Challenge Based Learning

Intersections with Mind and Brain Science

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August 2023

Citation

Nichols, M.H. (2023). Challenge Based Learning: Intersections with Mind and Brain Science. The Challenge Institute. https://www.challengeinstitute.org/CBL_and_Brain_Science.pdf

Over the last several decades, neuroscience, psychology and education researchers have gained significant insights into the learning process. While there have always been theories about effective (and ineffective) learning environments, these ideas typically emerged from personal experience and classroom-level studies rather than scientific insight into how our brains function (National Research Council, 2000, p.3). While the viewpoints on brain science and learning are still evolving, important findings that impact the design of effective learning environments and processes continue to emerge.

Neuroscience is a multidisciplinary field that focuses on the scientific exploration of the nervous system and the brain. It aims to unravel the complexities of the brain and nervous system, shedding light on how they function, develop, and interact with the environment. Educational neuroscience, or mind, brain, and education science (MBE), is an interdisciplinary field that seeks to bridge the gap between neuroscience, psychology, and education (Fischer, 2009; Tokuhama-Espinosa, 2010). It involves studying how the brain learns and processes information and how this knowledge applies to improving teaching practices, learning environments, and educational outcomes.

Challenge Based Learning (CBL) is a framework that empowers learners to engage with authentic and meaningful challenges personally, within their communities, and globally. The framework organizes learning into three phases: Engage, Investigate and Act, which guides the acquisition of knowledge and skills through active participation. Rather than passively receiving information, learners are active co-owners and co-authors of the learning process. Consequently, CBL changes the role of the teacher from the keeper and dispenser of knowledge to an experienced guide, co-author and co-learner. CBL provides a framework for acquiring academic knowledge and developing durable skills such as critical thinking, creativity, communication, collaboration, and lifelong learning.

While early conceptualizations of CBL track to initial efforts to understand learning through brain research (Bransford et al., 1999), the Apple approach builds on prior educational approaches, case studies, societal changes, and personal experience with formal and informal learning (Nichols & Cator, 2008). However, as research on the brain and learning sheds light on how we learn, MBE now appears to support the underlying ideas and processes of CBL. This essay explores these connections to spur further conversations and research about what happens when your brain is on CBL.

MBE is only one perspective for determining effective educational practices. The hard-earned wisdom of educators and educational research are still highly valued sources of information

[1] This essay was inspired by a series of lectures delivered by John Medina to the learners in the Apple Developer Academies.

about effective practice. And, when the MBE research, teacher experience and educational research intersect, we should take particular interest.

Finally, the goal of this essay is not to contribute to the "neuromyths" in education (Torrijos-Muelas et al., 2021). Rather, the hope is to elicit critical thinking, exploration, and experimentation. Ultimately the best way to test a theory about learning is through action research in an authentic context.

Intersections

Fourteen areas in MBE science intersect with and support the efficacy of the CBL framework. In this essay, each area is briefly explained and connected to a key idea within CBL. While there is some overlap between the intersections, it is informative to address them individually. Note that all MBE concepts presented are grounded in complex understandings of the brain that continue to evolve. This essay does not directly address the scientific research. Refer to the reference section for a deeper scientific and research dive.

1. Meaningful Engagement

The brain processes the meaning of input before processing the details (Medina, 2015). In other words, we must understand why something is relevant before focusing on the details. Relevance and personal connections activate the brain's reward systems, boosting attention, memory, and overall learning. We also tend to ignore or tune out information that is not immediately relevant.

CBL focuses learning on real-world challenges that are personally relevant, triggering meaningful engagement and intrinsic motivation. By understanding the meaning (or relevance) of learning during the Engage phase, the following opportunities to learn the details have a structure and purpose to be explored, processed and retained. The essential questioning process in the Engage phase explicitly explores the questions of meaning and relevance of the Big Idea. What does this mean to me in my context? In other words, why should I care enough to continue to learn? Through exploratory cycles of guiding questions and activities during the Investigation and Act, there is an ongoing consideration of the relevance while knowledge is acquired.

