Theoretical Perspectives on Affect and Deep Learning

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The first author's study of emotions began in 1974 when he was a teaching assistant in George Mandler's course on emotions at University of California at San Diego. That was a special moment in history when the cognitive revolution was in full swing and the interdisciplinary field of cognitive science was emerging. George Mandler's mission at that time was to make sure that emotions and consciousness were seriously embraced in the cognitive research communities in addition to the standard components of cold cognition: perception, attention, memory, judgment, decision making, problem solving, language, and so on. Mandler was busy writing *Mind and Emotion* (1976), a book that was the precursor of another book he published in 1984, called *Mind and Body: Psychology of Emotions and Stress.* The 1984 book was selected as the first interdisciplinary William James Book Award by American Psychological Association. And here we are, approximately four decades later, following some of Mandler's footsteps.

The textbook in Mandler's 1974 course described two dozen theories of emotions, a clear sign that the scientific study of emotions was floundering at a pre-theoretical stage. The science of emotions has seemed to progress somewhat after 40 years of research. There are now fewer major theories (perhaps 5-10) according to Pekrun's review in this edited volume, the recent *Handbook of Emotions* (Lewis, Haviland-Jones, & Barrett (2008), and Calvo and D'Mello's (2010) review of affect detection in the computer and social sciences. Theoretical convergence is one signal of progress in science.

One of Mandler's fundamental lessons was to resist the temptation of confusing words and psychological mechanisms. The fact that we have a word, label, or phrase to describe an emotion (e.g., shame, hope, catharsis, ecstasy) does not mean that we should reify it to the status of a scientific construct. The words we use to describe emotions are products of folklore, the historical evolution of the language, the social context of interpretation, and other cultural fluctuations that are guided by principles very different from scientific theories of psychological mechanisms. This lesson has been accepted by contemporary theories of emotions that differentiate the fundamental psychological dimensions of valence and intensity from the folklore, labels, and contextual interpretations of emotions (Barrett, 2006; Russell, 2003). It is therefore pointless to debate over whether confusion or guilt is an emotion, mood, affective state, or purely cognitive state. Researchers who debate over the precise meaning and theoretical status of particular emotion terms are better suited for a career in lexicography or ordinary language philosophy – not the science of emotions. We know that there are deep connections between cognition, affect, motivation, and social interaction so it is a waste of time to argue whether particular psychological states come under the umbrella of affect.

This chapter focuses on connections between affect and cognition that are prevalent during complex learning. Complex learning occurs when a person attempts to comprehend difficult material, to solve a difficult problem, and to make a difficult decision. For example, complex learning occurs when a person attempts to comprehend a legal document, to fix a broken piece of equipment, or to decide whether to take a new job in another city. Comprehension, reasoning, and problem solving normally require conscious reflection and inquiry because there is a discrepancy between (a) the immediate situation and (b) the person’s knowledge, skills, and strategies. The person is in the state of *cognitive disequilibrium* which launches a trajectory of cognitive and affective processes until equilibrium is restored or disequilibrium is dampened. It is assumed that the cognitive disequilibrium is ubiquitous in complex learning so we need a theoretical framework to understand its dynamics.

Cognitive Disequilibrium

Deep learning occurs when there is a discrepancy between the task at hand and the person's knowledge. Otherwise, the person already has mastered the task and by definition there is no learning. The discrepancy creates cognitive disequilibrium. Cognitive disequilibrium occurs when there are obstacles to goals, interruptions of organized action sequences, impasses, system breakdowns, contradictions, anomalous events, dissonance, incongruities, negative feedback, uncertainty, deviations from norms, and novelty. One question is how the person handles the disequilibrium over time. Another question is what gets learned. Answers to these questions depend on characteristics of the learner and the task, as will be discussed in this chapter.

Cognitive disequilibrium may occur at many cognitive levels, starting with sensation and extending to the person’s self concept and social interaction. Consider some concrete examples of cognitive disequilibrium.

Sensation. A crowd at a rock concert receives loud sounds and bright lights that are outside of the scope of typical stimuli. The sensory neurophysiological system responds while the person experiences shock, surprise, and eventually stress.

Perception. Modern art museums display works that deviate from our normal perception of reality. The deviations from perceptual and cognitive schemas draw attention and encourage explanation. Patrons notice many of the deviations from expectations and norms: An elephant in a lecture hall, a naked person in a church, a dog sitting at a bar. They experience surprise or curiosity at the novelty.

Comprehension. Readers of a novel spend time trying to comprehend atypical or anomalous events in a text they read. Why did Patty Hearst become attracted to her kidnappers? Why does the author or narrator bother mentioning that the main character has a scar? Readers get surprised or confused while reading these ideas that don't coherently fit in.

Action. The piano player is repeatedly interrupted by customers while singing her favourite songs. She becomes irritated or frustrated.

