12

CURIOSITY

Amanda Markey and George Loewenstein,
Carnegie Mellon University

It is a miracle that curiosity survives formal education.

—*Albert Einstein*

Curiosity, which has been defined as a desire for information in the absence of extrinsic reward, has long been recognized as a crucial motivation driving educational attainment. Cicero (1914, p. 48), for example, referred to curiosity as an "innate love of learning and of knowledge . . . without the lure of any profit." Aristotle (1947, p. 243) wrote that, "All men by nature desire to know," and in a different treatise noted that men study science "not for any utilitarian end" (Posnock, 1991, p. 40). Yet, many of the most fundamental questions regarding this key motivation remain largely or totally unanswered. Why are people so often strongly attracted to information that, by the definition of curiosity, bears no extrinsic benefit? What are curiosity's situational determinants? Are there ways to encourage and cultivate curiosity in the classroom? These questions have been the focus of limited empirical research over the past half century, much of which we review.

We organize our review of the literature into four sections. In the first section, we discuss the definition of curiosity, outlining what is, and what is not, included in the construct. The second section describes the information-gap theory proposed by the second author (Golman & Loewenstein, 2012; Loewenstein, 1994). This theory posits that curiosity develops when people become aware of a gap between what they know and what they don't know. We discuss the theoretical predictions generated by the information gap theory, and we discuss an expansion of the theory that outlines three categories of determinants of curiosity: importance, salience, and surprise. We then review empirical research on situational determinants of curiosity, focusing specifically on studies conducted in educational settings. We begin by discussing environments that can lead to the *suppression* of curiosity but then discuss, more constructively, how instructors can actively foster curiosity through capitalizing on curiosity's three factors. The final section concludes the chapter with a discussion of potentially fruitful directions for future research.

CURIOSITY'S DEFINITION AND DIMENSIONALITY

What do we mean by "curiosity?" "Absent a clear definition of curiosity," Jirout and Klahr (2012, p. 126) note, in a paper on children's scientific curiosity, "our understanding of developmental mechanisms that underlie it cannot be advanced, and the effectiveness of instructional processes aimed at stimulating and increasing it . . . cannot be assessed." The fact that the field has, in fact, not coalesced around a single clear definition of the construct can be seen in the diversity of methods used to measure curiosity—for example, by the number of questions a person asks, the amount of interaction with novel objects in a waiting room, a preference for complex visual stimuli as determined by eye gaze, a desire to see images repeatedly, and explicit ratings of the desire to obtain information. Yet, there has been some convergence over time in researchers' interpretation of the construct. Such convergence has often resulted from researchers' recognition that the construct was being used in different ways, and consequent narrowing of the definition by discarding specific interpretations as not being commensurate with curiosity.

One important refinement to the construct was proposed by D. E. Berlyne (1950, 1954a, 1954b), who was the first researcher to devote sustained attention to the topic. As his research on, and thinking about, curiosity progressed from the 1950s through the 1970s, Berlyne began to distinguish between two quite different phenomena: (1) "specific exploration," when "an animal is disturbed by a lack of information" (1966, p. 26) and (2) "diversive exploration," when "an animal seeks out stimulation, regardless of source or content, that offers something like an optimum amount of novelty, surprisingness, complexity, change or variety" (p. 26). Ultimately, Berlyne came to view only the first of these—specific exploration—as commensurate with curiosity. Drawing an explicit comparison to specific exploration, Berlyne (1966, p. 27) wrote that diversive exploration "is not preceded by receipt of partial information about the stimulus patterns . . . and thus seems to be *motivated by factors quite different from curiosity* [emphasis added]" (see, also, Berlyne, 1978, p. 144). As will be evident, Berlyne's implicit suggestion that specific exploration is preceded by a receipt of partial information hints at what is the key ingredient of the information gap account of curiosity that forms the basis of the current paper.

Berlyne's definition of curiosity is as useful for what it excludes as for what it includes. Specifically, it excludes varieties of information search in which an animal (including a human) is engaged in an unfocused attempt to acquire information. Dashiell (1925), for example, observed that, even when hungry, rats would pay little to no attention to food and instead explore a new environment, a phenomenon that he attributed to an "instinct of curiosity" triggered by "novelty in the environment" (p. 208). Nissen (1930) likewise observed that rats would go so far as to cross an electrified grid to explore a maze, and Pavlov (1927) observed that dogs reflexively respond to changes in the world around them by orienting their eyes, head, and trunk toward the source of stimulation. Beyond the fact that one cannot know whether these animals' desire for information really was intrinsic, it is perfectly possible that they were seeking information so as to better be able to navigate their environment, rule out potential threats, or search for sources of food—Berlyne's distinction between diversive and specific exploration, and his association of curiosity with only the latter, suggests that such exploratory, or orienting, phenomena should not be treated as manifestations of curiosity. That is not to say that information seeking by nonhuman animals should never be interpreted as specific exploration and curiosity per se; anyone who has observed the propensity of cats to explore anything they have restricted access to—that is, from which they have experienced "receipt of partial information"—will be unlikely to blithely dismiss the idea that nonhuman animals engage in specific exploration.

Berlyne and other behaviorists maintained a focus on state curiosity, which refers to the temporary experience of curiosity in a given situation. This is contrasted with trait curiosity, which corresponds to an individual's personality disposition toward experiencing curiosity. Many trait curiosity scales have been developed in the past 50 years (e.g., Perceptual Curiosity Scale [Collins, Litman, & Spielberger, 2004]; Curiosity and Exploration Inventory [Kashdan, Rose, & Fincham, 2004]; Epistemic Curiosity Scale [Litman & Spielberger, 2003]; Melbourne Curiosity Inventory [Naylor, 1981]; Curiosity/Interest in the World Scale [Peterson & Seligman, 2004]). As one can infer from the scale titles, these trait curiosity scales measure a diversity of constructs, and this diversity is also manifest in the questions composing the scales, which range from, "I really enjoy learning about other countries and cultures" to "When I am participating in an activity, I tend to get so involved that I lose track of time" to "When I see a new fabric, I like to touch and feel it."

While trait curiosity scales are useful for examining the correlates—for example, life-outcomes and other measured traits—of the diversity of constructs they measure, they are limited in their ability to inform educational practices. Individuals with high trait curiosity probably do make superior students and scientists, on average, but this ability to measure differences would, at best, aid in sorting or tracking students on the basis of their curiosity. These scales have limited capability to inform practices to encourage and capitalize on curiosity. In contrast, an improved understanding of state curiosity has the potential to suggest practical methods to stimulate curiosity, and, furthermore, if trait differences reflect the cumulative effect of situational factors, then these interventions, if effective in stimulating state curiosity, might ultimately serve to enhance trait curiosity. Therefore, in this chapter, we focus on the state curiosity, its situational determinants, and its application to educational settings and specific instructional techniques.

Drawing both on the historic interpretation of curiosity and Berlyne's refinement in what follows, we adopt the definition of curiosity as a desire for specific information in the absence of extrinsic reward.[1] Few researchers would exclude such a desire for specific information as a variant of curiosity, but some would deem the definition to be excessively narrow. We agree with Berlyne, however, that a more parsimonious definition of the curiosity that excludes, for example, unfocused exploration or a preference for novelty provides a superior foundation for development of an empirically grounded understanding of the phenomenon. We also believe it provides for a more effective application to instruction in education.

