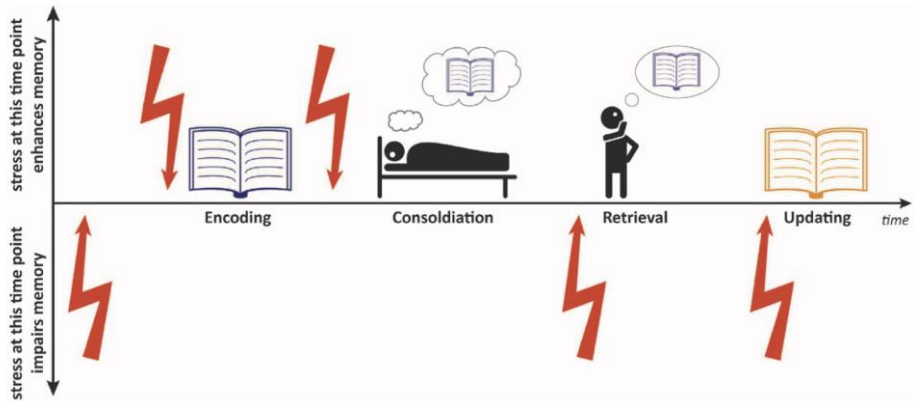
Pitch at appropriate level of challenge (Derek & Darlington, 2020:520). If you want to engage and motivate your students to learn, it is important to think about the right balance between too easy and too hard, so the learning opportunity offers a real challenge that students want to take up. Challenges should be gauged to your students' zone of proximal development (Daniels, 2010). Furthermore, it benefits your students' learning if you divide big challenging assignments into smaller, more manageable ones (LeDoux & Phelps, 2008). As mentioned before, there is no one size fits all: what challenges one student might not challenge another student.

Challenges trigger the release of two neurotransmitters in the brain: dopamine and norepinephrine. A recent study (Schulz 2016) has shown that dopaminergic neurons are more active in a challenging situation mixed with some kind of risk-taking (i.e. reward uncertainty). These dopaminergic neurons project their axons to a wide range of brain structures, such as the nucleus accumbens, the prefrontal cortex and the hippocampus, thereby influencing neural activity in these regions involved in reward and learning. As a result, neural networks become stronger. Challenging students is thus an interesting and important teaching strategy to promote your students' learning.

The neurotransmitter norepinephrine (adrenaline) is best known for its role in stress reactions. Norepinephrine raises our alertness and attention. As we will see in the next module on attention, norepinephrine modulates the alerting attention network (Posner, 2011). This attention network is

responsible for achieving and maintaining high sensitivity to incoming information. Heightened attention makes it more likely that the learning opportunity will be remembered. In particular, Vogel & Schwabe (2016:3) state that *stress shortly before or after the presentation of new information generally enhances subsequent memory performance.* Too much stress, however, has a negative impact on attention, learning and memory formation (LeDoux & Phelps, 2008). Stress reduces the capacity of the working memory system in the lateral prefrontal cortex (Gazzaniga, 2019:418).

The figure below, taken from Vogel & Schwabe (2016:3), illustrates when stress promotes learning and when it impairs learning. Moreover, if stress continues for an extended period, it can even damage the hippocampus (Gazzaniga et al., 2019).



> *The exposure to prolonged or repeated stress, as well as stress during critical periods of brain development may also have strong effects on learning and memory in children which need to be better understood to counteract the impairments they may cause. .*
>
> - Vogel & Schwabe (2016:7)

In conclusion, challenge and a little bit of stress during learning lead to better memorisation and learning.

- Why is offering challenges important for learning?
- What is meant by *Pitch at appropriate level of challenge*?
- Explain which two neurotransmitters are released in the brain by challenging learning contexts.
- When does stress promote learning? When does it impair learning?

Checking for understanding

@H5P: single choice@

1. What is meant by *Pitch at appropriate level of challenge*?

- **A. If you want to engage and motivate your students to learn, it is important to think about the right balance between too easy and too hard.**
- B. If you want to engage and motivate your students to learn, you should only choose topics that interest your students.
- C. If you want to engage and motivate your students to learn, challenges should be tailored to what students already know.
- D. If you want to engage and motivate your students to learn, big challenges are preferred above smaller, more manageable ones.