Memory. A grandfather tries to remember his account number while trying to draw out some money for vacation. He slaps his head in frustration.

Problem solving. A foreign student tries to solve a math problem on an exam for admission to college. He has an anxiety attack when he gets stuck.

Writing. A doctoral student has a writing block before a proposal deadline. Frustration advances to rage, and occasionally aggression.

Decision making. A mother's child gets a sprained ankle so she searches the web to find out what to do. One web site recommends ice, another heat, whereas others have a more complex story. The mother experiences confusion and anxiety at the contradictions until she reads a web site with the complete answer.

Argumentation. The teenager argues with her parents on why she wants a tattoo. The parents explain that it will take 2 years to get rid of it so she changes her mind. The parents are hoping that the teenager's resentment will shift to epiphany and enlightenment.

One could go on with this exercise of mapping affective states onto cognitive processes. Cognitive equilibrium launches cognitive and affective processes at multiple levels of cognition and these are the foundations of deep learning. The role of cognitive disequilibrium on learning and emotions has been known for decades (Festinger, 1957; Graesser et al., 2005; Lazarus, 1991; Mandler, 1976; Piaget, 1952; Stein, Hernandez, & Trabasso, 2008). What we don't know very much about is the trajectory of cognitive-affective processes over time and also the impact of these trajectories on learning.

Some generalization can be made about general impact of cognitive disequilibrium on the body and brain. We know that activities of the sympathetic nervous system increase when there is cognitive disequilibrium compared to a neutral state. We know that anomalies trigger EEG activities of the N400 or N600. We know that the amygdala and other components of the limbic system are involved when there are emotions aligned with learning. The body and brain participate in complex learning. These activities are part of the emotions that people experience.

Our recent research has also unveiled some generalizations about the types of emotions that accompany cognitive disequilibrium during complex learning. The affective states are not particularly pleasant during the disequilibrium phase, but the more positive emotions do often emerge as equilibrium is restored. We have documented in a number of studies (Baker, D'Mello, Rodrigo, & Graesser, 2010; Craig, Graesser, Sullins, & Gholson, 2004; D'Mello & Graesser, in press-a; Lehman, Matthews, D'Mello, & Person, 2008) that the prominent emotions that occur during problem solving, reasoning, and comprehension of technical material are the negative affect states of confusion, frustration, boredom, and anxiety; the positive affective states of delight and a genuine flow experience (i.e., when time flies and fatigue is invisible, Csikszentmihalyi, 1990) are comparatively rare, although most students do often experience sustained engagement with the task. Surprise occasionally occurs but is comparatively infrequent. It is important to acknowledge that these affective states are very different from the Ekman's (1992) six basic universal emotions: anger, disgust, fear, joy, sadness, and surprise. Our landscape of learning-centered emotions in a typical academic learning environment is very different from Ekman's big six.

We have discovered that the affective state of confusion is the best predictor of learning among these affect states (Craig et al., 2004; Graesser et al., 2007; Graesser, Jackson, & McDaniel, 2007). Confusion is a signature of thoughtful reflection, reasoning, and problem solving so this affect state is expected to be diagnostic of deep learning. Jackson and Graesser (2007) also reported that students had the lowest ratings of enjoyment during learning in those conditions where they learned the most. Thus, liking is not positively correlated with deep learning. As one student succinctly put it, "Thinking hurts!"

Positive emotions hopefully emerge after cognitive disequilibrium shifts to equilibrium. Our analysis of sequences of affect states support the claim that there are *virtuous* cycles of cognition and affect (D'Mello & Graesser, in press-a; D'Mello, Taylor, & Graesser, 2007). Delight occurs when goals are met and problems are solved. We expect the delight to be more extreme when the task is more difficult, when there has been a time-consuming commitment, and when the goal has high utility. Our best interpretation of Csikszentmihalyi's flow state is that it is an emergent affect state from a set of smaller-scale cycles that involve modest challenges, high engagement, timely achievement, and delight. This is experienced while playing games so an important pedagogical mission is to design games that smuggle in serious learning (Conati, 2002; Gee, 2003; Shaffer & Graesser, 2010). When learners get a sudden insight that solves a difficult problem, they have a very positive eureka (ah hah!) experience. However, our research has revealed that eureka experiences are extremely rare during complex learning.

Cognitive disequilibrium can also spawn unfortunate trajectories of negative affective states, or what we have sometimes called *vicious* cycles (D'Mello & Graesser, in press-a; D'Mello, Taylor, & Graesser, 2007). When the learners experience repeated failures, confusion transitions into frustration, which in turn may result in disengagement and boredom. The learner attributes the failure to one or more potential causes (Dweck, 2002; Weiner, 1986), such as their own limited abilities, the subject matter being boring, or the learning environment being inadequate. These attributions are of course unfortunate. It would be better for the learners to take on the obstacle as a challenge and to work harder, but unfortunately many students do not have a strong enough self-concept to take that leap. The ideal learner is an academic risk taker (Meyer & Turner, 2006) who wants to master the material rather than being prisoners of extrinsic rewards and positive feedback.