AN INFORMATION-GAP ACCOUNT OF CURIOSITY

In the mid-twentieth century, two different, although not inherently contradictory, theoretical accounts of curiosity were proposed. One, of which Berlyne was the most prominent advocate, viewed curiosity as a drive motivating information acquisition, much as hunger motivates seeking of food and thirst motivates seeking of drink. Like hunger, thirst, and other drives, Berlyne noted, curiosity produces a negative feeling when not satisfied but is pleasurable when satisfied by the acquisition of desired information. An important difference between curiosity and many other drives, such as hunger and thirst, however, is that curiosity does not tend to intensify over time when it is not satisfied. In this respect, curiosity is more like the sex drive, which (although it does tend to intensify if not satisfied for some interval) is largely stimulus bound.

Skirting these features of curiosity that the drive theory was intended to highlight, "incongruity" theories focused on the question of what stimuli arouse curiosity. Just as sexual desire is activated by any kind of sensory contact with any sexually charged object (typically a person), the incongruity theories posited that curiosity was triggered by incongruity in the environment, and specifically by a violation of expectations (e.g., Hebb, 1949; Hunt, 1963).

The information gap account of curiosity proposed by Loewenstein (1994) was an attempt to integrate insights from drive theory, incongruity theory and decision theory. Curiosity, according to this account, arises when people become aware of the gap between what they know and what they don't know. Such a gap could be triggered by violated expectations, as posited by incongruity theories, but it could also be triggered by many other varieties of stimuli, such as hearing snippets of a conversation at an adjoining table in a restaurant, or, somewhat trivially, being asked a question to which one does not know the answer. Like drive theories, the information gap account assumes that unsatisfied curiosity is aversive and that satisfying curiosity is pleasurable.

To make sense of these, and a variety of other features of curiosity, the information gap account draws on the concept of an informational reference point—a salient state of knowledge. Curiosity, according to this account, arises when an individual's attention is drawn to a potential state of knowledge different from, and specifically greater than, their current state. The information gap is then the difference between the individual's current state of knowledge and this salient alternative state of knowledge. Curiosity, which according to this account results from the desire to close an information gap, can be distinguished from interest. In Chapter 11, interest has been defined as "the feeling of being engaged, caught-up, fascinated, curious . . . a feeling of wanting to investigate, become involved" (Izard, 1977, p. 216). As is quite explicit, this definition encompasses curiosity within the larger construct of interest. In contrast, we view curiosity and interest as distinct phenomena. We define interest as a psychological state that involves a desire to become engaged in an activity or know more, in general, about a subject. If an individual is interested in pottery, for example, that person may want to sit down and throw pots, or that person may want to know more about the technique, the materials, and the history. Curiosity, in contrast, according to our definition, only arises when a specific knowledge gap occurs, such as, "What is the difference between high and low fire pottery?" Thus, curiosity and interest differ by their objects of desire (specific knowledge vs. general knowledge/activity engagement). Furthermore, while interest is often subdivided based on its causal source—situational interest is generated by particular conditions in the environment, and individual interest is generated by relatively enduring predispositions—curiosity is agnostic about its origin. A final distinction is phenomenology, which refers to what each state feels like. Interest is often, though not always, associated with positive affect (Hidi, 2000, p. 312). In contrast, while the satisfaction of curiosity provides pleasure, curiosity itself is an aversive state associated with deprivation (e.g., Day, 1982; Litman & Jimerson, 2004; Loewenstein, 1994; Todt & Schreiber, 1998).[2]

What, then, determines the intensity of curiosity? In a recent elaboration of the theory (as well as an attempt to integrate curiosity with a wide range of other informational phenomena), Golman and Loewenstein (2012) specify that curiosity depends on three factors: (1) importance, (2) salience, and (3) surprise.

Importance indicates how much the information matters to the individual—that is, how differently the individual will feel if the information gap is filled in different ways. Because most people care more about themselves than about other people, missing information about anything relating to the self—for example,, whether one is a good person, good looking, intelligent or even an above-average driver—will tend to be important, and hence to evoke curiosity. In general, people will tend to be especially curious about things that matter to them. An investor will be curious about the state of the market, parents about the welfare of their children, and a botanist about the name or characteristics of a plant. In the common situation in which individuals face myriad information gaps, the importance of a missing piece of information, and hence the individuals' curiosity to obtain it, will naturally be increasing in the number of gaps the information can address.

One implication of the latter prediction is that insight problems should generally evoke greater curiosity than incremental problems because, with insight problems, there is a possibility that a single piece of information can throw light on the entire problem. With incremental problems, in contrast, any single piece of information is unlikely to yield a sudden solution. To test this prediction, participants in a study conducted early in the days of the personal computer were asked to click on 5 of 45 squares on a screen, ostensibly to familiarize themselves with the operation of the mouse (Loewenstein, Adler, Behrens, & Gillis, 1992). For half of the participants, the 45 squares, when exposed, formed an image of a single animal, but several squares had to be exposed before the identity of the animal could be determined. For the other participants, each square, when clicked on, revealed a different animal. Curiosity was measured by how many excess squares participants voluntarily turned over, beyond the required 5. As predicted, based on the information-gap perspective, participants voluntarily turned over more squares in the single animal condition than in the multiple animal condition.

Salience refers to the degree to which the individual's environment highlights a particular information gap. The conversation happening at the next table is likely to evoke curiosity because the proximity of the table, the unusual appearance of the diners, and the tantalizing snippets of conversation overheard, all make that conversation especially salient. The conversations happening at more distant tables, or even at the most interesting tables around the world, in contrast, fail to evoke much curiosity at all. Salience will tend to be high when a question is asked explicitly, and it will be even higher if there is another identifiable and proximate individual who knows the answer. By the same token, curiosity will decline almost instantly if attention is drawn away from an information gap.

Finally, surprise captures the central insight of incongruity theories—that the receipt of information can trigger (or in some cases squelch) curiosity. A person who views another person as intelligent, for example, might be surprised when the latter person gives an obviously wrong answer to a simple question, which would open an information gap in the form of a desire for an explanation for the discrepancy. Consistent with such a role for surprise, Berlyne (1954b, 1957) found that questions subjects indicated to be "surprising" coincided closely with those they reported to be evoking of curiosity.

An important implication of this framework for education is that curiosity will tend to be positively related to one's knowledge in a particular domain; thus, the accumulation of knowledge tends to beget a desire for further knowledge. First, when one has more knowledge of a topic one tends to have more information gaps, so that new knowledge is more likely to address a larger number of gaps. This is exemplified by the classic mystery novel; revealing the killer's identity promises to immediately unlock the key to all of the seemingly inconsistent and inexplicable clues, allowing the reader to make sense of multiple puzzles at once. Second, the more one knows, the more salient a gap is likely to become. When a botanist walks along a trail in a densely packed forest, an undiscovered plant would capture her attention and likely elicit questions of its species, its unique markings, its growth conditions, and so forth. A casual hiker, on the other hand, will likely not even notice the unusual plant, and even if informed of its presence, will be unlikely to request further details. Third, the more one knows, the more likely one is to be surprised when one acquires new knowledge. If you see a speaker you don't know at a conference who is obviously suffering from stage-fright, you are unlikely to be surprised; it is a common occurrence. If you do know the speaker, however, and know that she is a superb teacher, is comfortable in social situations, or generally has a blasé attitude, the stage-fright is much more surprising, and, as a result, curiosity evoking.