@H5P: Single choice@

2. Challenges trigger the release of the following two neurotransmitters

- A. Serotonin and norepinephrine
- B. Dopamine and serotonin
- **C. Norepinephrine and dopamine**
- D. Dopamine and acetylcholine

@H5P: Single choice@

3. Which answer does not fit?

- A. Too much stress impairs students' attention, learning and memory formation.
- B. Heightened attention makes it more likely that the learning opportunity will be remembered.
- C. Challenges and a little bit of stress during learning lead to better memorisation and learning.
- **D. Students' learning benefits from big challenging assignments.**

3.3.4. SHARING INFORMATION AND ATTENTION

> *An exciting new domain tests how performance in learning tasks may be influenced not only by the presence of others, but also by communication with others, such as communicated rules, advice, or other forms of explicit instructions.*
>
> - van Duijvenvoorde et al. (2016:143)

We, humans, are social beings. From an evolutionary perspective, living together in groups was crucial for our survival: as a group, we were stronger against threats and enemies; hunting and foraging were also easier as a group than alone. Social cognition is hard-wired in our brain (Gazzaniga, 1985). In fact, from infancy onwards, we learn through interaction with others.
In his meta-analysis, Hattie (2012) has demonstrated that using didactic methodologies such as student interaction, cooperative learning, and peer tutoring positively impacts students' learning performance. So, as the saying goes: two heads are better than one! Working in pairs or discussing ideas and communicating them in different ways to each other might benefit your students' learning.

For our brain, positive social environments are rewards (Steinberg, 2008; Blakemore and Mills, 2014). Sharing information with others or working together on the same tasks involves shared attention. Sharing of attention triggers the release of dopamine and consequently increases activity in the reward system (Fleissbach et al., 2007; Schilbach et al., 2010). Peer collaboration or cooperative learning thus facilitates an approach response: it motivates students and encourages them to engage more in the learning opportunity, making it more likely that students will learn from it.

Stimulating positive interactions, peer collaboration with other students, and cooperative learning are interesting and effective teaching strategies to promote your students' learning. Some additional benefits are (Tokuhama-Espinosa 2016:207-208):

- development of empathy
- appreciation of other's viewpoints
- developing the ability to listen and respond to one another's ideas

- age-appropriate exchanges of information
- explain information in alternative forms or vocabulary.

- Explain why the strategy ‘sharing information and attention’ might benefit your student’s learning.
- Give 2 examples of teaching strategies based on the strategy ‘sharing information and attention’.
- Give 3 additional benefits of sharing information and attention besides promoting students’ learning.

Checking for understanding

@H5P: drop@

1. For our brain, positive social environments are <<**rewards**>>. <<**Sharing information**>> with others or <<**working together**>> on the same tasks involves <<**shared attention**>>. Sharing of attention triggers the release of <<**dopamine**>> and consequently increases activity in the <<**reward system**>>. <<**Peer collaboration**>> or cooperative learning thus facilitates an <<**approach response**>>.

@H5P: Single choice@

2. Which answer does not fit?

A. Peer interaction
B. Direct instruction
C. Peer teaching
D. Cooperative learning

4. CLASSROOM ACTIONS

> *The emerging cognitive neuroscience of reward, memory and their interrelation promises a new perspective on the potential role of reward in education, and particularly in the development of educational games.*
>
> - Howard-Jones & Jay (2016:70)

This section presents inspiration for classroom actions you can try in your classroom. As mentioned above, there is no one size fits all, so experimentation and further catering to your specific context are key.

CLASSROOM ACTION 1: QUIZZES

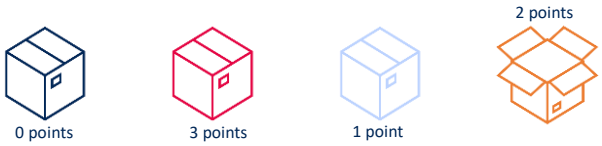
Quizzes are an easy tool to engage your students. Quizzes make use of the strategy 'rewards': if a student gives a correct answer to a question, she or he receives one or more points. As explained in section 3.3.1, rewards trigger the release of dopamine, thereby increasing the activity in the reward system and brain regions involved in attention and memory formation. Rewards thus enhance engagement with the learning opportunity.