Timing and Regulation of Affective States

The time course of the different affect states during complex learning has only recently been initiated (D'Mello & Graesser, in press-b). One would hope that frustration and boredom does not last too long and that the learning environment would stretch the window of delight and flow. Exactly where confusion lies is an excellent question. Perhaps some confusion is good, but not too much because the student runs the risk of transitioning to frustration, disengagement, and boredom, as discussed above. D'Mello and Graesser (in press-b) have tracked the affect states while students work on difficult questions with the AutoTutor system on computer literacy. We found that the half-life duration of surprise and delight were significantly shorter than that of confusion, boredom, and engagement/flow, with frustration in between. The fact that surprise was a short duration is intuitively plausible. A person would appear insane if they exhibited a lengthy stretch of surprise. One might like delight to last longer, but perhaps happiness is fleeting.

Basic research on the temporal chronometry of emotions offers minimal guidance on understanding the time-course of affective states during complex learning. The claim is sometimes made that true emotions are short-lived, person 2-3 seconds or less whereas moods can last hours and emotional traits can last years. This chapter addresses affective states during complex learning so we are most concerned about states that last seconds to minutes. Given the lack of research on this important topic, we can only offer speculations on the basis of general theories in the cognitive, learning, and social sciences.

We assume that the cognitive and task constraints play a central role in dictating the time-course of cognitive disequilibrium and affiliated affective states. However, these states and processes are mediated by self-concepts, goals, metaknowledge, social interaction, and the learning environment (Calvo & D'Mello, 2010; Pekrun, 2006, chapter 3; Schultz & Pekrun, 2007). Below we discuss these factors in a bit more detail.

Cognitive processes of the task. Some cognitive processes are executed automatically and unconsciously, such as those aligned with sensation, perception, and recognition memory. Familiarity, novelty, and positive versus negative valence of a word are examples of these fast automatic processes that are executed in less than a second (Mandler, 1976; Zajonc, 1984). Surprise is elicited quickly and unconsciously, with a short duration, when the source of cognitive disequilibrium involves sensory, perceptual, and pattern recognition processes. This includes surprise that follows quick flashes of insight when the appropriate content accrues in working memory. Novelty can elicit curiosity under conditions that are mediated by the person's prior knowledge and interests. In contrast, there is the risk of boredom or low engagement when the stimuli and tasks have low novelty for a sustained period of time (Berlyne, 1960).

The automatic cognitive processes and associated affective states are ubiquitous in everyday life, particularly when we are living on auto-pilot throughout the day. However, central to deep learning are the more conscious and deliberate cognitive processes that occur in difficult learning activities that involve comprehension, reasoning, and problem solving. As the learners struggle with challenges, there is cognitive disequilibrium at multiple levels. When the degree of cognitive disequilibrium meets or exceeds some threshold T_a, the person experiences confusion. When this threshold is exceeded for a long enough duration (D_b) or cycles of interaction with the world, then there is the risk of frustration; and with a longer duration (D_c) or cycles of interaction with the world, the risk of disengagement and boredom. At the other extreme, the degree of cognitive disequilibrium may be lower than a different threshold T_d when there is not enough novelty, challenge, or source of disequilibrium for the person to be engaged; when this occurs for a lengthy duration that exceeds some value (D_e), there is the risk of boredom. Thus, boredom can result from a sustained period of too much disequilibrium as well as too little, a curvilinear prediction analogous to the Yerkes-Dodson law.

The durations and thresholds obviously depend on the complexity of the stimuli and tasks, as well as the person's cognitive appraisal of the situation, cognitive demands, and their emotions (Ortony, Clore, & Collins, 1988; Scherer, 2009). As illustrated below, the parameters are systematically affected by the person's self-concept, goals, meta-knowledge, and social interaction.

Self-concept. Academic risk takers have a high priority in mastering the material so they push the envelop in taking on challenging tasks, even to the point of tolerating failure and negative feedback (Meyer & Turner, 2006). In contrast, the cautious learner prefers safe tasks that ensure success and positive feedback. The duration parameters would therefore be longer before the academic risk takers would encounter frustration (D_b) and disengagement (D_c). It is also conceivable that their parameter values for D_e would be longer, T_a would be higher, and T_d would be lower to the extent that they master the material and have interest. Interest in the topic is an important dimension of self-concept. People presumably persist longer and are more patient on subject matter and tasks that they view as interesting and that are within the realm of what they consider important for them to know about.

