H. G. Wells said that human history is a race between education and catastrophe. Although formal education is a historical development that has only been around for a few thousand years, teaching is ubiquitous in human cultures. In contrast, at most a few nonhuman species of animals teach their young about how to eat and get around in the world. For humans, teaching is a standard activity of parents and other caretakers, but it is also a profession as teachers, professors, managers and others work to transmit what they know to children and other students.

Because of their practical importance, teaching and education are the subjects of scientific investigation, going back at least to the educational psychology of William James and John Dewey. Since the 1990s, there has been increasing interest in applying insights from neuroscience to deepen understanding of the psychology of education and to suggest better ways of teaching. Current initiatives go under the headings of educational neuroscience, neuroeducation, and studies in mind, brain, and education.

It is not at all obvious, however, how to apply what is known about the brain to improve professional activities in education. Skeptics have worried that the gap between what brains do and teaching is too great for educational neuroscience to be useful. Most brain research uses scanning techniques such as fMRI to identify correlations between mental activities and activation in brain areas, but the educational significance of such
correlations is hard to extract. Oddly, neuroeducation has had much discussion of learning in individual brains, but largely ignored the social process of teaching.

Various companies that sell products to schools have claimed, with little supporting research, to be “brain-based” in their approaches to learning and teaching. Like the general population, teachers have been susceptible to neuromyths, such as beliefs that individual differences in left/right brain hemispheres generate different learning styles.

Theoretical neuroscience offers a different route to neuroeducation. Instead of relying on disconnected experimental observations and popular myths, educators can benefit from an empirically founded but highly general theory of how the brain works. This chapter will use semantic pointer theories of cognition and communication to provide new perspectives on the nature of learning and teaching. Neural mechanisms of representation, binding, competition, and transfer provide a novel understanding of how brains operate when they are learning and teaching.

On this view, learning in individuals is primarily acquisition of semantic pointers - multimodal representations that can combine verbal, sensory, motor and emotion representations. This approach can accommodate some of the most interesting recent approaches to educational theory, including the multiple intelligences of Howard Gardner. Moreover, because semantic pointers integrate cognition and emotion, they can also illuminate current findings about the importance to learning of motivation and learning.

Educational neuroscience requires much more than a good brain-based theory of individual learning, because teaching is a social activity depending on interactions among one or more learners and one or more teachers. Accordingly, education needs to attend to social mechanisms as well as cognitive and neural ones. Neuroscience usually only studies
individual brain processes, but education requires an appreciation of how the knowledge and expertise in the brain of the teacher can be transmitted to the brain of the learner.

The key to bridging from the individual to the social is the expansion of the semantic pointer theory of cognition to a general theory of communication, as previous chapters have illustrated. For education, the key step is to understand teaching as communication of semantic pointers from the minds of the teachers to the minds of the learners. This transfer is much more than the communication of words and sentences, for it requires the large range of sensory, motor, and representations mentioned in earlier chapters. Teaching would be a lot easier if it only required getting words from the teachers’ heads into the learners’ heads. Rather, it requires the transfer or instillation of much more complex representations including visual images, motor patterns, emotional values, and motivating goals.

There are many areas of learning and teaching that could demonstrate the applicability of semantic pointer theories. For this chapter, I illustrate their relevance by considering an important current issue in public education concerning vaccination. In recent years, there has been a serious drop in the rates of vaccination for dangerous diseases such as measles and whooping cough, because of misapprehensions about the dangers of vaccines. As a result, some diseases that had virtually been eradicated in wealthy countries such as the USA are making a comeback. Experts in public health and epidemiology are attempting to find ways of educating the public to reestablish full practices of vaccination. To assist this project, I present a social cognitive-emotional workup of vaccination education.
The lessons from this workup transfer naturally to many other educational problems, such as improving teaching in science and mathematics. In particular, the semantic pointer approach has major implications for understanding conceptual change as acquisition, deletion, reclassification, and revalencing of concepts, construed as semantic pointers. This approach can provide explanations that contribute to the 3-analysis of the concept *teach* shown in table 11.1.

<table>
<thead>
<tr>
<th><em>Exemplars</em></th>
<th>Parent-child, schools, universities, religions, management</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Typical features</em></td>
<td>Teacher, learner, transfer of knowledge and skills</td>
</tr>
<tr>
<td><em>Explanations</em></td>
<td>Explains: spread of culture, why people learn faster than they could alone</td>
</tr>
<tr>
<td></td>
<td>Explained by: transfer or instillation of semantic pointers</td>
</tr>
</tbody>
</table>

**Table 11.1** 3-analysis of *teach*

Standard examples of teaching occur in families, schools, and religious and business organizations. Typically, teaching involves one or more teachers, one or more learners, and transfer or implanting of the knowledge (or at least beliefs) of the teacher to the learner, including skills (procedural knowledge) and emotional attitudes crucial for motivation. Teaching explains why beliefs and cultural practices spread through social groups and why learning can operate much more rapidly than if people had to learn everything by themselves. Finally, my explanation of how teaching works will be based on semantic pointer communication.

**Vaccination: Social Cognitive-Emotional Workup**

In the United States, cases of measles have increased dramatically in recent years, from virtually none in 2000 to many hundreds in 2014. This reemergence is a result of the
refusal by many parents to have their children vaccinated, often because they think that there is a link between the measles vaccine commonly given to young children and the incidence of autism. Health agencies such as the US Centers for Disease Control and Prevention have tried to inform skeptical parents about the benefits of vaccines, but these efforts have actually made some skeptics even more opposed to vaccines. More effective means of education should benefit from understanding the mental mechanisms operating in people who resist being educated about the values of vaccines.

**Concepts and Values**

The debate about vaccination depends on numerous concepts that may operate very differently in the minds of ordinary people from how they operate in the minds of scientists. What is the nature of concepts like *vaccination, vaccine, virus, measles,* and *disease*? Chapter 10 provided a 3-analysis of a scientific concept of disease that included numerous exemplars, a wide array of typical features, and complex explanations based on mechanisms. Concepts of disease held by ordinary people may be much more limited, with inclusion of only a few exemplars, a limited set of typical features such as a group of symptoms, and little understanding of the mechanisms that cause disease and that connect diseases to symptoms.

As the semantic pointer theory of concepts implies, helping people to acquire a more sophisticated concept of disease is not a matter of just giving them a verbal definition. Rather, concept learning can be better accomplished by expanding and correcting people's understanding of the exemplars, typical features, and explanations associated with the concept. Therefore, to teach people the general nature of disease or particular diseases, it should be helpful to expand their range of exemplars, to incorporate understanding of
harm and broken mechanisms, and to impart a grasp of how mechanisms explain normal physiological functioning and how breakdowns in mechanisms explain disease.