Quizzes are effective in engaging your students at the beginning of your class. You can use the quiz to activate your students' prior knowledge about today's topic. Or, you can use the quiz to consolidate knowledge, for example, what they learned in the previous class.
You can, however, also use a quiz throughout your class. In this way, the quiz keeps students engaged and motivated during your class. You can even add a challenge: *try to score at least 10 points*.

Whereas the examples above use certain rewards, you can also make use of reward uncertainty in your quiz. In this case, a chance factor determines whether a student 'wins' the reward or not. Chance-meditated rewards motivate students to seek opportunities to have a shot at winning a reward. As such, they increase students' engagement (see 3.3.1).

Scenario 1

Instead of giving your students a certain reward after providing the correct answer to your question (i.e. correct answer = one point), you can let students choose the number of points themselves by selecting one of three/four boxes.



Other options are using a wheel of fortunes or dices to determine how many points a student wins.

Scenario 2

You play your quiz in small teams. If the answer to a question turns out to be correct, the team has two choices:

(1) receive one point (= certain reward);

(2a) take a chance (=uncertain reward) and receive either three or zero points based on a spin of a “wheel of fortune” that has a 50/50 chance of landing on “win” or “lose”.
(2b) take a chance and receive points based on throwing one or two dices.

CLASSROOM ACTION 2: GAMIFICATION

Gamification refers to the use of game mechanisms in an educational context (Kapp, 2012). Some examples of game mechanisms are missions, challenges, levels, rewards, real-time feedback, countdown, and boosters. Game mechanisms which can be used to engage students in learning opportunities are:

- Levels
- Badges
- XP-points

These game mechanisms are examples of the strategy 'rewards' and 'challenging tasks' and thus can be used to influence the release of dopamine and the activation of the reward system (see 3.3.1 and 3.3.3). A benefit of these game mechanisms is that they may engage and motivate students for a more extended period.

More about gamification:

- Kapp, K. M. (2012). *The gamification of learning and instruction: game-based methods and strategies for training and education*. John Wiley & Sons.
- *Classroom Game Design* by Paul Andersen at TEDxBozeman (https://youtu.be/4qlYGX0H6Ec)

LEVELS

Like in games, your students progress from one level to the next. Your levels can be equivalent to your learning objectives or to (challenging) assignments students must accomplish. Students can move to the next level when they achieve a previous level's goal. Providing clear success criteria and immediate feedback to your students is essential to keep students engaged and motivated.

BADGES

The idea of badges is borrowed from the Scouts Association. When students prove mastery of a particular set of learning objectives, they receive a badge. Providing clear success criteria for obtaining a specific badge is essential. Badges can be spread throughout the semester.

XP-POINTS

Unlocking a new level or obtaining a badge does not have to be an all-or-nothing event. You can offer students some choice by using **XP-point** (XP= experience). In this case, students must collect specific points to unlock the next level or receive a badge.

> *Example.* To unlock level 2, you have to collect 10 XP-point. You can choose from the exercises below:

	XP-Points

Exercise 1	5
Exercise 2	3
Exercise 3	5
Exercise 4	2
Exercise 5	3

These XP-points can also be used to 'buy' **boosters**. Boosters are additional resources a student can use to complete an assignment. For instance, the course book, a reference book, a dictionary, calculator, periodic table, atlas, etc.

CLASSROOM ACTION 3: USE HOOKS AT THE START OF YOUR CLASS

Start with a good headline (Churches et al., 2017:42). As discussed in 3.3.2, our brain is sensitive to novelty and curiosity. Novelty and curiosity are especially interesting strategies to use at the beginning of your class to 'hook' your students in. Novelty and curiosity help engage your students in the upcoming new learning opportunity.

