Core Emotion and Engagement in Informal Science Learning

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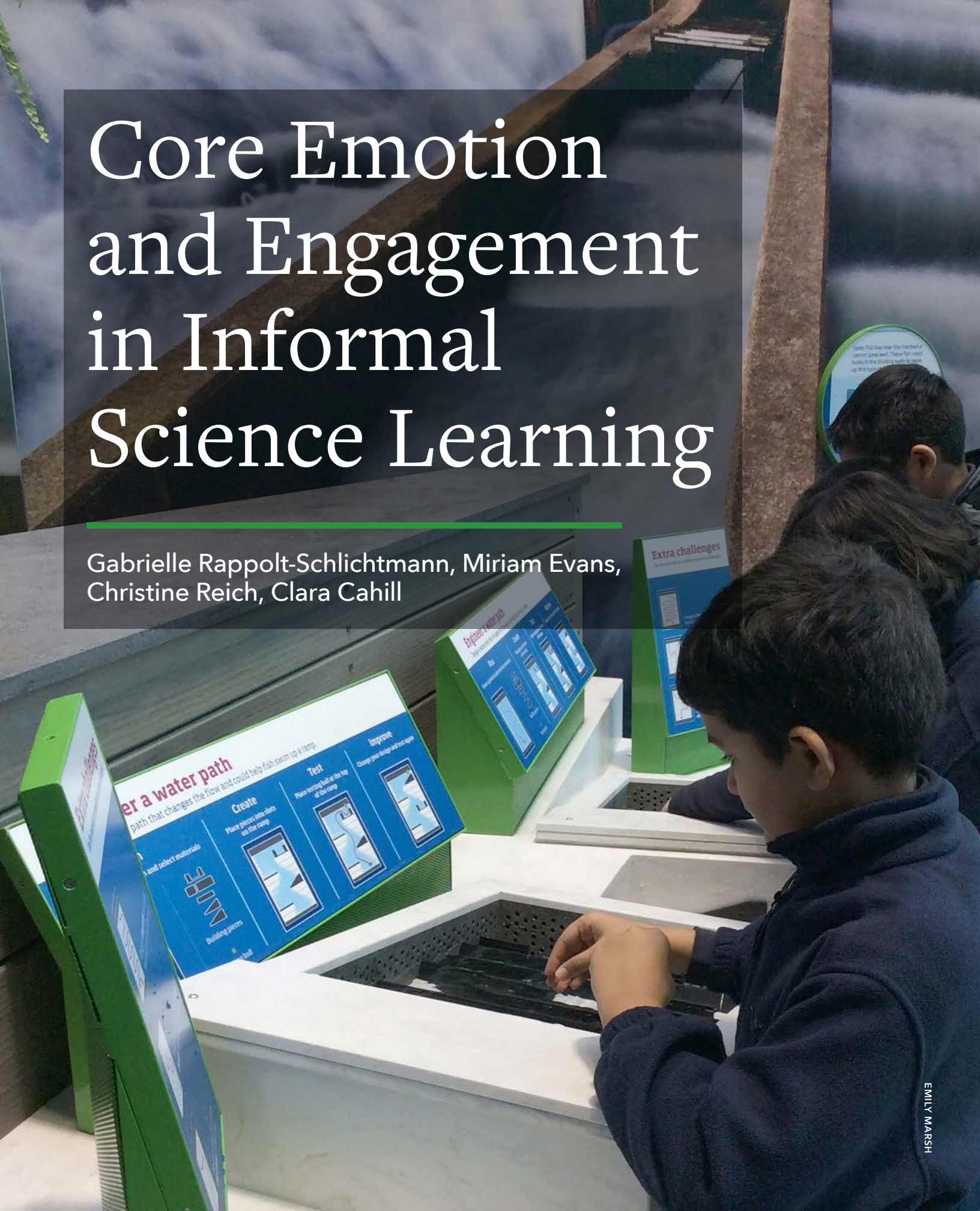

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left Designed to engage and challenge visitors: an engineering activity in the *Yawkey Gallery on the Charles River*.

Dynamic and reflexive, interpersonal and powerful, emotions guide and mediate visitors' behaviors, motivations, engagement, and learning.