2. Top Down Processing

In top-down processing, our prior knowledge, expectations, beliefs, and experiences influence how incoming sensory information is perceived and interpreted. The brain connects new information to old (Tokuhama-Espinosa, 2011). Prior experience allows learners to form new hypotheses, anticipate outcomes, test them, and apply relevant information to the task. For successful knowledge acquisition, a schema that supports top-down processing dramatically impacts acquisition and retention.

CBL provides a framework or schema that supports top-down processing by moving from a Big Idea to an increasing level of detail and application through the Engage, Investigate and Act phases. With each exploratory cycle in the Investigation phase the learners build on prior knowledge and make connections allowing them to move forward. The CBL framework supports top-down processing across all knowledge areas and in formal and informal learning environments.

3. Pattern Seeking

Closely related to top-down processing is our brain's search for meaning. The primary way we find meaning is through identifying and understanding patterns. Observations and experiences are organized into patterns and then attributed meaning. Future experiences will reinforce or change our perspective of meaning. Those that connect with prior patterns are more likely to be remembered (Devlin, 2010). The better we identify patterns and give them meaning, the better we learn and survive (Medina, 2014).

The CBL framework provides an overall structure and ongoing opportunities for identifying and creating patterns. At the structural level, the CBL phases Engage, Investigate, and Act provide a ready-made structure for organizing learning experiences into patterns. The phases include a series of exploratory cycles (Guiding Questions, Guiding Activities and Resources, findings, synthesis) providing opportunities to identify patterns and relationships.

4. Crystalized and Fluid Intelligence

Within MBE science, there is some agreement that human learning and intelligence fall into two areas - crystalized and fluid. Crystallized intelligence consists of the acquisition of knowledge and procedures. Fluid intelligence refers to applying existing knowledge and procedures to unique and novel circumstances (Medina, 2015). One can easily see why both of these forms of intelligence are critical to surviving and thriving in a complex environment.

CBL provides a framework that honors both types of intelligence. The framework expects, creates space, and provides an authentic purpose for acquiring content knowledge and procedures. CBL also calls on the learners to apply crystalized intelligence to solve real-world challenges that are fluid, novel and unpredictable. The crystallized and fluid intelligence balance in CBL supports better knowledge acquisition, retention, and application.

5. Hypothesis Testing

MBE science confirms the observations about learning that parents or anyone that has worked with infants and small children have observed. From birth, learning is an ongoing process of hypothesis testing (Medina, 2014). This active and physical approach to understanding how things work is the essence of human learning.

The CBL framework includes a series of exploratory cycles that allow for active hypothesizing and testing. Instead of learning out of context and being tested on it, in CBL, we contextually hypothesize, test, reflect, and learn from the experience. The prior hypothesis identification, testing and synthesis lead to the next set of questions and hypotheses. Finally, the Act phase provides an opportunity to test the overall hypothesis of the Challenge solution with an authentic audience. Learnings from one Challenge can result in new Big Ideas, Challenges and the opportunity to develop and test additional hypotheses.

6. Active Learning

MBE research demonstrates that active participation enhances neural connections, reinforcing learning and long-term memory retention. Active Learning connects to the positive effects of physical activity. The more we move, the more oxygen is available for the brain, resulting in better learning and retention (Tokuhama-Espinosa, 2010; Medina, 2014). A logical extension of this thinking is that being in a passive and static learning environment inhibits learning and that any movement enhances learning (Greenleaf, 2003). Additionally, retention of knowledge and procedures is associated with the context and circumstances of the learning experience. Evidence shows that if we want to be able to retrieve and use information in the future, it is best to actively learn it in the environment and under the circumstances where it will be retrieved (Medina, 2014). If our goal is that the learners can apply knowledge to real-world situations, it is best that they learn in situations that are as close to the real world as possible.

CBL promotes active and experiential learning by encouraging learners to move beyond the four walls of the classroom to investigate, learn and apply knowledge in authentic settings. Building meaning and placing the learners actively in charge of their learning in authentic settings increases the chance of encoding knowledge and effectively using it in the future.

7. Collaboration and Social Interaction

Research into the science of social decision-making reveals that different brain regions work together and connections are strengthened during social interaction (Rilling & Sanfrey, 2011). At a very basic level, there is agreement that we are social learners resulting in potential positive and negative consequences. On the positive side, peer interactions can stimulate the brain's social cognition networks, enhancing understanding and knowledge acquisition. On the negative side, these interactions can cause biases and the learning of inaccurate information and improper behaviors.