Similarly, most people have a limited concept of vaccination compared to medical professionals. Vaccination is not just getting a needle, but a complex medical intervention known to be effective for the prevention of many diseases. Table 11.2 provides a 3-analysis of the concept of vaccination familiar to public health officials. There are many standard examples ranging from centuries-old inoculations against smallpox to modern vaccines against childhood illnesses, influenza, and shingles.

<table>
<thead>
<tr>
<th>Exemplars</th>
<th>Vaccines to prevent smallpox, polio, measles, whooping cough, shingles, pneumonia, etc.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Typical features</strong></td>
<td>Vaccine, delivery by injection or other means, autoimmune response, ongoing resistance to disease</td>
</tr>
<tr>
<td><strong>Explanations</strong></td>
<td>Explains: why vaccinated people do not get sick</td>
</tr>
<tr>
<td></td>
<td>Explained by: mechanisms of the immune system</td>
</tr>
</tbody>
</table>

**Table 11.2** 3-analysis of *vaccination*

The typical features of vaccination are not the salient experience of a shot, but rather the biological contributions of transfer of biological material such as an attenuated virus, and an autoimmune reaction that secures degrees of immunity against future infections. Providing vaccinations explains why incidences of diseases like smallpox and measles have been dramatically reduced. The efficacy of vaccinations as well explained by how the body’s immune system reacts to exposure to a modified infectious agent by preparing the body for dealing with future infections. Hence education about vaccination requires
helping people to achieve a broader concept including some understanding of the underlying mechanisms that play a role in explanations.

Although vaccines are occasionally used against bacteria, as for pneumonia, most of the diseases against which people are vaccinated are caused by viruses. Hence understanding vaccination requires a concept of virus more sophisticated than usually found in ordinary people. Many people do not know the difference between viruses and bacteria, which leads them to request antibiotics from their doctors that kill bacteria but not viruses.

The historical development of the concept *virus* began with a very general meaning of a poison implicated in a disease. In the nineteenth century, the concept narrowed to concern an entities that cause disease even though they could pass through filters that stop bacteria. Twentieth-century advances in theory and instruments led to the modern concept of viruses as infectious agents viewable with an electron microscope and possessing small numbers of genes. Ordinary people have a limited set of exemplars, typical features, and explanations in their conception of viruses. A 3-analysis of the much richer medical conception of viruses would indicate the educational target that must be hit for people to acquire an understanding of viruses needed for appreciating vaccines.

This discussion of the concepts *disease*, *vaccination*, and *virus* may give the misleading impression that such concepts are entirely verbal. But vaccination also has associated sensory representations such as the visual appearance of the needle, the pain of a shot, and the crying of an injected child. Moreover, specific disease concepts may be associated with sensory symptoms, such as the redness of the measles rash, the itchiness of chickenpox, the runny nose of a cold, the fevered heat of influenza, and the hacking
sound of whooping cough. Chapter 10 described the immobility and lassitude of depression, which requires a kinesthetic representation. Hence people’s mental representation of specific disease concepts such as measles have important multimodal aspects accommodated by the semantic pointer theory of concepts through its incorporation of sensory-motor information.

Another advantage of taking concepts to be semantic pointers is their capacity to incorporate emotional information, generating values. Public health debates always concern values as well as facts. I have been arguing that values are not just words, preferences, social constructions, or abstract entities, but rather mental representations that combine emotions with cognitive entities such as concepts and sentences. Because emotions incorporate cognitive appraisals as well as physiological perceptions, they can be evaluated as rational or irrational in accord with whether they fit with beliefs based on evidence and the needs of the appraiser. Similarly, saying that values are mental representations does not imply that they cannot be objective if they reflect legitimate needs and beliefs.

The debate about vaccines is as much a conflict about values as about beliefs. The field of public health has a common set of values including those shown in figure 11.1. Health is not just a personal concern, but a human right that people and governments should work collectively to protect and promote, especially for the most vulnerable people like children, the poor, and the elderly. Public health institutions should rely on scientific research to suggest how to improve health care quality and delivery.
Figure 11.1 Core values in public health

The public health values shown in figure 11.1 support vaccination policies, as shown in figure 11.2. This map ties the concepts of vaccines and vaccination with views about scientific evidence and the promotion of health. Vaccines are emotionally positive because scientific research shows that they promote health by reducing disease.

Figure 11.2 Value map of pro-vaccine view

In contrast, figure 11.3 maps the values and attitudes of vaccine skeptics. The difference with figure 11.2 is not just that vaccines are considered harmful, but also that vaccine is tied to other emotionally powerful concepts such as dangerous chemicals and greedy pharmaceutical companies. Figure 11.3 shows scientific research as neutral, but
some vaccine skeptics are openly mistrustful of it as corrupted by commercial interests. The value map should make it clear that education about vaccination requires more than adding new concepts and beliefs, but also shifting values and emotional attitudes. Educating people to shift from the view shown in figure 11.3 to approximately the view held by public health officials requires substantial transformations discussed below.

**Figure 11.3** Value map of anti-vaccination views

**Images and Embodiment**

The use of words in figures 11.2 and 11.3 suggests that the relevant concepts are verbal, but they also involve many kinds of sensory, motor, and emotional imagery. For ordinary people, vaccination is not just an abstract concept of application of a virus to generate an immune response. It also has associated imagery such as a picture of a nurse injecting a vaccine into the arm of a child and the motor motion required for the injection. There can also be auditory associations with vaccination, such as the “ouch” of a flinching adult or the wail of a distressed child.

Emotional imagery can also play a powerful role in parents’ decisions not to vaccinate their children. Parents can generate emotional images of how distressing it would
be to vaccinate a child who later becomes unresponsive and mentally disabled, and they can also imagine the unhappiness of an autistic child. Reading about vaccine critics such as Jenny McCarthy who had to deal with the problems of their own autistic children makes the negative associations connected with autism and vaccines all the more vivid. Hence public education about vaccines has to deal with sensory, motor, and emotional images as well as verbal claims.

The power of images in public health education is shown by a 2015 study by Zachary Horne and colleagues of effective means of countering anti-vaccination attitudes. Previous studies found that pro-vaccine messages failed to improve people's attitudes toward vaccination, and could even backfire when they made vaccine skeptics more negative about vaccinations. Informing people by debunking earlier studies claiming an association between vaccines and autism actually led people to associate vaccines with autism more strongly.