Emotions emerge from the intersection of individuals and their environment, and take form as visitors react to the people, objects, resources, and activities around them. Emotions are subjective and take many forms, including excitement, pride, joy, struggle, frustration, and calm reflection—each recognizably important aspects of museum experiences and learning. By studying emotion in museum exhibitions, we seek to broaden understanding of the critical role of emotion as a mediator of engagement, and to learn how exhibit designers and developers can leverage emotion to enhance an exhibition's value and impact for visitors.

Our research reflects the convergent interests of professionals with divergent expertise. Included in our team are researchers who are experienced studying the role of emotion in formal learning environments, as well as researchers and practitioners who work in the informal learning setting of a museum. What brings us together is the understanding that emotion plays a critical role in learning for all people across a wide variety of settings, and is particularly important for learners who have not traditionally excelled in classroom settings (such as learners with learning disabilities). Little is known about the emotional experiences of visitors in museum exhibitions, and even less is known about how those emotions affect visitor engagement. Together, we are seeking to gain a better understanding of ways museum professionals can better design exhibitions that lead to productive emotions to foster deeper learning and engagement amongst all our visitors. What we describe in this article is the first phase of our research, where we sought to learn about the kinds of emotions visitors experience in science museum exhibitions, and the relationship between these emotions and deeper cognitive and behavioral engagement.

Core Emotion: How It Mediates Engagement and Cognition

From a neurological perspective, emotions are physiological responses that guide behavior, thought, and action as a person judges his or her environment as either beneficial or detrimental.[1] This process of appraisal manifests as "core emotion"—a simple, raw expression of how a person feels in two dimensions. One dimension is the level of stimulation or activation, ranging from low levels associated with passivity and relaxation, to high levels associated with focus, attentiveness, and excitement. The highest levels of activation represent a tipping point where the fight-or-flight response is engaged, which leads to feelings of anxiety, aggression, and withdrawal.

1 Elizabeth A. Linnenbrink, "Emotion Research in Education: Theoretical and Methodological Perspectives on the Integration of Affect, Motivation, and Cognition," *Educational Psychology Review* 18, no. 4 (October 18, 2006): 307–14; James A. Russell, "Core Affect and the Psychological Construction of Emotion," *Psychological Review* 110, no. 1 (2003): 145–72.

The other dimension is valence, which ranges from negative perceptions (displeasure) to positive perceptions (pleasantness and pleasure).[2] Subjective feelings like joy, anger, and sadness map to our core emotion state as we become consciously aware of how we are feeling. For example, you might describe that you feel excited at the beginning of a movie you have been waiting to see—your core emotion is highly activated and positive. Surprise is also a high activation state, but it can be either pleasant or unpleasant. Imagine your core emotion when you arrive at your surprise birthday party but you've just come from a particularly intense exercise class. You are highly activated and may be excited, but feel worried about your appearance, leaving you on the negative side of "surprise." As core emotion varies, it influences motivation, behavior, and engagement.[3] In this way, core emotion mediates visitors' experiences, continuously changing in response to their assessment of themselves with respect to their surroundings.[4]

To understand the implications of this model of core emotion for museum experience design, we first must examine two key questions: What are visitors' core emotion experiences as they move through an exhibition? And, what is the relationship between core emotion experience, and cognitive and behavioral engagement in exhibitions? We explored these two questions through *Emotion and Thinking in Designed Informal Science Environments*, a National Science Foundation-funded research study that began in 2013 and focused on children's engagement in museum exhibitions. The purposes of this study were 1) to describe what emotional engagement looks like as visitors interact with a science museum exhibition, and 2) to create a model describing the interplay of visitors' emotional, behavioral, and cognitive engagement across a range of exhibits and visitors of diverse socio-economic, racial, ethnic, and disability backgrounds. Findings from this study provide insights on the complexity of visitors' core emotion experience and emotional engagement in exhibitions and the role that emotion can play in museum learning.