To test the relationship between knowledge and curiosity, Loewenstein et al. (1992) randomly assigned experimental participants to view photographs of parts of an individual person (hands, feet, and torso). Participants viewed between one to three photographs, and afterwards, they were given a choice to see a photograph of the whole person or receive a bonus payment of $0.50. Participants who had uncovered more body parts were more likely to view the picture and forsake the money, even though they had objectively less to learn from doing so.

A final important, if somewhat obvious, implication of the information gap account is that curiosity should be directly related to the perceived ability of a piece of information to close the gap. Large information gaps will generally not tend to evoke much curiosity because the individual will perceive closing the gap as an unattainable goal. Smaller gaps will more likely be perceived as closeable and subsequently arouse more curiosity, a phenomenon that resembles the notion of an approach gradient, whereby motivation tends to increase as an organism nears a goal (e.g., Hull, 1932; for a reference point-as-goals account, see Heath, Larrick, & Wu, 1999).

Loewenstein et al. (1992) found evidence for the prediction that curiosity will tend to increase as one perceives oneself as close to filling an information gap. Participants in an experiment were given words and definitions and asked to match them. For words they were unable to identify, they rated their "feeling of knowing" and whether the answer was on the tip of their tongue. Self-reported curiosity was highly correlated to these measures. Litman, Hutchins, and Russon (2005) also found a positive correlation between self-reported curiosity to answer a question and the degree to which the answer was perceived to be at the tip-of-the-tongue. Other research that we discuss below shows that children's curiosity is enhanced in environments that boost their self-confidence, self-esteem, and agency. These findings could be explained by the idea that all of these states are likely to increase the child's confidence that they will be capable of answering questions—of closing information gaps—hence, leading to intensified motivation to make the attempt (e.g., Kashdan, 2009).

In sum, Loewenstein's original information gap theory describes curiosity as the desire to reach an informational reference point, which is established when it becomes apparent that what one wants to know exceeds what one currently knows. This theoretical reference point account, with the additional insight that curiosity's intensity is a product of importance, salience, and surprise, generates specific predictions about what will, and what will not, evoke curiosity as well as who will, and who will not, be prone to curiosity. In the remaining sections of this chapter, we use the information gap theory to discuss how to foster curiosity and exploit its motivational power in educational settings.

CURIOSITY IN EDUCATION

When presented with a prepopulated list of character traits, over 75% of teachers chose curiosity as one of the top five characteristics they strive to encourage in their students (Hackmann & Engel, 2002, as cited in Engel, 2011).[3] Additionally, various science curricula explicitly aim to encourage curiosity (e.g., The University of Chicago Laboratory School Science Curriculum, n.d.; National Science Teachers Position Statement, Association Curriculum Recommendation, 2003), and the National Education Goals Panel proposes that "openness and curiosity about new tasks and challenges" affect children's learning and is an indicator of school readiness (Kagan, Moore, & Bredekamp, 1995, p. 23). There is evidence that this encouragement of curiosity is warranted, given its facilitation of memory, attention, and information-seeking behavior. In one fMRI study, researchers demonstrated that level of curiosity is correlated with activation in regions that have been associated with anticipated rewards and memory, and when answers were provided to curiosity-inducing questions, there was a stronger neural activation overall (Kang et al., 2009). Furthermore, they found that curiosity was correlated with pupil dilation, a common measure of attention. Numerous behavioral studies have shown that answers to questions that elicit curiosity are much more likely to be remembered minutes, days, and weeks later (Berlyne, 1954b,1966; Kang et al., 2009) and that individuals who experience curiosity are more likely to exert effort to learn an answer (Litman et al., 2005; Loewenstein et al., 1992). In sum, there is widespread agreement that curiosity is a valuable form of motivation promoting learning in and outside of the classroom and that curiosity should be actively fostered in and outside the classroom.

The question of how curiosity can be fostered, however, may inadvertently distract us from an important insight. Beyond the techniques they can use to stimulate curiosity (a point we turn to momentarily), an even more fundamental goal for educators should be to not get in the way of a powerful and innate drive that is evident both in children and in other animals. As Parvanno (1990; quoted in Jirout & Klahr, 2012, p. 126) observed, "Children are born scientists. From the first ball they send flying to the ant they watch carry a crumb, children use science's tools—enthusiasm, hypotheses, tests, conclusions—to uncover the world's mysteries." But many commentators on education, including Einstein in his opening quote, have suggested that education somehow gets in the way. Parvanno continues, "somehow students seem to lose what once came naturally." Consistent with such a perspective, although admittedly open to alternative interpretations, many scholars have either commented upon (Hall & Smith, 1903) or even documented empirically (Engel, 2009; Labella, 2009; Tizard & Hughes, 1984) the tendency for children who ask questions at home to dramatically reduce such question asking when they enter the classroom.

John Locke (1909–1914, pp. 209–211), who early on proposed techniques that parents could use to stimulate their children's curiosity, advised parents "not to check or discountenance any enquiries he shall make, nor suffer them to be laugh'd at; but to answer all his questions, and explain the matter he desires to know, so as to make them as much intelligible to him." These same two prescriptions that Locke applied within the family apply equally well to educational settings. Considerable research supports Locke's proposals that, to avoid suppressing curiosity, authority figures should create a safe and welcoming environment in which children feel comfortable taking risks, and they should answer questions clearly and accurately.

Moore and Bulbulian (1976) randomly assigned a confederate to encourage and approve of, or aloofly criticize, preschoolers' organization of a miniature farm set. The researchers found children in the aloof-critical condition took significantly longer before beginning exploration, engaged in less exploratory behavior overall, and were less likely to volunteer guesses in a game. Similarly, Henderson (1984) found that children explored significantly less when adults showed indifference as opposed to watching children explore, and actively encouraging exploration with smiles, eye contact, and positive verbal responses. Hackmann and Engel (2002, cited in Engel, 2011) found patterns of systematic variation in students' curiosity levels, as measured by their willingness to explore a "curiosity box" with many drawers containing different items. Approving teacher behavior, such as encouragement to examine the box and positive feedback in response to exploration, facilitated exploration, while a lack of approval discouraged it.

Information seeking by even characteristically curious students can be squelched in the right (or wrong) environment. Peters (1978) examined the behavior of college students measured to be low or high in trait curiosity, in classrooms with intimidating or nonintimidating professors. In low-threat classrooms, students with high trait curiosity asked more questions, but in high-threat classrooms, this difference disappeared because both groups asked few questions.

It would be an overstatement, however, to state that adults can only get in the way of children's natural curiosity. Indeed, other researchers have found that the absence of adults can suppress children's exploration. In one study, Hutt (1966) found that children were more apprehensive of novelty when an adult was absent from the room, and subsequent research has observed similar patterns specifically for children and parents. For example, Henderson, Charlesworth, and Gamradt (1982) observed children in a natural science museum, either in peer groups or with a parent, and found that children in the company of their parents explored exhibits more thoroughly and asked more questions than children who were with peers but with parents absent.