In contrast, success in changing people's minds about vaccines came by drawing attention to the consequences of not vaccinating children against measles and other diseases. When parents received warnings of the severity of these diseases in the form of graphic pictures and anecdotes, they became more aware of the risks associated with failures to vaccinate, with resulting improvements in behaviors and attitudes. Abstract arguments that allegations about the risks of vaccine are not scientifically well-established pale in comparison to a few stories and pictures about children afflicted with measles.

The importance of imagery in education is highlighted by applications of Howard Gardner's theory of multiple intelligences to pedagogic practices. Gardner argues that there is much more to intelligence than the linguistic, logical, and mathematical talents that have
been so prized in the West and measured using standard tests. He identifies other kinds of intelligence: musical, bodily-kinesthetic, spatial, interpersonal, and intrapersonal. All of these are strongly connected with embodied imagery rather than mere words.

Musical intelligence benefits from auditory perception and imagery. Bodily-kinesthetic knowledge is based on motor control and senses of balance and proprioception, which tells you how your body parts are related to each other. Spatial intelligence concerns more broadly where you are located in your environment, which requires visual representations and a sense of movement. Interpersonal intelligence includes the ability to read the intentions and desires of others, which is partly based on emotional imagery as practiced in the three modes of empathy using analogies, mirror neurons, and multimodal rules. Finally, intrapersonal intelligence is knowledge of a person's own internal aspects including the range of emotions. Various educational projects have found value in understanding people's mental capacities as involving all of these kinds of perception and imagery in addition to more conventionally valued linguistic skills.

It is therefore important to understand education as embodied, going beyond words to use images that are sensory, motor, and emotional. However, instruction about vaccines would be deficient if it relied only on embodied images and neglected many more abstract concepts that qualify as transbodied. For example, viruses are naturally imagined as small particles or animals. But they are too small to be seen through a light microscope and can only be detected by electron microscopes that operate very differently from the human eye. Viruses consist of a small number of genes, usually fewer than 200, where genes are inadequately visualized as beads on a string. More accurately, genes are strands of DNA, again too small to be adequately visualized.
Understanding how vaccines work also requires grasping how the body's immune system reacts to invaders such as viruses and how antibodies can attack the invaders and prepare the immune system to attack invaders in the future. Although pictures may be of some help in conveying the operation of the immune system stimulated by vaccines, there is no replacement for verbal descriptions of the immune system. As is in concepts in general, representations of how vaccines work needs to be both embodied and transbodied.

Values concerning vaccination are clearly transbodied as is evident in the examples in figures 11.1 to 11.3. Concepts like health, protection, and human rights may have embodied aspects, but their exemplars, typical features, and explanations go beyond the senses by introducing abstractions through recursive binding. For example, the concept of health depends on other abstractions such as an organism having well-functioning mechanisms and avoiding disease.

Beliefs and Rules

Education requires much more than the acquisition of concepts and values. The magnitude of the problem of educating people about vaccines is evident from considering the intense beliefs held by vaccine skeptics, extolled on various websites. Here are some of the core beliefs.

Vaccines are dangerous. Vaccines have not been adequately tested for toxicity especially for their adverse effects when delivered in combination. Vaccines are less effective in providing immunity than when children acquire diseases naturally. Vaccines have dangerous additives such as mercury and aluminum. Vaccines are contaminated by viruses and other such substances. Vaccines are likely responsible for declining health in
children as seen in increasing rates of autism, learning disability, and
chronic illnesses such as asthma. Vaccines frequently have adverse effects
such as seizures and serious diseases. Pharmaceutical companies are
fraudulent in conducting biased research and manipulating government
officials and journalists into supporting their commercial activities.

Because these beliefs are interconnected, convincing people to get vaccinations for
their children and themselves cannot depend on attacking them piecemeal. They form a
highly coherent system, often promulgated by proponents of naturopathic medicine who
think they have alternative treatments that are more effective than vaccines. The section
below on inference will describe how belief revision concerning vaccines needs to be a
process that operates in parallel to produce overall coherence, rather than assuming that
individual arguments can chip away at the beliefs held by vaccine skeptics.

The generalizations about vaccines in the list of beliefs presented above naturally
translates into rules with an if-then form. Here are some action-guiding rules:

If you are vaccinated, then you are putting yourself in danger.

If children are vaccinated, then they become prone to many diseases such as autism.

If pharmaceutical companies say that a vaccine is safe, then don't trust them.

When such rules are put into words, they are open to conscious scrutiny concerning
evidence and overall coherence. But many of these rules are multimodal in that they
employ concepts that have important sensory, motor, and emotional aspects. As the section
above on concepts showed, vaccination is not just a verbal concept but also has sensory
aspects related to pain and movement. The concept danger is embodied because of the
physiological aspects of the associated emotions of fear and anxiety. For the vaccine
skeptics, vaccination has become an inherently negative concept, akin to barbaric medical practices such as bloodletting and infanticide. Any rule or other belief that includes concepts like danger, toxic, and disease is inherently emotional, because the concepts have negative valences resulting from past appraisals and ongoing physiological reactions. Hence revising concepts like vaccine will involve changing emotional attitudes as well as replacing an interconnected set of beliefs.

The discomfort that people feel in planning vaccinations for themselves or their children may be hard to pin down because it is based on general anxiety about medical treatments rather than on specific beliefs that are expressed verbally. Hence public health education may be similar to the problems of romantic couples described in chapter 4 and the problems of psychotherapy for people with depression described in chapter 10. Education then is not simply a matter of identifying false beliefs and challenging them, but rather of bringing to light and uprooting unconscious multimodal rules that have large effects on behavior.

Rules can also be a powerful way of expressing mechanisms, and part of the disagreement between public health advocates for vaccination and vaccine skeptics results from emphasizing different mechanisms based on different rules. The main mechanism behind judgments about the values of vaccinations can be stated as rules such as the following:

\begin{itemize}
  \item \textit{If people are vaccinated, then their immune systems respond by creating antibodies.}
  \item \textit{If people have antibodies then they will not be infected and get a serious disease.}
\end{itemize}

In contrast, vaccine skeptics assume a different mechanism captured by rules like these:

\begin{itemize}
  \item \textit{If people are vaccinated, then their bodies are damaged by toxic substances.}
\end{itemize}
If people's bodies are damaged by toxic substances, then they become susceptible to serious diseases such as autism.

In biology, mechanisms are often represented by diagrams and movies, not just verbal rules. It would be interesting to see whether videos about the mechanisms of vaccination and their valuable effects could help to change people's minds. To my knowledge, no one has tried to educate vaccine skeptics about the underlying mechanisms. But there is some evidence from research on climate change by Michael Ranney and his colleagues that communication about mechanisms can help to change people's minds by concisely explaining how greenhouse gases increase the world's temperature. Their effective technique teaches people about mechanisms visually, using short videos that combine words with dynamic pictures that show how global warming develops. Such visualization may be a powerful tool for conveying the multimodal rules describing mechanisms to people in a more comprehensible way. In line with the sensory-motor origins of causality proposed in Volume One, conveying multimodal rules about mechanisms may gain much from dynamic visual displays.