Study participants were children ages 10 to 14 who experienced the exhibition on their own or with a parent or other legal guardian. We studied these participants as they used the *Math Moves! Experiencing Ratio and Proportion* exhibition.[5] This permanent exhibition is installed at the Museum of Science and three other museums across the United States. We specifically chose this exhibition because it was developed by a collaborative of four museums and two research partners, and therefore reflected the design principles of multiple organizations across the field. We used a diverse range of instruments to study the visitors' reactions to their exhibition experience. We designed these instruments to measure the two dimensions of core emotion (activation and valence), as well as cognitive and behavioral engagement. To measure valence, children completed an experience-sampling measurement questionnaire after each exhibit component, which asked them to reflect upon both positive and negative feelings they had while experiencing the exhibit (fig. 1).[6] In addition to using the written questionnaire to assess positive and negative feelings, we assessed activation by asking visitors to wear wrist sensors throughout their visit to the exhibition. These sensors measured visitors' electrodermal activity; rising levels signify increases in visitors' skin conductance, a reliable indicator of increased activation of the sympathetic nervous system.[7] When a visitor's sympathetic nervous system is activated, they

2 Russell, "Core Affect and the Psychological Construction of Emotion."

3 Lisa Feldman Barrett, "Valence Is a Basic Building Block of Emotional Life," *Journal of Research in Personality*, Proceedings of the 2005 Meeting of the Association of Research in Personality 40, no. 1 (February 2006): 35–55.

4 Justin Storbeck and Gerald L. Clore, "On the Interdependence of Cognition and Emotion," *Cognition and Emotion* 21, no. 6 (August 28, 2007): 1212–37.

5 Funded by NSF, DRL-0840320.

6 Mihalyi Csikszentmihalyi and Kevin Rathunde, "The Measurement of Flow in Everyday Life: Toward a Theory of Emergent Motivation," in *Nebraska Symposium on Motivation, 1992: Developmental Perspectives on Motivation*, ed. Janis E. Jacobs, Current Theory and Research in Motivation, vol. 40 (Lincoln, NE: University of Nebraska Press, 1993), 57–97.

7 Jim Blascovich, "Using Physiological Indexes of Psychological Processes in Social Psychological Research," *Handbook of Research Methods in Social and Personality Psychology*, 2000, 117–37.

fig. 1. The experience-sampling measurement questionnaire used to measure emotional valence after each exhibit experience.

Please circle the response that best describes how you feel.

		Very	Pretty	A little	Not at all
1.	How **INTERESTED** were you in the last activity?	Very Interested	Pretty Interested	A little Interested	Not at all interested
2.	How **CONFUSED** were you in the last activity?	Very Confused	Pretty Confused	A little Confused	Not at all Confused
3.	How **FUN** was the last activity?	Very Fun	Pretty Fun	A little Fun	Not at all Fun
4.	How **DIFFICULT** was the last activity?	Very Difficult	Pretty Difficult	A little Difficult	Not at all Difficult
5.	How **HAPPY** did you feel in the last activity?	Very Happy	Pretty Happy	A little Happy	Not at all Happy
6.	How **FRUSTRATED** did you feel in the last activity?	Very Frustrated	Pretty Frustrated	A little Frustrated	Not at all Frustrated
7.	How **BORED** did you feel in the last activity?	Very Bored	Pretty Bored	A little Bored	Not at all Bored
8.	How **PROUD** did you feel in the last activity?	Very Proud	Pretty Proud	A little Proud	Not at all Proud
9.	How **NERVOUS** did you feel in the last activity?	Very Nervous	Pretty Nervous	A little Nervous	Not at all Nervous

fig. 2. A child and her mother participating in the *Emotion and Thinking* study. The two are wearing electrodermal sensors on their wrists (to measure levels of activation) and eye-tracking glasses (which follow visual attention), providing a first-person perspective of visitor engagement.

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may feel increased attention, focus, excitement or even a little anxious as levels increase. To study cognitive engagement, we used gaze-tracking goggles and software. By tracking visitors' gaze we were able to assess visual attention for both focus and duration. We also leveraged video-recorded observations to capture dwell time, attention, social interactions, and physical behaviors (fig 2).[8] Together, these measures provided a rich, multifaceted picture of visitor engagement in the exhibition.

Our study revealed two major findings about emotions and visitor engagement. The first relates to valence, and the nature of visitors' positive and negative emotional experiences. This finding emerged from our analysis of the experience-sampling questionnaires, which showed that visitors' negative feelings were associated primarily with frustration and confusion, while positive feelings were affiliated with a broad range of characteristics—such as interest, fun, and happiness. This suggests that it is possible to generate positive affective responses with a variety of engagement approaches, but that negative affective responses were primarily associated with challenges and difficulties the learner faced while engaging in the activity. It is important to note that positive and negative core emotions can co-occur and are independent; that is, children can feel positive (interested and happy) while also feeling frustrated or confused.