The information gap theory suggests that this relationship between welcoming and supportive environments and children's curiosity is due, in part, to the impact of self-efficacy and confidence. A supportive environment likely promotes students' feelings of self-efficacy and confidence, which increases students' perceived ability to close gaps and increases their level of curiosity. Additionally, a safe environment allows children to focus their attention on knowledge gaps as opposed to threatening stimuli, such as bullying peers or critical teachers. It is important to note that there is no research, which we know of, that directly measures self-efficacy and confidence, though numerous studies are consistent with the perspective proposed above. Rodrigue, Olson, and Markley (1987), for example, found that inducing negative affect stifles the desire for knowledge. Participants in the experiment were randomly assigned to a control condition or a negative mood condition in which they read statements aloud (e.g., "Every now and then I feel so tired and gloomy that I'd rather just sit than do anything") that became increasingly negative (see Velten, 1968). After this induction, participants read scientific studies and then rated the value of experiments and their desire to know more. Individuals in whom a negative mood had been induced rated the experiments as less valuable and showed a diminished desire to learn more, as compared with the control condition, and a third condition with a positive mood induction. These studies suggest that environments that breed negativity, low self-efficacy, and confidence, whether via peer bullying, threatening teachers, or negligent parents, can suppress curiosity. As Todd Kashdan observes, "At any age, we are more curious when we possess secure, safe havens," and when these safe havens are comprised, so is curiosity (2009, n.p.).

In addition to the creation of a safe haven, to avoid suppressing curiosity, educators should also directly answer questions or encourage students to answer questions themselves. Curiosity is reinforced when individuals receive concrete answers because stronger associations are formed between the positive feeling of closing the information gap (the "aha moment") and the feeling of curiosity itself. Additionally, satisfying curiosity should be reinforcing because it increases confidence in one's ability to close gaps and builds competence in the subject domain, both of which, the information gap theory predicts, should increase curiosity. Consistent with this prediction, research has found that unsatisfying answers stifle curiosity. Children who receive "I don't know" responses are less likely to ask subsequent questions than those who receive concrete answers (Endsley & Clarey, 1975). In an observational study, children who were offered less information by their parents, when playing in a room filled with different types of toys, explored less than students provided with more information. Even a promise of "not now, but later" can diminish curiosity, according to a study by Henderson and Moore (1980). The researchers simulated the response pattern of a busy, yet attentive, parent in their "unresponsive condition," in which an adult invited a child to play in a play area while she worked off to one side. When the child asked a question or tried to get the adult's attention, she indicated in a friendly way that she was too busy, but that the child should have fun playing and they would talk later. Children asked fewer questions in this condition than when the adult responded with factual, yet brief, answers, as well as a condition in which the adult didn't even answer the question, but instead asked the child back, "What do *you* think?" and then listened intently to the child's answer.

When given insufficient or vague answers, students' attention often wanders, and their desire for knowledge dissipates. Curiosity is a natural drive, but one that is easily suppressed. A lack of encouragement, an absence of adult figures, and insufficient answers can all extinguish curiosity's flame. The most basic goal of educators, insofar as curiosity is concerned, should be to not get in its way.

IMPORTANCE, SALIENCE, AND SURPRISE

Beyond the, perhaps obvious, goal of not suppressing curiosity by eliminating threats in an environment and avoiding unsatisfying answers, how can curiosity be actively cultivated by educators? The information gap perspective points to several approaches that facilitate learning through capitalizing on the three factors of curiosity discussed earlier: importance, salience, and surprise.

Importance specifies how much a piece of information matters to an individual; the more important the information, the more curiosity aroused. Research demonstrates that interest, a key input to importance, is associated with higher comprehension and retention, and recent trends in education on tailoring instruction and culturally responsive teaching also reflect how importance can stimulate curiosity and learning. Interest is defined as "a motivational variable [that] refers to the psychological state of engaging or the predisposition to reengage with particular classes of objects, events, or ideas over time" (Hidi & Renninger, 2006, p. 112). A topic of interest is, by definition, a topic of importance, and, across studies, interest has been shown to facilitate curiosity and subsequent memory for assimilated information.

Asher, Hymel, and Wigfield (1978) evaluated fifth graders' interests by having them rank photographs of different topics (e.g., jet planes, butterflies, cats). One week later, children read either high- or low-interest passages, based on their previously indicated interests, and, while reading the passage, filled out a single-word blank that measured their comprehension. The high-interest groups demonstrated significantly higher comprehension than the low-interest group. In another study, Bernstein (1955) assigned ninth graders to read one of two passages, previously rated as high- or low-interest by a group of independent peers, and then to take a comprehension test with both objective and free response components. High-interest passages were associated with significantly better comprehension as well as greater reading speed. In another study, Hidi and Baird (1988) created a text to accentuate characteristics believed to be determinants of interest: activity level (i.e., material that describes more intense actions and feelings), character identification, and novelty. Students reading the version intended to enhance interest recalled more information and experienced less forgetting one week later than a control group of typical, unmodified texts. This pattern of interest facilitating learning holds for a variety of ages, from young children to college students, and across a variety of domains (for a review, see Hidi, 1990).

Teachers commonly tailor content in curricula to appeal to individual students' interests, background, and culture, in an effort to increase curiosity by increasing the relevance of content to students' lives. Inner-city teachers, for example, often seek to include course materials, such as readings, that convey the perspectives of individuals with similar ethnic backgrounds as their students' (e.g., Gay, 2010; Wlodkowski & Ginsberg, 1995) or history texts that give voice to marginalized characters (for a review of the impact of culturally responsive practices on student outcomes, see Irvine & Hawley, 2011).

Salience, the degree to which the individual's environment highlights a particular information gap, is commonly utilized in educational environments. Diverse research suggests that instructional techniques that increase the salience of gaps result in better student outcomes. For example, in one focusing treatment in the previously discussed study in which children explored more when exposed to an attentive adult who smiled and made eye contact (Henderson, 1984), adults actively pointed out novel features and asked leading questions, thereby highlighting the salience of information gaps. Children in this condition explored as much as the active interest condition, and children in both groups explored significantly more than those in the control group. Similarly, Bonawitz and colleagues (2011) found that children whose attention was drawn to incomplete information were more likely to explore novel features of a toy. In two conditions, children were either explicitly shown uses of a toy by an adult or saw an adult accidentally discover a use, and then were given the opportunity to play with the toy. In the latter condition, children were more likely to explore other features of the toy and discover other uses. When information is portrayed, implicitly or explicitly, as being complete, then the formation of a reference point, along with curiosity, is stifled, but when an information gap is highlighted, curiosity is aroused and exploration increases.

Instructional techniques that capitalize on salience are diverse and include questioning and highlighting controversy. As Berlyne (1960, p. 289) observed, "the skillful lecturer excites curiosity in his audience by putting questions to them . . . which it has never occurred to them to ask themselves." Questions serve a multitude of purposes in the classroom, not only sparking curiosity but also serving as a check for students' understanding so that teachers can diagnose whether students comprehend the material presented. By bringing information gaps to the attention of students, question asking has been shown to increase retention of material (e.g., King, 1994; Redfield & Rousseau, 1981; Rosenshine, Meister, & Chapman, 1996; Wong, 1985).