** Analogies and Metaphors

 Analogies and metaphors are not at the core of the debate about vaccinations, but nevertheless contribute. The science of immunology that provides the theoretical basis for vaccination relies heavily on metaphors. Public health advocates attempting to educate people about the value of vaccinations use analogies to try to convince people that vaccines are valuable rather than scary. In response, vaccine skeptics have their own set of metaphors that they use to convey what they see as the emotional threats of vaccination.
Immunology developed by specifying mechanisms for how the body grows antibodies to defend against viruses, bacteria, and other infectious agents. But immunology also employs metaphors as part of the explanation how the body responds to infectious threats and prepares itself to deal more effectively with future threats. Since its origins in the work of Macfarlane Burnet, immunology has relied on a systematic metaphor of the self and non-self, to be distinguished by the immune. There is no literal self and non-self in the biological systems studied by immunology, but the analogy with psychology which studies how people think of themselves and contrast themselves with others has suggested ways of thinking about how immune system operates.

Various other metaphors drawn from the social sphere are used by immunologists: bacteria and viruses are invaders that must be attacked by antibodies. The immune system can cause problems in autoimmune diseases and organ transplants when it undesirably tells cells to reject the transplanted organ. The concepts of invasion, attack, and rejection are metaphorically transferred from the social sphere into the biological one.

Public health advocates sometimes resort to metaphors in order to convince people that vaccines are good practice. Here's some metaphors that have been advocated as useful for teaching people about vaccines.

Vaccination is like a dress rehearsal for your immune system so it is prepared for the 'real show'.

Getting a vaccine is like putting on bug spray before going out in the woods.

Unvaccinated people are like drivers who are never, ever given instruction on how to drive then made to drive from California to New York. It can be
done, but it's risky. Vaccination is like getting taught how to drive, then practicing driving for a while, then driving across the continent.

An experimental study also found that metaphors can be useful for getting people to decide to get vaccinated for influenza, for example by comparing flu to a weed and a flu vaccine to a weed killer. There are obvious problems with this analogy, because the operation of vaccines is more complicated than the operations of antibiotics that can actually kill bacteria like a herbicide kills weeds. Nevertheless, the analogy can help people to see that vaccines can be a useful response to a serious health problem.

Naturally, vaccine skeptics also marshal analogies to defend their position. One says that vaccines are like time bombs, where we do not know when the next one will maim or kill a child. Another compares urging people to vaccinate to urging people to drill for oil despite major oil spills.

Thus the debate about vaccines, like many others, is partly a matter of competing metaphors. Are vaccines like weed killers or like time bombs? Dealing with metaphors is not just accepting some beliefs and rejecting others, because analogies depend on a whole complex of interconnected meanings and emotions. The validity of analogical comparisons depends not just on counting the similarities and differences, but also on considering the use the analogies based on their associated goals. The goal of public health educators is to convince people that vaccines are valuable, resulting in positive comparisons to herbicides and bug spray. In contrast, the goal of vaccine skeptics is to stop people from getting vaccinations, resulting in emotionally negative comparisons to bombs and oil spills. The evaluation of these analogies and metaphors needs to be part of a larger process of coherence that involves emotions as well as evidence.
Emotions and Actions

The debate about vaccination concerns actions, not just beliefs. Should people act to arrange vaccinations for themselves and their children? Actions never follow from beliefs alone, because psychologically they also require desires. People get vaccinated if they desire to be healthy and believe that vaccines will help them stay healthy. A much richer account of the causes of actions is available in Volume One, chapter 9, which describes how beliefs, intentions and emotions distributed across multiple brain areas can cause actions triggered in motor areas.

Emotions are a crucial part of producing actions at the neural level, and we have seen many ways in which emotions contribute to people’s decisions about whether or not to vaccinate. People who choose to get vaccinations can feel happy that they are doing something to promote their health goals, and they can feel proud that they are looking after their children by getting them vaccinated. At the other extreme, vaccine skeptics experience fear at the thought of getting vaccines that they deem to be dangerous, and anger that the mainstream press and government are in cahoots with pharmaceutical companies to spread lies concerning the safety of vaccines. Skeptics can also feel empathic sadness for people whose children have allegedly become autistic or otherwise ill because of vaccines. People who act on their skepticism and resist attempts to make vaccinations mandatory can feel happy that they are managing to escape the ravages of vaccines, and proud that they are going against the establishment to resist treatments that they consider harmful.

The last section described the vaccination debate as a battle about metaphors, but it is even more starkly a battle about emotions. Everyone wants to feel happy about their own
health and proud that they are looking after their children, but the vaccine debate puts these emotions at odds with each other. As the last chapter on depression showed, changing emotions is not simply a matter of changing beliefs, but sometimes also requires changing goals and physiological states. Convincing people of the value of vaccines requires overcoming intense emotions of fear and anxiety, a process much more complicated than simply refuting beliefs about bogus studies that purported to show a link between vaccines and autism.

More generally, for students to learn effectively in schools, they need to regulate emotion-driven behaviors that impede teaching. Self-discipline is a better predictor of academic achievement than IQ. Acquisition of new conceptual systems benefits from mental executive functions that encourage deliberate planning, impulse control, and goal-directed behavior. Teachers’ understanding of students’ emotions should help to foster self-regulation that encourages learning by enabling students to focus on tasks at hand.

**Inferences**

It is often assumed that inference and reasoning are the same, but they are actually very different. Inference is a neural process that is private, parallel, multimodal, emotional, unconscious, fast, and automatic. In contrast, reasoning is usually public, serial, verbal, dispassionate, conscious, slow, and deliberate. So the contributions of reasoning to inference are unclear, and it is legitimate to ask why people including teachers should bother with reasoning at all.

If reasoning and inference were the same, then it should be fairly easy to teach people about the benefits of vaccinations and the deficiency of the arguments against them. Educators could simply mount a set of arguments that provide empirical and theoretical
reasons why people should favor vaccinations. In practice, however, the successes of this kind of reasoning are limited, because verbal communication can only begin to influence people to make inferences that actually change their minds about what to believe, feel, and do.

Chapter 2 suggested a different way of thinking about inference as a parallel brain process that reaches conclusions based on parallel constraint satisfaction involving both explanations and emotions. Accordingly, the most that one can hope reasoning will do to change people's minds is to provide them with some of the elements and constraints that can then feed into judgments of explanatory and emotional coherence. Fortunately, there is evidence that sometimes such provision works: experiments found that informing people vividly about the dangers of not vaccinating can lead people to do it; and experiments found that people could change their minds about global warming when informed about the mechanisms that produce it. Ideally, public health education needs to combine evidence and goals, enabling people to what is true and what ought therefore to be done.