The second major finding deals with visitors' activation levels, and the impact on cognitive and behavioral engagement. There was wide variability in the level of activation visitors experienced, both between different visitors who engaged with the same exhibit components and within one visitor's experience across the whole exhibition. Roughly half of the children in the study (47%) maintained a relatively passive state throughout their 20-minute experience in the exhibition, registering one or no activation peaks. Others demonstrated as many as eight or nine activation peaks overall. In addition, the number of activation peaks that each individual child experienced varied from exhibit to exhibit.

8 Jrene Rahm, "Multiple Modes of Meaning-Making in a Science Center," *Science Education* 88, no. 2 (2004): 223–47; Chantal Barriault and David Pearson, "Assessing Exhibits for Learning in Science Centers: A Practical Tool," *Visitor Studies* 13, no. 1 (March 31, 2010): 90–106.

Importantly, the impact of high activation on cognitive and behavioral engagement seemed to depend on a visitor's valence while experiencing an exhibit. Confusion or frustration, along with higher activation levels, produced deeper cognitive and behavioral engagement when visitors maintained positive valence about the experience. Confusion seemed productive for deeper engagement and perhaps learning, when a visitor's core emotion was activated and positive.

These findings raise the tantalizing possibility that exhibits could be explicitly designed to support emotional engagement states like "productive struggle," now that we are beginning to understand what visitors' emotional experiences are really like in all of their rich complexity. Identifying trends within this complexity and the contextual factors that are affiliated with them will be key to creating effective and resonant learning experiences for all of the diverse people that visit museums. Importantly, we saw evidence (though less overt) of other potential emotional engagement states that might be supported through the exhibit design, including mindful reflection and exhilaration.

To contextualize and concretize these findings and the potential of this work we offer the following case example of "Jack," one of the study participants.

Emotional and Behavioral Engagement Is Complex: A Vignette

Jack was 11 when he and his father participated in our study. The two explored *Math Moves!* together for a total of 20 minutes. At each exhibit, Jack and his father engaged with each other and with the exhibit task or activity. They asked each other questions, gave each other instructions and suggestions, and thought aloud as they worked through the tasks together. Both seemed to enjoy themselves. They smiled and laughed frequently throughout the session, though Jack's father maintained more of a cheerful and relaxed expression and posture than Jack, who often exhibited an intent, focused facial expression. Occasionally, he pursed his lips or put his fingers to his chin in a seemingly pensive position.

This was the case when Jack and his dad engaged with "Shadow Fractions" (fig. 3), designed to encourage visitors to experiment with the concept of scale while observing how the size of a shadow changes based on the distance of an object from its light source. This exhibit features a table with numbered grid lines; on the table are objects of different sizes. A vertical LED screen at the back of the table casts shadows of the objects on the table. The interpretive labels encourage visitors to move the objects, growing or reducing their sizes to make scenes with the shadows (e.g., "How can the smallest wolf be twice as tall as the biggest tree?").

Jack's father watched as his son walked over to the exhibit and immediately began moving around objects and observing the changes

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fig. 3. The "Shadow Fractions" activity in *Math Moves! Experiencing Ratio and Proportion* at the Museum of Science, Boston.

We would posit that without explicitly attending to core emotion, designers are essentially flying blind to the motor of engagement in of itself.

in their shadows. Soon, he started to make suggestions ("Try using two bunnies," and "Make these two the same size"). Jack attempted to follow these suggestions, pursing his lips as he tried out different positions of the objects. His father asked him questions to guide him ("So what does this one measure?" "So if I put this one at five, where do you think this one would go?"). Again pursing his lips, Jack looked back and forth from the objects to the shadows before answering his father's questions. Jack and his father continued to engage in the exhibit in this way until they decided that they were finished.

Throughout the session, Jack's behavior and demeanor suggested strong focus, but relative calm. However, his electrodermal activity, measured with his wrist sensor, showed high levels of activation several times, suggesting peaks of intensive psychological engagement. Jack's responses on the event-sampling survey, administered immediately after this activity, indicated a range of positive emotions (i.e. pretty happy, pretty fun, a little proud, pretty interested). Yet, he also indicated some feelings of struggle (i.e. a little difficult, a little nervous).