Some hooks you can use at the start of your class:

- an interesting picture or video
- an intriguing or thought-provoking question or problem
- an unusual perspective on today's topic
- a novel context in which students have to apply their prior knowledge
- an ambiguous statement that needs further explanation and thought
- a different approach than usual, e.g. let students generate their own questions about today's topic

If you want to read more about novelty and curiosity:

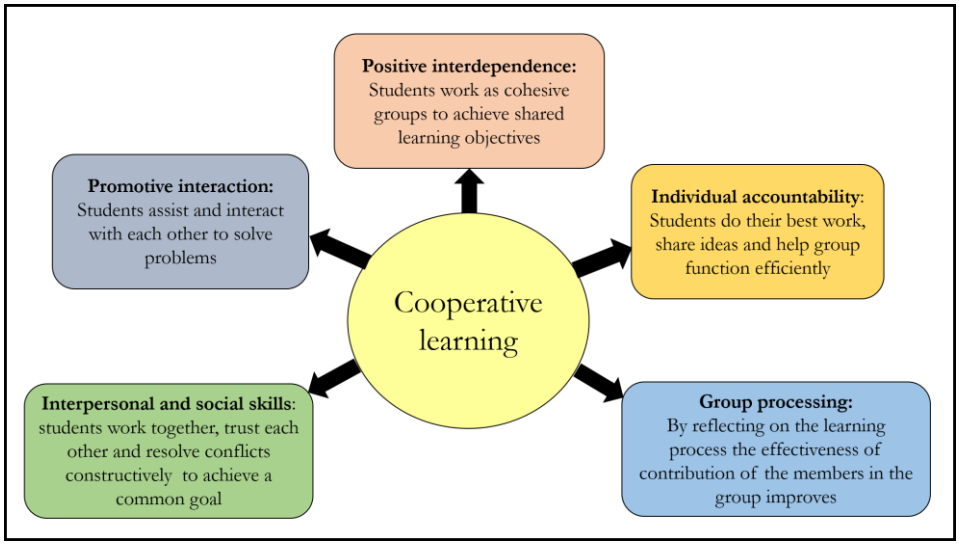
- Boykin, A. W., & Noguera, P. (2011). *Creating the opportunity to learn: Moving from research to practice to close the achievement gap*. ASCD.
- Musallam, R. (2017). *Spark Learning. 3 Keys to Embracing the Power of Student Curiosity.* Dave Burgess Consulting Inc.

CLASSROOM ACTION 4: COOPERATIVE LEARNING

> *Cooperative learning is based on the human need for social exchange, goal setting and relationship acquisition.*
>
> - Tokuhama-Espinosa, (2014:207)

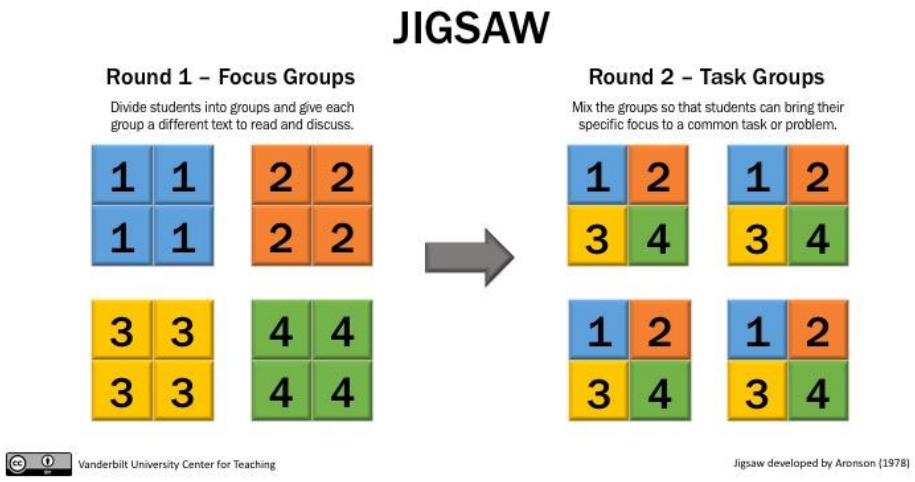
Cooperative learning is a type of active social learning in which students work together in small groups to achieve a common goal, e.g. learning new concepts or solving a challenging assignment. Cooperative learning thus takes advantage of the strategy of 'sharing information and attention' (see 3.3.4) and helps engage students more in the learning opportunity. In cooperative learning, students are encouraged to share information, pay attention to each other, listen to each other, discuss ideas, ask questions, and collaboratively formulate solutions to a problem.