Education would be much easier if people started with empty minds that could simply be filled up by the concepts, beliefs, and values provided by teachers. Such filling rarely works, however, because even 6-year-old children starting school already have concepts and beliefs that they have acquired from their parents and personal experience. The section below on conceptual change provides a more detailed account of the sorts of changes in concepts and beliefs required for educational success.

Belief change depends on explanatory and emotional coherence, but coherence is not simply a relation among sentences or other purely verbal representations. Because coherence construed as parallel constraint satisfaction can draw on nonverbal
representation such as pictures, sounds, tastes, movement, and emotions, inference should be able to employ all the different kinds of intelligence available to people, including spatial, kinesthetic, and interpersonal.

Some people who have to decide whether to get vaccinations for themselves and their children may not have many preconceptions, and therefore can be reached by a simple kind of deductive reasoning. Doctors say vaccinate; doctors are always right; so vaccinate. Today, however, many people are skeptical about whether doctors are always right, and they acquire their beliefs about vaccination from nonmedical sources such as friends, websites, Facebook, or naturopathic doctors. In these cases, education requires convincing people to abandon beliefs and emotional attitudes that they have acquired concerning the dangers of vaccines. Giving reasons is only the beginning of a much larger process of explanatory and emotional coherence that can lead eventually to dramatic shifts in beliefs and practices.

What makes this process all the more difficult is that people are prone to use modes of thinking that are much less effective than explanatory and emotional coherence: motivated, fear-driven, and rage-driven inference. Motivated inference impedes learning about vaccines in several ways. First, there are people such as peddlers of alternative treatments who have an interest in exalting their own medical beliefs over those of the medical establishment. Naturopaths and homeopaths are highly motivated to enlarge the market for their goods and services by convincing people to be treated by them rather than by conventional medical sources.

Second, even for ordinary people, there can be motivations for avoiding vaccines that incline people to fit their beliefs to their goals, rather than their goals to their beliefs.
as evidence-based thinking requires. People are highly motivated to secure their own health, and decent parents care deeply about the health of their children. People want to help their children flourish with minimal medical problems, so they may be convinced to trust sources that say vaccines may be dangerous.

Even more powerfully, fear-driven inference can fuel rejection of medical opinion and avoidance of vaccines. Autism and the many other serious conditions that have been attributed to vaccines are genuinely scary. Once you begin to think about the possibility of an association between vaccines and autism, or between influenza shots and autoimmune diseases, it is hard not to keep thinking that the vaccinations and the diseases might go together, just because it is so frightening that they might go together. Negative emotions focus the mind mightily, and such focusing can exclude considerations of relevant evidence. When put into words, the inference that vaccines must be dangerous because you am afraid that they are looks silly, but unconscious mental processes can produce the same result. Websites and videos use testimonials of parents whose children had disastrous occurrences after vaccination to whip up fears and anxieties to foster fear-driven inference in people who become convinced to avoid vaccines.

For the fanatics who generate anti-vaccine websites, the inference that vaccines are dangerous seems to be in part driven by rage against doctors, scientists, and public health officials who conspire to make money for big pharmaceutical companies. Inevitably, drug companies are prone to motivated inference because they want to increase profits by selling vaccines, and therefore risk distorting experimental results in their own favor. There have been enough scandals about unscrupulous commercial practices, for example concerning antidepressant drugs, to warrant some skepticism about the scientific research that supports
vaccines. Nevertheless, there are many people outside the pharmaceutical industry, such as scientists, doctors, and public health officials, who are not subject to the same kind of motivated inference and therefore are capable of more evidence-based judgments. Hence rage-driven inference concerning vaccinations is not justified, but nevertheless can merge with motivated and fear-driven inference to support emotional conclusions about the dangers of vaccines.

In sum, educators concerned with communicating about theory and practice should not naïvely assume that verbal reasoning is a solid route to changing people's minds. Rather, inference at its best is a complex parallel process of considering many constraints concerning evidence, explanations, and emotional goals. This does not mean that reasons should not be given, because sometimes that is the best way to enable people to notice the evidence, constraints, and legitimate goals that should shape their belief revisions and decisions. But giving reasons is likely to work best when combined with nonverbal communication such as pictures and gestures, along with emotional communication based on tone of voice, facial expressions, and body language. Even after students have acquired a new conceptual system for fields such as mathematics and science, the old system is not simply deleted, so that executive functions such as inhibition are important for focusing attention on superior new concepts and beliefs.

Moreover, educators dealing with controversial issues such as vaccination, climate change, and biological evolution need to be aware that inference is sometimes swamped by motivation, fear, and rage. Then teachers need to identify the goals and emotions of learners to forestall the motivated, fear-driven, and rage-driven inferences that unconsciously fuel peoples misunderstandings. In these common situations, education is
like psychotherapy as described in Chapter 10. Emotions are indispensable in human minds and brains for evaluation, attention, and motivation, but their power can sometimes lead people away from more effective considerations of evidence and goal accomplishment. On this view of inference, as a parallel, unconscious, often emotional process distinct from verbal reasoning, education is as much managing emotions as conveying information. An emotional gestalt shift may be required for some people to learn that vaccines are generally valuable and that climate change is substantially caused by human carbon emissions. Managing emotions and conveying information both require communication by teachers.

**Communications**

The most obvious communication in education is from teacher to student, but this is only part of the system. There also needs to be communication from student to teacher, because teachers need to understand what is going on in the minds of the students if they are going to be effective at modifying their concepts and beliefs. Effective learning also occurs among students who can absorb as much from each other as they do from their teachers. Finally, teachers need to communicate among themselves, in order to ensure a coherent curriculum and to exchange ideas about more effective teaching.

All of these kinds of communication can be fostered by appreciating that they require much more than mere transfer of words. A good teacher has a rich and coherent system of concepts, values, images, beliefs, and metaphors that cannot be conveyed merely by sentences. Images can help even with the more verbal aspects of this cognitive system, for example by presenting diagrams and value maps. Analogies can help students bridge between what they know and what the teacher wants them to know.
Emotions are also crucial to educational communication, because teachers need to convey what is interesting, important, and worth learning. Interest is a mild emotion marked physiologically by dilated pupils, akin to the stronger emotions of curiosity, wonder, and surprise. In a saying of unknown origin, education is not filling a pail, but lighting a fire. Emotions provide motivation, and without motivation students will not spend time putting in the effort to learn very much.