Jack and his father took advantage of the exhibit's intentional support for social engagement and collaboration, and deliberately open-ended structure for inquiry and experimentation.[9] These design strategies also factored into Jack's emotional engagement as he experienced a range of core emotions, from cheerful active engagement, to focused challenge, to the more passively positive feeling "pretty good" or "pretty happy."

An analysis of this family's behavior—characterized by exhibit-focused conversation, attention to and physical manipulation of the exhibit, following instructions and also conducting visitor-driven inquiry—are primarily reflective of deep, meaningful engagement.[10] Jack productively struggled—a complex and important emotional engagement state, one that not only allows for, but explicitly leverages, high levels of activation and negative feeling. The design of the exhibit facilitated the dyad to maintain a positive view and to manage the discomfort of negative feelings like confusion and frustration. But, not all visitors had this experience at this exhibit. Some did not maintain a positive view and engaged only cursorily after beginning to feel that struggle, or only passively experienced the challenge put forth in the exhibit, with little or no activation. Visitors vary in how they appraise exhibits, eliciting a range of core emotion experiences and emotional engagement states. How can we better leverage our knowledge of visitors' core emotion experience in the design of exhibits to better engage visitors in meaningful

9 Rahm, "Multiple Modes of Meaning-Making in a Science Center."

10 Barriault and Pearson, "Assessing Exhibits for Learning in Science Centers."

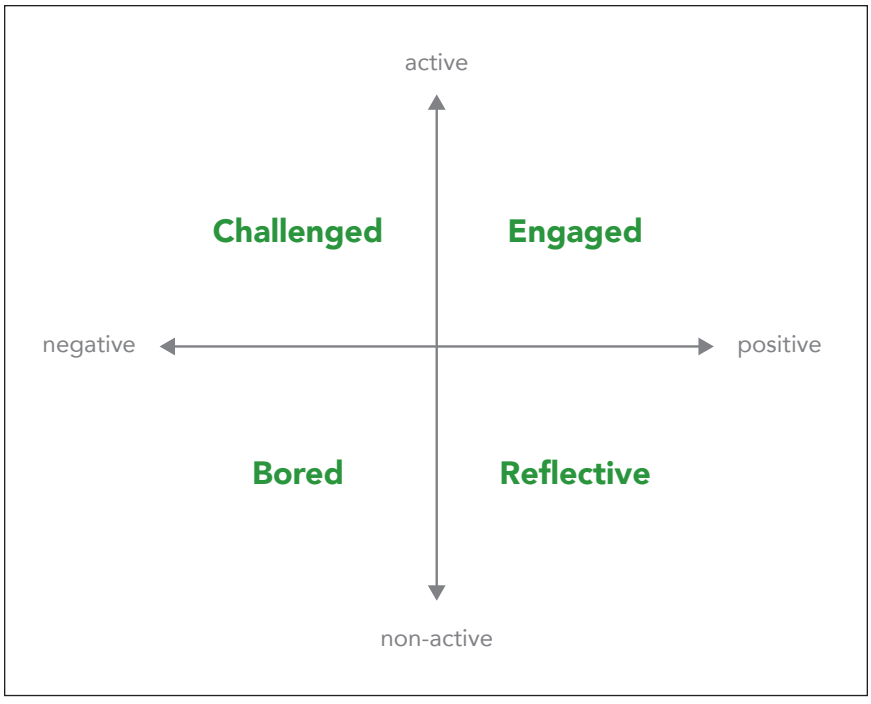

fig. 4. The core affect model of emotional engagement. The axes of core affect are valence, which ranges from positive to negative, and activation, which ranges from passive to highly activated. Core emotion is the product of valence and activation; for example, active and positive emotions manifest in feelings like engagement; negative and active emotions manifest in feelings like challenge or frustration (adapted from James A. Russell, "Core Affect and the Psychological Construction of Emotion," *Psychological Review* 110, no. 1, 2003).

experiences—like those of Jack and his father?

Putting Research into Practice: How We Can Apply Core Affect Theory in Exhibition Design

Emotion is an important part of the informal learning experience, yet to date, we've known very little about the complexity of visitors' emotional experiences and even less about how these experiences affect visitors' engagement. Findings from our research suggest that understanding and designing to support a spectrum of fruitful core emotion states is important for facilitating the emergence of meaningful experiences across diverse visitors. We would posit that without explicitly attending to core emotion, designers are essentially flying blind to the motor of engagement in of itself.