While question asking generally promotes curiosity and retention, not all questions are created equal; the questioner, timing, and type of question all matter. In one study, Ross and Killey (1977) showed children slides and allowed them to ask questions about them. Children had the highest retention for answers to their own questions, as contrasted with questions asked by peers. Although it is possible that this result simply reflects the fact that children tend to ask questions about topics they are interested in, other research has found that encouraging students to generate their own questions, specifically through the cognitive strategy of "self-questioning," is an effective strategy for enhancing curiosity and improving comprehension and retention (King, 1989; Rosenshine et al., 1996; Wong, 1985). In another study examining the impact of timing and content of questions, Rickards (1976) found that conceptual questions asked before readers engage with a text are more effective in promoting recall than conceptual or verbatim questions administered after such engagement. Questioning is effective in promoting the salience of information gaps, which in turn seems to promote deep engagement with material and, ultimately, understanding and retention.

Another educational technique that capitalizes on salience is to highlight controversy. In one study, Lowry and Johnson (1981) assigned elementary school students to small groups to learn about a topic in social studies. In one condition, children were encouraged to focus on controversy and uncertainty, whereas in another, children were encouraged to work together to learn the facts. Children in the controversy condition learned more and were more likely to forgo recess to watch a film on the topic after the unit was over. By highlighting controversy, an obvious information gap is highlighted: which view is right and which view is wrong.

While many existing educational techniques, including question asking, naturally play on salience, a more explicit understanding of how and why salience affects learning, via its impact on curiosity, could be a useful insight to impart to teachers. Imagine, for example, a teacher who was introducing a unit on the topic of simple machines. She could present students with the machine and ask them to try to figure out what it does before demonstrating its operation, or she could demonstrate its operation and ask them to try to figure out how it works before providing the answer. Teachers attuned to the importance of salience as a stimulus of curiosity might themselves benefit from asking themselves, and trying to answer, the question: How can I make manageable information gaps salient to my students?

A final educational technique that capitalizes on salience and has been shown to increase learning is the Know-Want-to-know-Learned chart (KWL; see Deck, 2012, and Ogle, 1986, for a case study of its effectiveness). A KWL chart is a graphic organizer that exemplifies building curiosity through increasing salience. The chart is a table with three columns titled something like: What I Know, What I Want To Know, and What I Learned.

Before students begin a unit, book, or daily lesson, they fill out the chart, beginning with what they know and what they want to know. Then, either throughout the content or at the very end, students revisit the chart and write what they have learned, often in ways that directly relate to what they wanted to know. For example, suppose a seventh-grade social studies class is learning about the Kobe Earthquake in Japan in 1995 as part of a larger unit on when and how governments are useful in society. First, the teacher would have students brainstorm what they know about earthquakes and government involvement. Students might write in the first column, "Earthquakes occur when tectonic plates collide" or "Governments sometimes evacuate cities because of natural disasters." Following this activation of prior knowledge, the class would then brainstorm things they want to learn about the 1995 Kobe Earthquake, such as "How many people were injured or killed?" or "How long did it take the Japanese government and aid organizations to respond?" Finally, throughout the lesson or after, students would fill out knowledge they gained in the third column: "Japan has strict building codes and regularly holds earthquake drills" or "The Kobe Earthquake had a magnitude of 7.2." Through this process of activating prior knowledge, generating information gaps and then explicitly writing out information that fills the gaps, students are more likely to retain the material in this format. Making information gaps salient, whether through teacher questioning, highlighting controversy, or using graphic organizers, effectively engages student attention, builds curiosity, and ultimately facilitates learning.

Surprise, which occurs when expectations are violated, can open information gaps, thereby stimulating curiosity and information seeking. A number of studies support the idea that surprise stimulates curiosity (Berlyne, 1957; Charlesworth, 1964; Minton, 1963), and facilitates memory and learning (e.g., Pearce & Hall, 1980; Rescorla and Wagner, 1972; Schultz & Dickinson, 2000). In one rather complicated study on surprise, curiosity, and recall, Berlyne (1954b) had participants read multiple-choice questions on various animals, rate whether each question surprised them, and mark questions that they would most likely have answered. In a second phase of the experiment, subjects received statements, a subset of which answered the original questions. Subjects then rated whether the statements were surprising and whether they believed that the statement answered a previous question. In the third phase of the experiment, the questions were presented in open-ended format, and subjects attempted to provide answers. Berlyne (1957) found that questions originally marked as surprising were more likely to elicit curiosity, which was directly measured by asking participants to mark 12 questions "whose answers they most wanted to know" (p. 258). He also found some evidence that statements marked as surprising were more likely to be recalled in phase three. Beyond theory and basic research in the lab, utilizing surprise to facilitate learning is a common prescription in teaching guides.

In the book *How Learning Works*, Susan Ambrose and her colleagues (2010) argue that explicitly pointing out and correcting inaccurate prior knowledge is beneficial and results in students updating their understanding. Beyond the usual benefits of feedback, such feedback is likely to initiate surprise when students find they were wrong about topics they believed they knew; as a result, curiosity is likely to be aroused. Another instructional technique that plays on surprise is to have students make predictions. The Center for Research on Learning and Teaching (Brown, Hershock, Finelli, & O'Neal, 2009), for example, suggests that, to increase retention, teachers should "ask students to make predictions by applying course concepts to unfamiliar situations." When predictions turn out wrong, the resulting surprise can, again, stimulate curiosity and motivate learning. For example, a physics teacher, who has been teaching for 28 years, asks his students, every year, on the first day, "Which will hit the ground first—this paper or this textbook, and why?" After students share their forecasts that the textbook will hit first because it weighs more, he crumples up the paper, drops both, and, to the amazement of the students, they hit the ground at exactly the same time. Thus begins the conversation of kinematics. Unfortunately, unlike the instructional techniques described above that capitalize on salience and importance, in the case of surprise, there are no empirical studies (which we know of) that measure the effectiveness of surprise-inducing techniques in classroom or other educational settings.

In conclusion, the three factors of curiosity—importance, salience, and surprise—can each be fostered in educational settings in order to maximize curiosity and to maximize learning. By modifying content to make it interesting and relevant to students, by explicitly or implicitly pointing out information gaps, and by violating students' expectations through correcting prior knowledge and utilizing prediction, teachers, parents, and other educators can harness the power of curiosity and maximize learning.

CONCLUSION

As our review of the literature has hopefully highlighted, research in curiosity, including that which focuses specifically on education, is still at an early stage. On the one hand, given how long philosophers, social scientists, and educators have been discussing curiosity, this is both surprising and disappointing. On the other hand, researchers, including education researchers, should be encouraged that curiosity remains wide open in offering opportunities for those ready to use rigorous methods to attack the wide range of unaddressed, or inadequately addressed, important questions. Some of these opportunities include:

- *Uncovering the relationship between state and trait curiosity.* At the beginning of the chapter, we suggested that if trait differences reflect the cumulative effect of situational factors, then interventions that stimulate state curiosity might ultimately serve to enhance trait curiosity. There is no research, which we know of, that examines state curiosity over time or its relationship to trait curiosity, despite the obvious and important educational implications.
- *Determining what instructional methods are most effective in promoting curiosity.* We discussed instructional methods that capitalize on importance, salience, and surprise. However, studies that examine the effectiveness of these instructional techniques rarely measure the impact on curiosity directly. In addition, it is difficult to determine which techniques are most effective. Is it more effective to begin a novel with a KWL chart, or is it better to provide students with surprising facts and generate interest? Teachers have a limited amount of time, and while different techniques will work better for different teachers, it is also useful to have larger scale empirical comparisons between different instructional methods and curricula.
- *Exploring alternate methods to increase curiosity.* One blog classifies rearranging toys in a child's room as one of their "top five" strategies to increase curiosity. Another recommends imaginative play. A third stresses the importance of lengthening a child's attention span. There is a lot of advice out there, and most likely, a

lot of it is good. However, the advice to experimental support ratio is low. There are relatively few studies that manipulate children's (or adult's) environments and then measure the impact on curiosity. We've cited the majority of state curiosity studies conducted, and none of them address the propositions above.