For teachers to understand the emotions of students, empathy is a crucial set of mechanisms. Teachers can use verbal analogies to put themselves in their students' shoes in order to grasp their emotions. More directly, the two more physical modes of empathy can be useful for teachers when they grasp some of what their students are feeling by means of mirror neurons and multimodal rule simulation. Students can contribute to this process by means of reverse empathy, prompting teachers to appreciate the students' emotional feelings about what they are learning. Students collaborating on group projects will also need to use empathy and verbal communication in order to work productively with their partners.

The theoretical key to integrating verbal and nonverbal communication is the mechanism of transfer or instillation of semantic pointers, combining verbal, sensory, motor, and emotional information. This perspective makes it easy to see why education is so difficult, much more difficult than one would expect if it were simply a matter of passing words from the head of the teacher into the heads of the students. Unlike the rapid transfer of computer files, education is a laborious decades-long process of building up in the students' minds the rich set of semantic pointers already possessed by the teacher. Inevitably, the students will not end up with exactly the same set of neural representations.
as the teacher, because their learning histories and innate capacities are not the same. Nevertheless, teachers can strive by multiple verbal and nonverbal methods to enable students to acquire some approximation to the teacher’s mind.

This view of educational communication fits well with many of the most effective classroom practices as determined by educational experience and experiments. Tracey Tokuhama-Espinoza lists 50 classroom practices whose effectiveness ought to be explainable by semantic pointer transfer. Here are just a few examples.

*Plan activities that grab attention.* Attention is limited because of brain capacity for complex bindings, and it is controlled by semantic pointer competition. If the teacher does not communicate in a way that enables new information to surpass the thoughts and emotions operating in the minds of the students, then communication fails and no learning takes place. This limitation justifies my long-time practice banning use of laptops in my classes, because my best efforts have trouble outcompeting students’ interest in Facebook and cat videos.

*Use the Socratic method.* In Plato's dialogues, Socrates taught by asking questions and then responding to students’ answers, a method still commonly used in philosophy classes and law schools. From the perspective of semantic pointer communication, this method has the advantage of enabling teachers to recognize what is going on in the minds of students rather than just assuming that they will absorb whatever is being said in a lecture. Dialog enables communication from the students to the teachers who need to adapt their messages to the audience.

*Be passionate.* Emotion in education is not an optional addition, but an integral part that goes beyond the installation of facts to communicate the values of concepts, beliefs,
goals, and methods. Learning requires students to make implicit decisions about how to spend their time and attention, and decisions depend on emotional assessments of value. A passionate teacher will communicate enthusiasm and values by gestures, facial expressions, and body language. The semantic pointer theory’s integration of cognition and emotion makes it clear why emotional communication is a crucial part of education. I will provide some more general advice for improving teaching after discussing conceptual change.

**Conceptual Change**

For decades, conceptual change has been an important topic in developmental and educational psychology, but always with meager understanding of the nature of the concepts that are supposed to change. Understand how teaching can bring about conceptual change requires good theories about concepts and belief revision. This section rethinks conceptual change from the perspective of the semantic pointer theory of concepts.

The contention of the semantic pointer theory that concepts are brain processes would not cause problems for most psychologists, who accept that the mind operates by the brain. But several other aspects of the theory are more contentious and therefore more interesting for changing understanding of conceptual change. If concepts are semantic pointers that bind sensory, motor, and emotional information as well as verbal, then there is more to conceptual change than just the changes in sentences that psychologists have usually assumed. Conceptual change can be multimodal.

In the vaccination case, the most dramatic changes are emotional, when education revalences the concept of vaccine from negative to emotionally positive. Accepting vaccination may also require shifts in other values, for example concerning scientific
approaches to medicine. Earlier chapters described other important kinds of revalencing, for example in overcoming prejudice.

In other cases of conceptual change, both in the history of science and in science education, there may also need to be changes in visual representations. For example, at the beginning of the 20th century, there was a dramatic change in the concept of atom which since the ancient Greeks had been by definition indivisible. Experiments showed that atoms contain particles within them as well as much empty space. Hence atoms need to be visualized as systems of moving parts like the solar system rather than as solid balls. Therefore, educators who want to bring about conceptual change in their students need to be aware that changing concepts requires changing more than words.

Another strength of the semantic pointer theory of concepts is that it provides unified explanations of many psychological experiments that show that concepts include exemplars, typical features, and explanations. Accordingly, accounts of conceptual change ought to look for changes in all three of these aspects. For proponents of vaccination, standard examples include the indisputably successful applications of vaccines to prevent smallpox and polio, along with others in table 11.1. In contrast, critics focus on a different set of more contentious examples, such as the swine flu scare of 1976, the measles vaccinations that are allegedly associated with autism, and controversial vaccinations for HPV virus to prevent cervical cancer.

Pro and anti-vaccination camps also tend to focus on different typical features of vaccines. On the mainstream public health view, vaccines are typically moderate in cost and highly effective in preventing diseases. In contrast, for vaccine skeptics the typical features of vaccines are low effectiveness and high negative side effects. Changing the
concept of vaccine requires both shifting exemplars and dramatically replacing the associated set of typical features, producing a very different prototype of vaccines.

In addition, the concept of vaccine plays a very different explanatory role in the minds of vaccine advocates compared to its role in the minds of vaccine skeptics. For vaccine advocates, vaccination provides a salutary explanation of the virtual eradication of diseases like smallpox and polio, as well as dramatic drops in the number of cases of measles and whooping cough. In contrast, the salient explanations for vaccine skeptics are ones in which vaccine are followed by bad results such as autism in children. Hence changing the concept of vaccine as part of public health education about vaccination is more than simply modifying the the definition of the word “vaccination”, requiring large shifts in exemplars, typical features, and explanations.

Some instructional problems require conceptual changes more radical than those needed for education about vaccination. Students often have difficulty grasping Darwin's theory of evolution by natural selection. First, it requires acquisition of abstract concepts that are far from the embodied experience of the students, such as random variation in the genes of organisms and selection for desirable genes because of their contribution to survival and reproduction. Second, for many students the theory of evolution runs counter to religious views that species, especially humans, were created by God. Third, the kinds of explanation that evolution gives for species is markedly different from familiar ones based on simple causes. The development of species is a statistical process with emergent properties that are qualitatively different from their predecessors. For example, humans have cognitive abilities not found in our ape ancestors such as the ability to use complex
Hence to grasp the theory of evolution by natural selection, students need to acquire new concepts, beliefs, and explanatory styles.