Goals. The learners' goals presumably influence the parameter values in a systematic manner. If there is a high value on the task goal and a high expectation they can complete the goal, then the values of all three duration parameters would increase and T_d would decrease, but the status of T_a is uncertain. Learners of course persist on content that is relevant to their goals even when their prior knowledge about the material is modest (McCrudden & Schraw, 2007). The parameter values are likely to vary as a function of intrinsic versus extrinsic rewards and as a function of mastery versus performance goals (Deci & Ryan, 2002; Dweck, 2002; Pekrun, 2006).

Metaknowledge. Metaknowledge is knowledge that person has about cognition, pedagogy, emotions, and communication (Graesser, D'Mello, & Person, 2009). Psychological research has supported the conclusion that the accuracy and sophistication of most people's metaknowledge is unspectacular. For example, Maki's (1998) extensive review of the research on comprehension calibration has indicated that there is only a .27 correlation between college students' ratings on how well they understand technical texts and their scores on an objective test of comprehension. During tutoring, it is the students with higher domain knowledge who are more prone to express to the tutor that they do not understand something (Graesser & Person, 1994; Miyake & Norman, 1979). This suggests that high domain knowledge would lower the threshold of T_a: It is the knowledgeable student who would be more sensitive to various sources of cognitive disequilibrium. Regarding emotions, our research has led us to conclude that students' knowledge of their emotions during learning is not sufficiently trustworthy for us to automatically believe what they report (D'Mello, Craig, & Graesser, 2009). We need to compare the students' self judgments with those of peers, judges trained on emotions, master teachers, automated sensing devices (D'Mello & Graesser, 2010; see chapter by D'Mello & Graesser), and physiological measures. The gold standard of truth remains a mystery.

Social interaction. Contemporary theories of emotion assume that emotions are constrained and sometimes defined by social interactions with others. Students typically do not want to appear inadequate to their teachers and too brainy to their peers. They become anxious when they take instructors' exams and the high-stakes tests administered by the government. These pressures presumably influence the threshold and duration parameters, but there is no systematic research as to how. A tutor who is supportive, empathetic, and polite is likely to influence the parameters in a way that minimizes the occurrence of frustration, boredom, and disengagement (Johnson & Valente, 2008; Lepper & Woolverton, 2002).

Learning environments. Features of the learning environment have perhaps the most robust influence on the trajectories of cognition and affect during complex learning. We know that a system's feedback on the students' performance has a large impact, particularly when it signals cognitive disequilibrium (D'Mello & Graesser, in press-a; Graesser et al., 2008). Students sometimes are confused or frustrated when the system is unresponsive to the student or not coherently connected to what the student is saying or doing. Students are more motivated when they have some options and choices (Lepper & Woolverton, 2002), but not when they are saturated with requests for trivial decisions.

Many learning environments are entirely under student control. Students can move at their own pace when they read books and interact with hypermedia, for example. Unfortunately, students learn surprisingly little deep knowledge when left to read a textbook on their own (VanLehn, Graesser et al., 2007). Their meta-comprehension skills are inadequate so they cannot reliably detect whether they are understanding material. Similarly, the strategies of self-regulated learning and question asking are underdeveloped for most students (Azevedo & Cromley, 2004; Graesser & McNamara, 2010) so they tend to guided by shallow rather than deep learning. Students need substantial training and scaffolding of metaknowledge, self-regulated learning, and question asking before they can productively use open learning environments.

Conclusions

There has been some progress on advancing theoretical perspectives on affect and learning during the last 40 years. This chapter has focused the affective states that occur during deep learning, when students struggle to comprehend difficult subject matter and when they solve challenging problems that require reasoning and conscious reflection. We have argued that cognitive disequilibrium is a fundamental driver of deep learning. Cognitive disequilibrium occurs when there are obstacles to goals, interruptions of organized action sequences, impasses, system breakdowns, contradictions, anomalous events, dissonance, incongruities, negative feedback, uncertainty, deviations from norms, and novelty. A number of emotions are affiliated with cognitive disequilibrium, but notably confusion, frustration, boredom, anxiety, engagement/flow, surprise, and delight. The transitions and timing of these affective states depend on the cognitive tasks, self-concept, goals, meta-knowledge, social interaction, and features of the learning environment.

We believe that an important next phase of research is to build learning environments that are sensitive to student emotions during the course of facilitating deep learning. The systems need to detect and track the learners' emotions automatically, with sufficient reliably and accuracy. The systems need to respond to the learners in ways that are sensitive to the students' emotions in addition to their cognitive states. We also welcome systems that will train the students how to productively self-regulate their learning in ways that reflect a mature understanding of their own meta-cognition, meta-emotions, and other forms of meta-knowledge. We imagine a day when the students understand the meaning of confusion, its pedagogical value, how to manage it, how to use it to guide learning, and maybe even how to enjoy it.

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