- *Measuring self-efficacy, confidence, and other potential mediators of curiosity.* As discussed, there is reason to believe confidence and self-efficacy increase curiosity, yet there is limited research directly supporting this claim due to a lack of measurement and manipulation. It is critical to understand what interventions increase curiosity, but it is also valuable to understand why, and how, these interventions work.
- *Exploring the neurophysiological correlates of curiosity.* Does curiosity have a distinct neurophysiological signature? How does the neurophysiology of curiosity relate to interest, flow, and drive states, such as hunger and sex? In what conditions, if any, is curiosity painful? Few researchers have explored the neurophysiological correlates of curiosity (for an exception, see Kang et al., 2009), yet such studies have the potential to shed light on these, and many other, intriguing questions.
- *Examining the potential harms of curiosity.* While curiosity is commonly viewed as a desirable trait (for many good reasons, as we discussed), this was not always the case. Berlyne (1978, p. 99) observed that, traditionally, "curiosity meant lack of self-restraint, encroachment on other people's privacy, prying into matters that did not concern one," and Pandora, Eve, and the cat provide a few cautionary tales. Curiosity is sometimes cited as the culprit motivating teenage drug use (Lee, Neighbors, & Woods, 2007), yet this line of research remains largely uncharted. In addition, morbid curiosity, the desire to view disgusting and unnatural phenomena, has received relatively little attention despite its long-standing prevalence.[4] While curiosity can be a powerful motivating force in education due to its facilitation of memory, attention, and learning, it is valuable to understand when, and why, this force drives undesirable behavior.

Despite the still raw state of research on curiosity in education, educators should nevertheless be able to derive a few relatively confident conclusions from the research just reviewed. These include:

- *Curiosity increases in supportive environments.* Students ask more questions and are more likely to explore novel environments in the presence of their parents and other supportive adults. Students also ask more questions when educators show encouragement through smiling, eye contact, and positive verbal responses, and more generally, when educators are perceived as nonthreatening.
- *Curiosity is naturally reinforcing when questions are answered effectively.* Students tend to ask fewer questions when adults fail to provide answers, or answer them only after a delay. By the same token, students tend to ask more questions when adults answer their questions directly or pose the question back and listen intently to the student's answer.
- *Curiosity increases on topics of importance.* Students demonstrate higher comprehension and retention when reading high-interest passages and experience better academic outcomes when teachers tailor curriculum to reflect students' experiences and identities.

- *Curiosity increases when gaps are made salient.* Students exhibit greater curiosity when adults ask leading questions, or otherwise draw students' attention to open problems, unanswered questions, or controversies. Instructor questioning is especially effective when questions are asked before students interact with content. Self-questioning, a meta-cognitive strategy whereby students pose questions to themselves while reading, also promotes better comprehension and retention. Utilizing KWL charts, which activate and record prior knowledge before generating questions and answers, is an effective instructional technique that promotes curiosity and retention.
- *Curiosity increases when students are surprised.* Teachers should challenge students with questions and facts that are at variance with their existing knowledge and beliefs. Questions and facts that students find surprising elicit curiosity and, when answered, are associated with higher levels of retention.

In sum, while the literature on curiosity remains at a relatively primitive state, several consistent themes, as well as recommendations for educators who are interested in fostering curiosity, do emerge from existing research. In this review, we have sought to identify some of these themes and providing a conceptual framework for thinking about curiosity as an information gap. In addition, we propose the three core determinants of curiosity, which we term importance, salience, and surprise. As our review of the literature has made salient, however, there remain large gaps in our understanding of how curiosity can be instilled, and exploited, in the classroom. Hopefully, making these gaps salient will encourage curious researchers to pursue this vitally important topic.

NOTES

1. The editors of this volume asked us how curiosity relates to broader concepts, such as motivation, emotion, affect, and epistemic feeling. Such questions are always difficult to answer and involve a certain element of subjective judgment, but our answer is as follows.
   Curiosity's relationship to motivation is straightforward. It follows from our definition that curiosity is a motivational state and is included in the broader catalog of intrinsic motivation. We would also define curiosity as an emotion. The evolutionary account of emotion, which we advocate (Loewenstein, 2007), defines emotions as "superordinate programs" that orchestrate a concerted psycho-physiological response to recurrent situations of adaptive significance in our evolutionary past, such as fighting, falling in love, escaping predators, and experiencing a loss in status (Cosmides & Toobey, 2000). Curiosity can readily be viewed as a kind of program that evolved to orchestrate information-seeking in specific situations. Izard (1991, p. 14) characterizes an emotion as "a feeling that motivates, organizes, and guides perception, thought, and action." Certainly, curiosity would also fit this popular description. The terms "affect" and "affective processes" are sometimes used as superordinate labels that encompass emotion. In this case, it is obvious that affect would encompass curiosity. Additionally, the satisfaction of curiosity is typically associated with positive affect. The term "epistemic feelings," like emotions, has different definitions, though fortunately, not as many. Some scholars define it as a feeling about knowledge, hypotheses, and beliefs and associate it with certainty and doubt (e.g., de Sousa, 2008). Other scholars define it as a feeling that depends on unknown knowledge and associate it with fear and hope (e.g., Gordon, 1990). Using either definition, curiosity can be classified as an epistemic feeling because it is a feeling about the value of knowledge, and it is a feeling that depends on the existence of unknown knowledge. Although we were not asked if curiosity is a "drive," we address this question in the next section.
2. This is not to say that curiosity cannot take on a bittersweet flavor. Just as the anticipation of a lover's arrival at an airport can be simultaneously pleasurable and aversive, so can the anticipation of desired information. However, curiosity, like anticipation, is never purely pleasurable.
3. Less encouragingly, when teachers were asked to generate a list of characteristics they sought to encourage, rather than choosing characteristics from a given list, not one teacher's list included curiosity.

4. Over 2,000 years ago, St. Augustine observed that the object of curiosity can be distasteful and disgusting, such as when men seek out "the sight of a lacerated corpse." He didn't coin the term morbid curiosity, but he certainly knew about it.

REFERENCES

Ambrose, S. A., Bridges, M. W., DiPietro, M., Lovett, M. C., & Norman, M. K. (2010). *How learning works: Seven research-based principles for smart teaching.* San Francisco, CA: Jossey-Bass.

Aristotle. (1947). *Metaphysics.* In R. McKeon (Ed.), *Introduction to Aristotle* (pp. 238–296). New York, NY: Modern Library.

Asher, S. R., Hymel, S., & Wigfield, A. (1978). Influence of topic interest on children's reading comprehension. *Journal of Literacy Research, 10,* 35–47.