The Darwinian revolution also exemplifies extreme kinds of conceptual change that make it difficult to grasp by learners. A major role of systems of concepts is to provide taxonomies that systematically classify things. One rare but but important kind of conceptual change requires reclassification, where some things move from one part of the taxonomic tree to another. Darwin's views about the origins of species required one such major reclassification, with a shift from viewing humans as a special part of God's creation to recognizing our species as another kind of animal, like apes, canines, and insects. Some reclassifications have large emotional significance, because of the comfort associated with thinking of people as inherently special, and the anxiety provoked in some people by the realization that humans are not special in the universe, but merely another evolved animal.

Finally, the Darwinian revolution introduced another major kind of conceptual change that is hard for students to appreciate. Not only does Darwin's theory require reclassification, it also requires a fundamental change in how classification is done. Before Darwin, species tend to be classified on the basis of their appearance, for example depending on whether they have feathers or fur. Darwin introduced a completely different way of doing classification by historical descent, a kind of conceptual change I call meta-classification.

What matters after Darwin is not just what two species look like, but rather how they evolved from earlier species. With 20th-century discoveries about genes and DNA, genetic information can be used to make inferences about evolutionary history and therefore to provide new classifications of organisms. In the meta-classification kind of
conceptual change, the whole way of making classifications changes, which can also lead to reclassifications as well, for example the recognition that birds are related to dinosaurs.

Chapter 10 describes the need for a radical transformation of psychiatry based on new ways of classifying diseases. Sadly, medical illnesses are still classified largely on the basis of symptoms, as in DSM-5. It is widely recognized, however, that much deeper understanding and more effective treatment of mental illnesses should be realizable if the whole method of classifying mental disorders changed away from symptoms and toward causal origins. Such transformations have already occurred in classification of species based on evolutionary history, and in classifications of diseases based on their origins in infections, nutritional deficiencies, metabolic problems, autoimmune problems, and other mechanism breakdowns. Psychiatry awaits massive conceptual change from meta-classification as well as from the resulting reclassification of diseases, likely introducing new concepts to capture deeper biological understanding of how mechanisms breakdowns cause mental illness.

Even more generally, the brain revolution brings with it major kinds of conceptual change that need to be incorporated into educational practice. Many new concepts for understanding the mind are being introduced, such as neural binding and semantic pointers. Some concepts that are central to folk psychology need to be deleted, such as soul and free will (while maintaining free-ish will described in Volume One). Much reclassification is also required, for example recognizing that representations and meanings are processes, not things. The brain revolution even changes the way in which mental states and events should be classified (meta-classification), because their taxonomy can rely on underlying brain mechanisms rather than conscious experience. For example, brain scans identify
neural similarities between memory and imagination, which introspection might suggest to be different. The claims that concepts and other mental representations are brain processes is also a revolutionary reclassification. The radical conceptual changes that the brain revolution requires are a major challenge for teachers as well as students.

The difficulties that scientists have had in wrestling with these kinds of conceptual change should make us more sympathetic to the difficulties that young students have in trying to acquire theories and concepts that are very different from their previous experience. The best way to integrate these concerns about reclassification and meta-classification into semantic pointer theory of concepts is to notice that kinds are a very important part of the typical features that objects are supposed to have if they fall under a concept. For example, it is a typical feature of atoms that they are a kind of particle. Teachers need to figure out ways of bringing about in their students all the kinds of conceptual change described above, including addition of new concepts, deletion of old beliefs, and modifications in emotional values, exemplars, typical features (including kinds), explanations, and sometimes even the whole method of classification.

**Teaching Better**

The distinguished social psychologist Kurt Lewin said that nothing is as practical as a good theory. A theory of education based on deep accounts of cognition, learning, and communication should have strong implications for improving teaching. Here are some conjectures about how teaching might be improved based on the hypotheses in this chapter.

First, is important to think of teaching as much more than the transfer of words. Instead, teaching should be viewed as semantic pointer communication, where teachers have to struggle to instill in the minds of learners the complex mental representations that
they need to have in order to understand the subject material. Hence teaching should not be just talking, and lecturing needs to be supplemented by other techniques.

Second, the representations that need to be acquired by learners are multimodal, mixing sensory, motor, and emotional information with words. Depending on the domain, visual, auditory, and other perceptions and images may all need to be acquired by the student. Intelligence, therefore, is much more than linguistic and mathematical ability, because in some domains the sensory-motor aspects are just as important.

Third, for successful teaching, emotional aspects of instruction are just as important as cognitive ones. For students to acquire useful representations, they need to be able to attach emotional significance to specific concepts and beliefs as well as to the overall process of learning. Students need to acquire and change emotional values along with concepts and beliefs. Like overcoming prejudice in chapter 5 and treating depression in chapter 10, teaching often requires changing values.

Fourth, teaching and learning are both embodied and transbodied. They depend in part on the sensory-motor-emotional representations just mentioned, all of which are embodied. But for important domains such as science, engineering, and philosophy, teaching has to take learners beyond their sensory experience to acquire abstract concepts such as atom, equilibrium, and justice. Body-oriented education is a good start for many concepts such as force, but is inadequate for abstract learning of concepts such as gravity. Teaching techniques should integrate bottom-up, embodied methods such as discovery learning and phonics with top-down, transbodied methods such as whole-word reading and abstract instruction.
Fifth, teaching techniques need to understand the difference between reasoning and inference. A teacher cannot simply expect that merely providing verbal reasons to the students will change their minds. Rather, inference is a parallel process that integrates cognition and emotion, with effects that can be good if students reach conclusions based on explanatory and emotional coherence, but bad if they fall back on motivated and fear-driven inference.

Sixth, teachers need to be aware that learning is not simply a matter of accretion of new concepts and beliefs, but can require substantial amounts of conceptual change. Students often need to realize that their old concepts and beliefs are defective and need to be replaced by substantially new ones that alter how they classify the world.

Whether teaching can actually be improved by applying these lessons from new theories of cognition and communication is an empirical question. It will be interesting to see whether teachers can modify their teaching styles to make education more effective in ways suggested by semantic pointer theories of cognition, emotion, and communication.

Summary and Discussion

Educational neuroscience is the attempt to apply rapidly increasing knowledge about the brain to the practical goal of improving learning and teaching. This chapter has proposed a novel approach to neuroeducation based on advances in theoretical understanding of representation, binding, and competition. Semantic pointers provide new insights into learning by specifying what kinds of representations need to be developed in the brains of learners who are acquiring complex information. Some of this information is verbal, but learners need to be able to integrate this verbal information with other modalities such as pictures and sounds.
The importance of multimodal representations is evident in two of the biggest challenges in early education: reading and mathematics. The research of Stanislaus Dehaene and others has shown the need to integrate multiple sources of information in both math and reading. To learn how to read well, children must become proficient at appreciating the connections among mental concepts, spoken words, and written words. Words on paper have a visual form, as do some aspects of concepts that are about visible things. For example, to read the sentence “The bear is on the mountain”, a child needs to see the connections among the word “bear”, the sound of the spoken word, and the mental representations of bear that could include exemplars stored in memory as pictures of bears. Similarly, proficiency with numbers requires connecting all of these: the numeral 3, words such as “three”, the sound of the word “three”, the number sense for identifying small numbers such as three, visual representations of three things, and various procedural operations that can be done with numbers such as addition and subtraction. Multimodal representations are also required for simple concepts such as metal spring (visual, tactile, kinesthetic, auditory) and burning fire (visual, heat, auditory).