Five essential elements of cooperative learning are (Johnson & Johnson, 2009):



An often-used teaching method is the jigsaw:

1. The teacher provides students with a problem or challenge.
2. Students are divided into small groups and become experts in a particular part of the subject matter needed to solve the problem or challenge (round 1)
3. Students share their knowledge with non-experts (round 2). The group needs everyone's expertise to solve the problem or challenge collaboratively.



If you want to read more about cooperative learning:

- Ashman, A., & Gillies, R. (Eds.). (2003). *Cooperative learning: The social and intellectual outcomes of learning in groups.* Routledge.
- Gillies, R. M., Ashman, A. F., & Terwel, J. (2007). *The teacher's role in implementing cooperative learning in the classroom*. Springer.
- Johnson, D. W., Johnson, R. T., & Smith, K. A. (2014). Cooperative learning: Improving university instruction by basing practice on validated theory. *Journal on Excellence in University Teaching*, *25*(4), 1-26.
- Johnson, D. W., & Johnson, R. T. (2009). An educational psychology success story: Social interdependence theory and cooperative learning. *Educational researcher, 38(5),* 365-379. *doi:10.3102/0013189X09339057*
- Johnson, D.W., Johnson, R.T., and Smith, K.A. (2006). *Active learning: Cooperation in the university classroom.* Edina, MN: Interaction.
- Kagan, S. & Kagan, M. (2013). *Cooperative Learning Structures*. Kagan Publishing
- Kagan, S., & Kagan, S. (1994). *Cooperative learning.* San Clemente, CA: Kagan.

5. WRAPPING UP

The challenge is much greater to develop a sustained, deeper level of interest not only in the topic in questions but also for the subject more widely and ultimately learning as a lifelong process. (…) essentially moving from what they refer to as situational interest to individual interest. (…) Such a shift involves an emotional connection and commitment such that a student's interest goes beyond 'learning it for the exam'.

- Bell & Darlington, (2020:516)

Bell & Darlington (2020:520) offer an overview of concrete examples of classroom actions:

- Introduce a degree of novelty or surprise to generate curiosity about today's topic
- Establish an early sense of student ownership of the learning
- Take students' ideas seriously
- Relate to student's experiences and interests
- Encourage student questions
- Convey appropriate purpose for the learning in question
- Use of collaboration between peers and sense of common goal
- Pitch at appropriate level of challenge
- Sensitive use of social (e.g. praise) and tangible (e.g. points) rewards
- Sustain positive attitudes and relationships.

Looking back …

- What did you already know about engaging your students?
- What new information did you learn in this module?

6. CHECKLIST

To engage your students, you can …

- ❑ Introduce **novelty** and create **curiosity** about today's topic
- ❑ **Vary** the use of (social) **rewards**
- ❑ Use a **hook** at the start of your class**.**
- ❑ Provide opportunities for **ownership** by giving **choices**
- ❑ Show appreciation for **students' ideas**
- ❑ Think about the appropriate level of **challenge.**

7. BIBLIOGRAPHY

Adcock, R. A., Thangavel, A., Whitfield-Gabrieli, S., Knutson, B., & Gabrieli, J. D. (2006). Reward-motivated learning: mesolimbic activation precedes memory formation. *Neuron*, *50*(3), 507-517.

Apitz, T., & Bunzeck, N. (2013). Dopamine controls the neural dynamics of memory signals and retrieval accuracy. *Neuropsychopharmacology*, *38*(12), 2409-2417.

Ashman, A., & Gillies, R. (Eds.). (2003). *Cooperative learning: The social and intellectual outcomes of learning in groups*. Routledge.

Biederman, I., & Vessel, E. A. (2006). Perceptual pleasure and the brain: A novel theory explains why the brain craves information and seeks it through the senses. *American scientist*, *94*(3), 247-253.

Blakemore, S. J., & Mills, K. L. (2014). Is adolescence a sensitive period for sociocultural processing. *Annual review of psychology*, *65*(1), 187-207.

Boykin, A. W., & Noguera, P. (2011). *Creating the opportunity to learn: Moving from research to practice to close the achievement gap*. ASCD.