Berlyne, D. E. (1950). Novelty and curiosity as determinants of exploratory behavior. *British Journal of Psychology, 41,* 68–80.

Berlyne, D. E. (1954a). A theory of human curiosity. *British Journal of Psychology, 45,* 180–191.

Berlyne, D. E. (1954b). An experimental study of human curiosity. *British Journal of Psychology, 45,* 256–265.

Berlyne, D. E. (1957). Conflict and information-theory variables as determinants of human perceptual curiosity. *Journal of experimental psychology, 53,* 399.

Berlyne, D. E. (1960). *Conflict, arousal, and curiosity.* New York, NY: McGraw-Hill.

Berlyne, D. E. (1966). Curiosity and exploration. *Science, 153,* 25–33.

Berlyne, D. E. (1978). Curiosity and learning. *Motivation and Emotion, 2,* 97–175.

Bernstein, M. R. (1955). Relationship between interest and reading comprehension. *The Journal of Educational Research, 49,* 283–288.

Bonawitz, E. B., Shafto, P., Gweon, H., Goodman, N., Spelke, E., & Schulz, L. E. (2011). The double-edged sword of pedagogy: Teaching limits children's spontaneous exploration and discovery. *Cognition, 120,* 322–330.

Brown, M. K., Hershock, C., Finelli, C. J., & O'Neal, C. (2009). Teaching for retention in science, engineering, and math disciplines: A guide for faculty. Occasional Paper No. 25. Ann Arbor, MI: Center for Research on Learning and Teaching, University of Michigan.

Charlesworth, W. R. (1964). Instigation and maintenance of curiosity behavior as a function of surprise versus novel and familiar stimuli. *Child Development, 35,* 1169–1186.

Cicero. (1914). *De finibus bonorum et malorum* (Trans. H. Rackham). Cambridge, MA: Harvard University Press.

Collins, R. P., Litman, J. A., & Spielberger, C. D. (2004). The measurement of perceptual curiosity. *Personality and Individual Differences, 36,* 1127–1141.

Cosmides, L., & Tooby, J. (2000). Evolutionary psychology and the emotions. In M. Lewis & M. Haviland-Jones (Eds.), *Handbook of emotions* (pp. 91–115). New York, NY: The Guilford Press.

Dashiell, J. F. (1925). A quantitative demonstration of animal drive. *Comparative Psychology, 5,* 205–208.

Day, H. I. (1982). Curiosity and the interested explorer. *Performance and Instruction, 21,* 19–22.

Deck, A. L. (2012). *The ffects of KWL on ELL middle school students' listening comprehension of science content.* (Unpublished doctoral dissertation). The Ohio State University, Columbus, OH.

de Sousa, R. (2008). Epistemic feelings. In G. Brun, U. Doğuoğlu, & D. Kuenzle (Eds.), *Epistemology and emotions* (pp. 185–204). Burlington, VT: Ashgate Publishing Company.

Endsley, R. C., & Clarey, S. A. (1975). Answering young children's questions as a determinant of their subsequent question-asking behavior. *Developmental Psychology, 11,* 863.

Engel, S. (2009). Is curiosity vanishing? *Journal of the American Academy of Child & Adolescent Psychiatry, 48,* 777–779.

Engel, S. (2011). Children's need to know: Curiosity in schools. *Harvard Educational Review, 81,* 625–645.

Gay, G. (2010). *Culturally responsive teaching: Theory, research, and practice.* New York, NY: Teachers College Press.

Golman, R., & Loewenstein, G. F. (2012). Curiosity, Information Gaps, and the Utility of Knowledge. (Unpublished manuscript.) Department of Social and Decision Sciences, Carnegie Mellon University, Pittsburgh, PA.

Gordon, R. M. (1990). *The structure of emotions: Investigations in cognitive philosophy.* Cambridge, England: Cambridge University Press.

Hackmann, H., & Engel, S. (2002). Curiosity in context: The classroom environment examined. (Unpublished honors thesis). Williams College, Williamstown, MA. In Engel, S. (2011). Children's need to know: Curiosity in schools. *Harvard Educational Review, 81,* 625–645.

Hall, S. G., & Smith, T. (1903). Curiosity and interest. *The Pedagogical Seminary, 10*, 315–358.

Heath, C., Larrick, R. P., & Wu, G. (1999). Goals as reference points. *Cognitive Psychology, 38*, 79–109.

Hebb, D. O. (1949). *The organization of behavior.* New York, NY: Wiley.

Henderson, B. B. (1984). Social support and exploration. *Child Development, 55*, 1246–1251.

Henderson, B. B., Charlesworth, W. R., & Gamradt, J. (1982). Children's exploratory behavior in a novel field setting. *Ethology and Sociobiology, 3*, 93–99.

Henderson, B., & Moore, S. G. (1980). Children's responses to objects differing in novelty in relation to level of curiosity and adult behavior. *Child development, 51*, 457–465.

Hidi, S. (1990). Interest and its contribution as a mental resource for learning. *Review of Educational research, 60*, 549–571.

Hidi, S. (2000). An interest researcher's perspective: The effects of extrinsic and intrinsic factors on motivation. In C. Sansone & J. M. Harackiewicz (Eds.), *Intrinsic and extrinsic motivation: The search for optimal motivation and performance* (pp. 309–339). San Diego, CA: Academic Press.

Hidi, S., & Baird, W. (1988). Strategies for increasing text-based interest and students' recall of expository texts. *Reading Research Quarterly, 23*, 465–483.

Hidi, S., & Renninger, K. A. (2006). The four-phase model of interest development. *Educational Psychologist, 41*, 111–127.

Hull, C. L. (1932). The goal-gradient hypothesis and maze learning. *Psychological Review, 39*, 25–43.

Hunt, J. M. (1963). Motivation inherent in information processing and action. In O. J. Harvey (Ed.), *Motivation and social interaction* (pp. 35–94). New York, NY: Ronald Press.

Hutt, C. (1966). Exploration and play in children. *Symposia of the Zoological Society of London, 18*, 61–81.

Irvine, J. J., & Hawley, W. D. (2011) Culturally responsive pedagogy: An overview of research on student outcomes. *Culturally responsive teaching awards celebration.* Retrieved from www.edweek.org/media/crt_research.pdf

Izard, C. E. (1977). *Human emotions.* New York, NY: Plenum Press.

Izard, C. E. (1991). *The psychology of emotions.* New York, NY: Plenum Press.

Jirout, J., & Klahr, D. (2012). Children's scientific curiosity: In search of an operational definition of an elusive concept. *Developmental Review, 32*, 125–160.

Kagan, S. L., Moore, E., & Bredekamp, S. (Eds.) (1995). Reconsidering children's early development and learning: Toward common views and vocabulary. *Goal 1 Technical Planning Group Report 95–03.* Washington, DC: National Education Goals Panel. Retrieved from http://govinfo.library.unt.edu/negp/reports/child-ea.htm

Kang, M. J., 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*, 963–973.

Kashdan, T. (2009, August 4). Six ways for parents to cultivate strong, curious, creative children. *Huffington Post.* Retrieved from www.huffingtonpost.com/todd-kashdan/six-ways-for-parents-to-c_b_249031.html

Kashdan, T. B., Rose, P., & Fincham, F. D. (2004). Curiosity and exploration: Facilitating positive subjective experiences and personal growth opportunities. *Journal of Personality Assessment, 82*, 291–305.