Knowledge of visitors' core emotion experiences can be used to guide the design of individual exhibits—and entire exhibitions—to support deep engagement and to meet visitor values and expectations. For example, many visitors value "fun," or "entertainment."[11] These values and expectations would correspond with core affective states characterized by high levels of stimulation, and strongly positive feelings. At the same time, many value feeling challenged.[12] Being challenged requires experiencing somewhat negative feelings of confusion, difficulty, or frustration along with high levels of activation or stimulation while maintaining a positive view of the overall experience. Likewise, design that supports relatively low levels of activation, with highly positive feeling, may foster actively reflective experiences. In other words, exhibit designers and developers need to consider ways to create exhibitions that allow for and support a diverse range of emotional responses, including positive feelings of fun *and* negative feelings that are associated with challenge and struggle with new ideas or perspectives.

The Museum of Science, Boston has been putting this theory into practice in planning and designing new galleries by considering how to support the varied activation levels and positive and negative feelings that correspond with different feelings, behaviors, and outcomes (fig. 4). For example,

11 Jan Packer and Roy Ballantyne, "Motivational Factors and the Visitor Experience: A Comparison of Three Sites," Curator 45, no. 3 (2002): 183–98; Deborah L. Perry, *What Makes Learning Fun?: Principles for the Design of Intrinsically Motivating Museum Exhibits* (Lanham, MD: AltaMira Press, 2012).

12 Perry, *What Makes Learning Fun?*

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fig. 5. Designed to support reflection: The "River Table" exhibit in the *Yawkey Gallery on the Charles River*.

for the *Yawkey Gallery on the Charles River*—which explores the connections between engineering and nature on the waterway directly outside the museum's windows—the exhibit design team focused on intentionally fostering both challenged and engaged emotional states as well as calm, reflective experiences.

For challenge and engagement, the team created several engineering activities designed for inquiry and for open-ended, sustained, deep collaboration (intro image). We based the design of these activities on the research conducted by San Francisco's Exploratorium that sought ways to foster active and prolonged engagement.[13] In these activities, visitors engineer solutions to address unique, meaningful challenges. For example, "Engineer a Bridge Support" challenges visitors to create a support that will function properly in different river conditions.

Since research has shown that opportunities to reflect are also a valued part of the museum experience,[14] other parts of this permanent exhibition were designed to provide a more contemplative and reflective emotional experience for visitors. To be effective, calm reflection may require low levels of stimulation alongside positive or neutral feelings. To meet this need, we designed multiple calming spaces in the gallery for visitors to sit and observe the natural world. There are benches near the window overlooking the Charles River where we provide visitors with a series of prompts that encourage them to look at the exhibition in a different way. There are also benches located next to aquatic tanks that provide visitors with prompts about different observations to make about the animals that live within them.

There is also another part of the gallery, the "River Table" (fig. 5), which we designed to be both challenging and reflective. This exhibit occupies a separate, darkened, quiet room in the gallery, which is intended to create a more calming atmosphere. Stools are provided around several different activity stations in the room to enhance visitor comfort. The content, however, is a bit challenging. At each station, visitors make decisions about infrastructure and development, and observe and reflect how different policy and development choices impact local communities, stakeholders, and the health of the river ecosystem.

Emotion plays a critical role in modulating motivation, engagement, and behavior in the visitor experience. This signals its power as part of the visitor experience, yet there is still much for us to learn. We still do not have an understanding of how emotion affects different audiences, or how varying kinds of exhibition designs affect visitors' core emotion experiences. We also do not yet have a researched framework for how we can intentionally design for different kinds of emotional reactions. Through our previous

13 T. Humphrey and J.P. Gutwill, *Fostering Active Prolonged Engagement: The art of creating APE exhibits* (San Francisco, CA: Exploratorium, 2005).
14 Packer and Ballantyne, "Motivational Factors and the Visitor Experience: A Comparison of Three Sites."

research study, we have gained a better understanding of how to measure core emotion and emotional engagement in a science museum setting and the complexity and range of emotions visitors feel in an existing exhibition. Moving forward, we are beginning to explore ways to design exhibits that foster different kinds of emotional engagement. Such an understanding will bring us closer to the capability of being able to create informal learning environments that support emotional engagement and learning for a broad range of individuals. ▮

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