We live and learn in highly complex social environments. CBL works to capitalize on the positive elements of social interaction by aligning behind common challenges and emphasizing the value of working together. Even in individual challenges, there is the goal of building a symbiotic working environment rather than a competitive one. Providing time for reflection and encouraging critical thinking also offers an opportunity to identify and address biases and inaccurate information.

8. Problem-Identifying, Problem-Solving and Critical Thinking

Humans are, by nature, problem-solvers, and the ability to creatively solve problems is a critical element in the evolution of humans. MBE science reveals that problem-solving and critical-thinking opportunities activate the prefrontal cortex, which is responsible for higher-order thinking, decision-making, and planning, thus enhancing cognitive flexibility and problem-solving capabilities (Kleibeuker et al., 2013). The ability to identify problems and develop the cognitive flexibility and skills to solve them effectively are critical qualities for success in all areas of life.

CBL provides a forum and process for developing analytical thinking, cognitive flexibility, creativity and problem-solving skills. From the essential questioning of the Engage phase to the assessment of the Act phase, the CBL framework includes ongoing opportunities to identify problems, think critically and creatively, and develop and implement solutions. In their study of the impact of CBL, Johnson et al. (2009) found that the participants reported growth in critical thinking and problem-solving skills. A later study that included primary through higher education learners reinforced these findings (Johnson & Adams, 2011).

9. Personalized Learning

MBE science highlights that everyone's brain is unique or "wired" differently (Medina, 2014). As learning occurs, the brain changes. Since we all have different experiences, our brains are "wired" differently. Therefore, creating learning environments where everyone is treated equally and expected to learn at the same pace makes little sense. When creating learning environments and experiences, considering the different brains involved is critical for success.

CBL allows learners to explore topics of interest, builds personal ownership of the process, and emphasizes the importance of diverse perspectives and approaches. The result is customized and differentiated learning that caters to individual strengths and needs. Moreover, it does not put the full impetus of meeting the needs of diverse brains on the teacher. In CBL, every learner is responsible for understanding their brain and finding ways to move forward. The teacher is a critical element in this process but ultimately not responsible for creating the optimal learning environment for a classroom full of unique brains. Discovering the best way to learn becomes a partnership.

10. Reflection and Metacognition

MBE science shows that the default mode network (DMN) activates when the mind is at rest, allowing for active and dynamic internal processing, such as autobiographical memory retrieval, making connections, envisioning the future, and introspection (Yeshurun et al., 2021). The research in this area is complex and not fully understood, but it indicates that allowing the mind to move away from focused activities is an important part of learning. The literature also shows that increased consciousness developed through metacognition improves learning. Creating mental schemas and developing metacognitive skills are critical to learning and learning how to learn (Tokuhama-Espinosa, 2010). There are also indications that ongoing reflection helps learners build a better structure for future learning (Brown et al., 2014).

CBL places reflection and metacognition front and center in the learning process. Throughout the Challenge experience, learners continually reflect on the action. A component of every challenge is thinking about the process. The cycle of identifying questions, answering them, synthesizing the results and then reflecting on what was and was not effective is ongoing within CBL. Additionally, there is value placed on balancing focused and diffuse approaches resulting in deeper learning and increased creativity. The challenge naturally creates focused learning, and the emphasis on ongoing reflection allows for diffuse learning. Diffuse moments, or stepping away from being focused, result in deeper learning and "aha" moments where we make connections (Oakley, 2014).

11. Emotion and Memory

Emotion is crucial in learning and memory consolidation (Immordino-Yang & Damasio, 2007). MBE science demonstrates that emotionally charged events activate the amygdala and hippocampus, promoting the encoding and storage of information. Emotional states activate our ability to make connections and focus our brain resources. When involved with an emotionally charged experience, the brain focuses on the matter at hand and forms specific memories (LeDoux, 2002). Evidence suggests that learning, attention, memory, and decision-making are related to emotion (Immordino-Yang & Damasio, 2007).