Brod, G., & Breitwieser, J. (2019). Lighting the wick in the candle of learning: generating a prediction stimulates curiosity. *NPJ science of learning*, *4*(1), 1-7.

Churches, R., Dommett, E., & Devonshire, I. (2017). *Neuroscience for teachers: Applying research evidence from brain science*. Crown House Publishing Ltd.

Daniels, H. (2011). Vygotsky and psychology. In U. Goswami (Ed.), *The Wiley-Blackwell handbook of childhood cognitive development,* 673–696.

Deci E., Koestner R. & Ryan R.M. (1999). A meta-analytic review of experiments examining the effects of extrinsic rewards on intrinsic motivation. *Psychol Bull*, 125:627-668.

Den Ouden HEM, Daw ND, Fernandez G, Elshout JA, Rijpkema M, Hoogman M, Franke B, Cools R. (2013). Dissociable effects of dopamine and serotonin on reversal learning. *Neuron*, *80*(4), 1090-1100.

DiMenichi, B. C., Ceceli, A. O., Bhanji, J. P., & Tricomi, E. (2019). Effects of expressive writing on neural processing during learning. *Frontiers in human neuroscience*, 389.

Dufrene, B. A., Lestremau, L., & Zoder-Martell, K. (2014). Direct Behavioral Consultation: Effects On Teachers' Praise and Student Disruptive Behavior. *Psychology in the Schools*, *51*(6), 567-580.

Farooqi, I. S., Bullmore, E., Keogh, J., Gillard, J., O'Rahilly, S., & Fletcher, P. C. (2007). Leptin regulates striatal regions and human eating behavior. *Science*, *317*(5843), 1355-1355.

Fiorillo, C. D., Tobler, P. N., & Schultz, W. (2003). Discrete coding of reward probability and uncertainty by dopamine neurons. *Science*, *299*(5614), 1898-1902.

Fliessbach, K., Weber, B., Trautner, P., Dohmen, T., Sunde, U., Elger, C. E., et al. (2007). Social comparison affects reward-related brain activity in the human ventral striatum. *Science*, 318, 1305–1308.

Gallistel, C. R., & Matzel, L. D. (2013). The neuroscience of learning: beyond the Hebbian synapse. *Annual review of psychology*, *64*, 169-200.

Gazzaniga, M. S. (1985). *The social brain*. Basic Books.

Gazzaniga, M. S., Ivry, R. B., & Mangun, G. R. (2019). *Cognitive neuroscience: the biology of the mind* (Fifth edition.). W.W. Norton & Company.

Gillies, R. M., Ashman, A. F., & Terwel, J. (2007). *The teacher's role in implementing cooperative learning in the classroom*. Springer.

Hidi, S. E., & Renninger, K. A. (2019). Interest development and its relation to curiosity: needed neuroscientific research. *Educational Psychology Review*, *31*(4), 833-852.

Howard-Jones, P. (2020). *Engagement*: https://www.youtube.com/watch?v=kaeD7YZFsAI

Howard-Jones, P. A., & Demetriou, S. (2009). Uncertainty and engagement with learning games. *Instructional Science*, *37*(6), 519-536.

Howard-Jones, P. A., Jay, T., Mason, A., & Jones, H. (2016a). Gamification of learning deactivates the default mode network. *Frontiers in psychology*, *6*, article 1891.

Howard-Jones, P., & Jay, T. (2016b). Reward, learning and games. *Current Opinion in Behavioral Sciences*, 10, 65-72.

Howard-Jones, Paul & Ioannou, Konstantina & Bailey, Ruth & Prior, Jayne & Jay, Tim & Yau, Shu. (2020). Towards a Science of Teaching and Learning for Teacher Education. 10.4324/9781003016830-23.

Howard-Jones, P., Demetriou, S., Bogacz, R., Yoo, J. H., & Leonards, U. (2011). Toward a science of learning games. *Mind, Brain, and Education*, *5* (1), 33-41.

Howard-Jones, P., Demetriou, S., Bogacz, R., Yoo, J. H., & Leonards, U. (2011). Toward a science of learning games. *Mind, Brain, and Education*, *5*(1), 33-41.

Izuma, K., Saito, D. N., & Sadato, N. (2008). Processing of social and monetary rewards in the human striatum. *Neuron*, *58*(2), 284-294.