Semantic pointers are well-equipped to explain how such an integration takes place in the brain. The child's understanding of the concept three must bind together spelling, sounds, and visual information. The ability of semantic pointers to bind together information in various modalities into a package that can be useful for further inference provides a good start at explaining how people children learn to read and do mathematics. It would be a valuable project to work out in rigorous detail how such complex neural representations can contribute to learning how to read and how to do math.
This chapter, however, addressed a different question: how do people learn about the advantages of vaccinations? I provided a social cognitive-emotional workup of the vaccine debate, to show how people can learn why vaccines are valuable for public health and the protection of children. Teaching people about vaccines requires communication of many kinds of mental representation: concepts, values, images, beliefs, rules, analogies, and emotions. These representations include ones that are embodied, such as mental images of the pain associated with getting a needle, but also ones that are transbodied because of the importance of abstract concepts such as immune system.

Educating people about vaccines needs to take into account the complexity of the emotions and the inferences required. Convincing people to vaccinate children and themselves requires emotional change that lets people's natural attachment to the welfare of their children overcome fear of vaccination. The concept of vaccine needs to be revalenced to acquire positive emotional associations rather than negative ones. Inference is not a simple chain of verbal argumentation, but rather a complex, unconscious, parallel process of satisfying multiple constraints. People need to acquire a set of beliefs and values as a coherent whole, not as isolated beliefs supported by discrete arguments. Such wholesale inferential change can result from systematic education, but it needs to surmount psychological barriers such as the fear-driven inferences that tend to make people leery of vaccination.

Semantic pointer theories of cognition provide a new perspective on learning in individual brains, but they also yield a new view of social aspects of teaching because of the complementary theory of communication. Learning is occasionally a solitary process, but teaching is always social, requiring the interaction among one or more teachers and one
or more students. These interactions cannot be construed simply as the transfer of verbal information, but instead need to be viewed as the instillation of much more complicated kinds of mental representations that combine sensory, motor and emotional information with verbal representations. Teaching, therefore, needs to be interactive, multimodal, embodied, and emotional. The job of teachers is not just to get their words into the minds of students, but also a broader range of sensory, motor, information in the form of semantic pointers. A crucial part of this transfer is the transmission of emotional information about the value of particular concepts and beliefs, as well as the value of the whole educational enterprise.

From this perspective, education requires multilevel emergence at all four levels: molecular, neural, psychological, and social. Learning is a molecular and neural process because of the changes that need to take place for the brain to acquire synaptic connections that encode new information and change future behavior. Memory formation depends on changes in synaptic connections prompted by the neurotransmitter glutamate. Molecules such as dopamine and oxytocin are crucial for giving students the appreciation of reward and trust that are needed for learning in social contexts. Educational neuroscience should reach beyond connecting learning and teaching with the results of brain imaging, to consider interacting mechanisms that are molecular, psychological, and social as well as neural. Cognitive psychology is often indispensable for connecting neuroscience and education.

Patterns of neural firing and stored dispositions to generate such patterns constitute the semantic pointers that provide the means for combining multiple kinds of information. For teaching purposes, these representations are well described by psychological ideas
about mental representations such as concepts and beliefs. Learning by imitation and teaching are also social processes in which the interactions that an organism has with another determine what neural and molecular changes take place in brains. Teaching is a clear case of downward causation from the social to the molecular, because social interactions produce changes in brains right down to neurotransmitters such as glutamate and dopamine. Teaching is a kind of communication that requires transfer, prompting, instillation, replacement, and revalencing of semantic pointers.

The implications of this view of education go far beyond the profession of teaching. Many organizations besides schools require ongoing education. For example, a major role of managers and businesses is to teach their employees how to perform their jobs better, and ongoing education is also important in medicine, government, and engineering. Hence the view of learning and teaching as the acquisition and transfer of semantic pointers will be important for the chapters below on business leadership and engineering creativity. To facilitate valuable social changes, people need to be educated about beliefs and values concerning important issues such as vaccination and climate change. Understanding how the brain works can be an important part of improving all of these kinds of education.

Notes for Chapter 11

Csibra and Gergely (2011) argue that only humans teach, but Safina (2015) provides non-human examples such as meerkats and killer whales. See also Kline 2015.

Here are some books on educational neuroscience, neuroeducation, and mind, brain and education: Blakemore and Frith 2005; Della Sala and Anderson 2012; Mareschal, Butterworth, and Tolmie 2013; Posner and Rothbart 2007; Sousa 2011, 2014; Tokuhana-Espinosa 2014.

Attempts to understand and overcome skepticism about vaccines include: Downs, de Bruin, and Fischoff 2008; Horne, Powell, Hummel, and Holyoak 2015; Kata 2009; Nyhan et al. 2014; Poland 2011. Goldenberg 2016 argues that vaccine skepticism is partly based on mistrust of science, not just lack of scientific understanding.


My map of values in public health is loosely based on the Harvard School of Public Health: http://www.hsph.harvard.edu/about/core-values/.

My workup of anti-vaccination views is based on these web sites:

http://educate-yourself.org/vcd/

http://whale.to

http://www.stopmandatoryvaccination.com/vaccine-dangers/


Gardner 2006 argues for multiple intelligences. Uttal, Miller, and Newcombe 2913 describe how enhancing spatial thinking can improve science education.

Tauber 2015 discusses the history of immunology and self metaphors. Metaphors for improving understanding of vaccination are here: Scherer, Scherer, and Fagerlin 2015;

Angell 2009 reviews criticisms of drug companies.


Thagard and Findlay 2010 discuss cognitive impediments to Darwin’s theory of evolution.

The long overdue change in how mental illnesses are classified is illustrated in Clementz et al. 2015.


Projects: Apply semantic pointer insights to specific kinds of education such as reading, arithmetic, and science.
Csibra, G., & Gergely, G. (2011). Natural pedagogy as evolutionary adaptation. Philosophical Transactions of the Royal Society of London B: Biological Sciences, 366(1567), 1149-1157.