By addressing real-world and meaningful challenges, CBL seeks to embrace emotions and emotional moments to enhance learning. Furthermore, CBL presses learners to participate actively, building emotional investment and creating more memorable learning experiences. By embedding content within Challenges, the learners become emotionally invested, and there is a higher likelihood of retaining and retrieving knowledge.

12. Stress

The impact of stress on memory and learning is complicated and not fully understood. At a base level, there are indicators that stress can both enhance and inhibit memory and learning. There is also agreement that traditional learning environments, especially those that revolve around exams, and limited student control, can be stressful and may interfere with building lasting knowledge. Moderate stress during learning material that is related and meaningful and then put into action enhances memory formation (Vogel & Schwabe, 2016). Too much stress, or the timing of the stress (before vs during), negatively impacts immediate and long-term memory formation and learning. It also appears that a feeling of “lack of control” increases stress to a negative level. A complicating factor with stress is that it is experienced and impacts individuals differently. Finally, stress is an inevitable element of schooling, work and life. How we learn to manage stress is a significant component of learning to learn.

The CBL framework provides a safe space to experience and manage stress in a controlled environment that models real-life experiences. Giving learners control over an actionable Challenge they choose and supporting them through a structured and guided experience allows stress to enhance learning. The ability for learners to construct their learning path in the context of the Challenge also allows for individual perceptions of stress to be understood and managed. Finally, the ongoing reflection built into CBL allows the learners to monitor and learn about their stressors, manage them better for future learning, and build resilience.

13. Sharing

MBE research shows that shared information is reinforced and solidified in the brain (Tokuhama-Espinosa, 2010). We improve retention by working together to resolve challenges and sharing that knowledge with others. Sharing can also result in greater growth when the combination of ideas is greater than the individual's. There is even higher retention when we use the knowledge gained to teach others (Sousa, 2000).

A central tenet of CBL is that we are all learners; the flip side is that we are all teachers. Throughout the challenge, the learners reflect on and document their experience so they can share the experience with others. Instead of relying on and waiting for teachers to do all the work, CBL expects students to take responsibility for learning and sharing. The teacher still plays an active role as there is information and processing beyond students' capacity and adjustments needed for incorrect interpretations. However, as students learn, they are responsible for sharing, and this removes the teacher as the only source of knowledge and process. This process increases the likelihood of retention and creates a starting place and example for future learning.

14. Technology

The emerging MBE science questions the effectiveness of widely practiced approaches to formal schooling. Moving through a curriculum where we do not fully understand the purpose or sequence, sitting and listening for extended periods, not being emotionally connected, proceeding at a unified pace, treating all learners in the same way, not having sufficient time to reflect and process, and not actively using what we are learning do not align with the way our brains work. It then follows that adding technology to this environment will not be effective. Instead of using technology to support or amplify traditional practices, technology should be an opportunity to reorganize learning to align with how our brains work. (Pea, 1986).

CBL is a framework that supports how we naturally learn outside the four walls of the classroom and how we will learn in our post-school lives. In other words, CBL supports the ways our brains naturally work. In CBL, technology supports learning by giving us new ways to access information, connect with other learners, capture and reflect on experiences, test hypotheses with a worldwide community, collaboratively create/design/code new ideas and apply them to real-world problems. CBL presents a way to use technology to align learning with how our brains work.

Moving forward

This brief overview of MBE science and CBL scratches the surface and raises as many questions as answers. Hopefully, this introduction will spur the use of CBL as a laboratory to deepen MBE science and improve formal and informal learning. The world we prepare learners for is full of complex problems, and the most important and durable skill is knowing how to learn. CBL provides an effective and efficient framework for learning. To prepare learners for a complex and unpredictable world, we need to leverage the emerging science of MBE to optimize our learning environments.

The fusion of Challenge-Based Learning and MBE science provides educators with a powerful framework for learning how to learn. By capitalizing on the brain's natural learning processes, CBL integrates real-world challenges, collaboration, and active learning, enhancing cognitive development. As the understanding of MBE science continues to grow, educators have an unprecedented opportunity to create transformative educational experiences through CBL that unlock the full potential of each student's cognitive abilities.

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