Kolb, Bryan, & Whishaw, Ian Q. (2021). *Fundamentals of human neuropsychology* (Eight edition). Worth Publishers.

Kolb, Bryan, Whishaw, Ian Q, & Teskey, G. Campbell. (2019). *An Introduction to Brain and Behavior*(Sixth edition). Worth Publishers.

Laal, M., & Ghodsi, S. M. (2012). Benefits of collaborative learning. *Procedia-social and behavioral sciences*, *31*, 486-490.

LeDoux, J. E., & Phelps, E. A. (2008). Emotional networks in the brain. In M. Lewis, J. M. Haviland-Jones, & L. F. Barrett (Eds.), *Handbook of emotions,* 159–179.

Lisman, J., Grace, A. A., & Duzel, E. (2011). A neoHebbian framework for episodic memory; role of dopamine-dependent late LTP. *Trends in neurosciences*, *34*(10), 536-547.

Luria, E., Shalom, M., & Levy, D. A. (2021). Cognitive Neuroscience Perspectives on Motivation and Learning: Revisiting Self-Determination Theory. *Mind, Brain, and Education*, *15*(1), 5-17.

Min Jeong, K., Hsu, M., Krajbich, I. M., Loewenstein, G., McClure, S. M., Wang, J. T. Y., & Camerer, C. F. (2009). The wick in the candle of learning: Epistemic curiosity activates reward circuitry and enhances memory. *Psychological science*, *20*(8), 963-973.

Musallam, R. (2017). *Spark learning. 3 Keys to Embracing the Power of Student Curiosity*. Dave Burgess Consulting Inc.

Ozcelik, E., Cagiltay, N. E., & Ozcelik, N. S. (2013). The effect of uncertainty on learning in game-like environments. *Computers & Education*, *67*, 12-20.

Peterson, E. G., & Hidi, S. (2019). Curiosity and interest: current perspectives.

Puig, M. V., Antzoulatos, E. G., & Miller, E. K. (2014). Prefrontal dopamine in associative learning and memory. *Neuroscience*, *282*, 217-229.

Renninger, K.A., & Hidi, S.E. (2017). The Power of Interest for Motivation and Engagement (1st ed.). Routledge.

Schilbach, L., Wilms, M., Eickhoff, S. B., Romanzetti, S., Tepest, R., Bente, G., ... & Vogeley, K. (2010). Minds made for sharing: initiating joint attention recruits reward-related neurocircuitry. *Journal of cognitive neuroscience*, *22*(12), 2702-2715.

Schomaker, J., & Meeter, M. (2015). Short-and long-lasting consequences of novelty, deviance and surprise on brain and cognition. *Neuroscience & Biobehavioral Reviews*, *55*, 268-279.

Sprenger, M. (2018). *How to teach so students remember*. ASCD.

Steinberg, L., 2008. A social neuroscience perspective on adolescent risk-taking. *Developmental Review*, *28*, 78–106.

Steinberg, L., Albert, D., Cauffman, E., Banich, M., Graham, S., & Woolard, J. (2008). Age differences in sensation seeking and impulsivity as indexed by behavior and self-report: evidence for a dual systems model. *Developmental psychology*, *44*(6), 1764.

Sutherland, K. S., Wehby, J. H., & Copeland, S. R. (2000). Effect of varying rates of behavior-specific praise on the on-task behavior of students with EBD. *Journal of Emotional and Behavioral Disorders*, *8*(1), 2-8.

Tokuhama-Espinosa, T. (2014). *Making classrooms better: 50 practical applications of mind, brain, and education science*. WW Norton & Company.

Vogel, S., & Schwabe, L. (2016). Learning and memory under stress: implications for the classroom. *npj Science of Learning*, *1*(1), 1-10.

Ward, J. (2020). *The student's guide to cognitive neuroscience* (Fourth edition.). Routledge.

Weinstein, Y., Madan, C. R., & Sumeracki, M. A. (2018). Teaching the science of learning. *Cognitive research: principles and implications*, *3*(1), 1-17.

Weinstein, Y., Sumeracki, M., & Caviglioli, O. (2018). *Understanding how we learn: A visual guide*. Routledge.