King, A. (1989). Effects of self-questioning training on college students' comprehension of lectures. *Contemporary Educational Psychology, 14*, 366–381.

King, A. (1994). Guiding knowledge construction in the classroom: Effects of teaching children how to question and how to explain. *American educational research journal, 31*, 338–368.

Labella, M. (2009). *Encouraging exploration: The effects of teacher behavior on student expressions of curiosity* (unpublished honors thesis). Williams College, Williamstown, MA.

Lee, C. M., Neighbors, C., & Woods, B. A. (2007). Marijuana motives: Young adults' reasons for using marijuana. *Addictive Behaviors, 32*, 1384–1394.

Litman, J. A., Hutchins, T. L., & Russon, R. K. (2005). Epistemic curiosity, feeling-of knowing, and exploratory behaviour. *Cognition and Emotion, 19*, 559–582.

Litman, J. A., & Jimerson, T. L. (2004). The measurement of curiosity as a feeling of deprivation. *Journal of Personality Assessment, 82*, 147–157.

Litman, J. A., & Spielberger, C. D. (2003). Measuring epistemic curiosity and its diversive and specific components. *Journal of Personality Assessment, 80*, 75–86.

Locke, John. *Some thoughts concerning education.* (1909–1914). Vol. 37, Part 1. The Harvard Classics. New York, NY: P.F. Collier & Son. Retrieved from www.bartleby.com/37/1

Loewenstein, G. (1994). The psychology of curiosity: A review and reinterpretation. *Psychological Bulletin, 116*, 75–98.

Loewenstein, G. (2007). Defining affect (commentary on Klaus Scherer's "What is an emotion?"). *Social Science Information, 46*, 405–410.

Loewenstein, G., Adler, D., Behrens, D., & Gillis, J. (1992). *Why Pandora opened the box: Curiosity as a desire for missing information*. Working paper, Carnegie Mellon University, Pittsburgh, PA.

Lowry, N., & Johnson, D. W. (1981). Effects of controversy on epistemic curiosity, achievement, and attitudes. *The Journal of Social Psychology, 115*, 31–43.

Minton, H. L. (1963). A replication of perceptual curiosity as a function of stimulus complexity. *Journal of Experimental Psychology, 66*, 522–524.

Moore, S. G., & Bulbulian, K. N. (1976). The effects of contrasting styles of adult- child interaction children's curiosity. *Developmental Psychology, 12*, 171–172.

National Science Teachers Association. (2003). *NSTA position statement: Science education for middle level students*. Retrieved from www.nsta.org/about/positions/middlelevel.aspx?lid=ms

Naylor, F. D. (1981). A state-trait curiosity inventory. *Australian Psychologist, 16*, 172–183.

Nissen, H. W. (1930). A study of exploratory behavior in the white rat by means of the obstruction method. *Journal of Genetic Psychology, 37*, 361–376.

Ogle, D. M. (1986). KWL: A teaching model that develops active reading of expository text. *The Reading Teacher, 39*, 564–570.

Pavlov, I. P. (1927). *Conditioned reflexes*. Oxford, England: Clarendon Press.

Pearce, J. M., & Hall, G. (1980). A model for Pavlovian learning: Variations in the effectiveness of conditioned but not of unconditioned stimuli. *Psychological Review, 106*, 532–552.

Peters, R. A. (1978). Effects of anxiety, curiosity, and perceived instructor threat on student verbal behaviors in the college classroom. *Journal of Educational Psychology, 70*, 388–395.

Peterson, C., & Seligman, M. E. (2004). *Character strengths and virtues: A handbook and classification*. New York, NY: Oxford University Press.

Posnock, R. (1991). *The trial of curiosity: Henry James William James, and the challenge of modernity*. New York, NY: Oxford University Press.

Redfield, D. L., & Rousseau, E. W. (1981). A meta-analysis of experimental research on teacher questioning behavior. *Review of educational research, 51*, 237–245.

Rescorla, R. A., & Wagner, A. R. (1972). A theory of Pavlovian conditioning: Variations in the effectiveness of reinforcement and nonreinforcement. In A. H. Black & W. F. Prokasy (Eds.), *Classical conditioning II* (pp. 64–99). New York, NY: Appleton-Century-Crofts.

Rickards, J. P. (1976). Interaction of position and conceptual level of adjunct questions on immediate and delayed retention of text. *Journal of Educational Psychology, 68*, 210.

Rodrigue, J. R., Olson, K. R., & Markley, R. P. (1987). Induced mood and curiosity. *Cognitive therapy and research, 11*, 101–106.

Rosenshine, B., Meister, C., & Chapman, S. (1996). Teaching students to generate questions: A review of the intervention studies. *Review of educational research, 66*, 181–221.

Ross, H. S., & Killey, J. C. (1977). The effect of questioning on retention. *Child Development, 48*, 312–314.

Schultz, W., & Dickinson, A. (2000). Neuronal coding of prediction errors. *Annual Review of Neuroscience, 23*, 473–500.

Tizard, B., & Hughes, M. (1984). *Young children learning*. London, England: Fontana.

Todt, E., & Schreiber, S. (1998). *Development of interests*. In L. Hoffmann, A. Krapp, K. A. Remminger, & J. Baumert (Eds.), *Interest and learning: Proceedings of the Seeon Conference on Interest and Gender* (pp. 25–40). Kiel, Germany: IPN.

University of Chicago Laboratory Schools. (n.d.). *Educational Program: Curriculum: Science*. Retrieved from www.ucls.uchicago.edu/schools/lower-curriculum/index.aspx

Velten, E. (1968). A laboratory task for the induction of mood states. *Behaviour Research and Therapy, 6*, 473–482.

Wlodkowski, R. J., & Ginsberg, M. B. (1995). *Diversity and motivation: Culturally responsive teaching*. San Francisco, CA: Jossey-Bass.

Wong, B. Y. (1985). Self-questioning instructional research: A review. *Review of Educational Research, 55*, 227–268.

International Handbook of Emotions in Education

Edited by
Reinhard Pekrun and Lisa Linnenbrink-Garcia

Routledge
Taylor & Francis Group
NEW YORK AND LONDON

First published 2014
by Routledge
711 Third Avenue, New York, NY 10017

and by Routledge
2 Park Square, Milton Park, Abingdon, Oxon OX14 4RN

Routledge is an imprint of the Taylor & Francis Group, an informa business

Library of Congress Cataloging-in-Publication Data

Handbook of emotions and education / [edited] by Reinhard Pekrun and
Lisa Linnenbrink-Garcia.
pages cm. — (Educational psychology handbook series)
Includes bibliographical references and index.
1. Educational psychology—Handbooks, manuals, etc. 2. Affective education—Handbooks, manuals, etc. 3. Emotions—Handbooks, manuals, etc. I. Pekrun, Reinhard, 1952– editor of compilation. II. Linnenbrink-Garcia, Lisa, editor of compilation.
LB1072.H33 2013
370.15—dc23
2013032944

ISBN: 978-0-415-89501-9 (hbk)
ISBN: 978-0-415-89502-6 (pbk)
ISBN: 978-0-203-14821-1 (ebk)

Typeset in Minion
by Apex CoVantage, LLC

Printed and bound in the United States of America by
Edwards Brothers Malloy