Synthesis of Research on Brain Plasticity: The Classroom Environment and Curriculum Enrichment

Research with rats suggests that a stimulating, caring environment will enhance students' brain growth and learning ability.

The extensive research studies of Marian Diamond, Mark Rosenzweig, and others suggest that an enriched social environment can enhance the physical development of the brain's neural connections and glial support cells.

This research into the plasticity of the brain is part of a long-standing scientific and technological search for external agents that can enhance normal brain functions and remedy malfunctions. Recent widely publicized dramatic developments in this search (e.g., drug therapy, neural transplants, electronic implants) pose major moral, social, and educational issues (Kieser 1986, Shapiro 1986, Robinett 1985).

In this article I focus specifically on the enriched environment research, because of its current high visibility and because it raises especially intriguing educational issues. What follows is a nontechnical introduction to the research, a discussion of its educational implications, and suggested study sources that provide more detailed descriptions of the research literature.

The Research Base

The enriched environment investigations center on the development of the brain's neocortex. In the human brain, the neocortex is the deeply folded, dinner napkin-size (when unfolded) outer cellular layer of the two cerebral hemispheres, which comprise 85 percent of the human brain's three-pound mass. The tens of billions of interconnected neurons in the neocortex process the learned rational behavior that defines much of what students do in school.
Although most of the brain’s lifetime supply of nerve cells are in place shortly after birth, many of the neural axon/dendrite extensions, which transmit information throughout the brain, develop during childhood and adolescence when the brain expands from about one to three pounds. Genetic growth programs lay down the essential neural connections that define a human brain (neural specificity), and environmental challenges help shape the specific connections that gradually adapt each brain to its own environment and make it a unique result of its own experience (neural plasticity).

The basic developmental pattern is simple and straightforward: (1) create an initial excess of connections (axons/dendrites/synapses) among related areas, (2) use learning and experience to strengthen the useful connections and then prune away the unused and inefficient, and (3) maintain enough synaptic flexibility to allow neural connections to shift about throughout life as conditions change and new learning/problem-solving challenges emerge.

We experience an analogous plastic pattern in the making, pruning, and shifting of interpersonal connections in our lives. For example, when we first move into a neighborhood, we tend to check out area businesses and facilities before settling into the basic set we then normally patronize. If we live at the same residence for several years, we may change many of these initial connections (e.g., job, stores, friends, memberships). Despite these shifts our total number of relationships may remain relatively constant.

Many brain plasticity researchers study rats, whose overall mammalian brain development pattern resembles that of human brains. The basic research design (with variations) compares the brains of rats that have lived in different environments for differing periods of time, including (1) rats living alone in a small, unfurnished cage, (2) a group of 12–36 rats living together in a large cage that contains a regularly changed and stimulating collection of toys and other objects to explore, and (3) a group of rats living in a much larger outdoor seminatural rat habitat. Most of the research has focused on conditions 1 and 2.

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The researchers found that the best cortex development emerged from the social/environmental stimulation of the rat’s natural habitat, followed by the enriched/social cage, followed by the impoverished/social environment (Rosenzweig et al. 1972).

The seminatural and enriched social settings produce a thicker and heavier cortex—larger neurons, more and better interneuronal connections, and a greater supply of glial support cells—a potentially better brain for learning and remembering (defined in rat terms as maze-running behavior). Researchers consistently found the most effects in the occipital lobes (primarily concerned with vision), but all neocortical regions measured can respond positively to enriched environments. The researchers obtained these enhanced effects throughout the rats’ lifetime, but the brain’s plasticity is greater during the early developmental period. Further, Diamond and others (1986) found that the effects are similar regardless of whether 12 or 36 rats are living together in the 3’ x 3’ enriched environment.

Although the neocortex has a remarkable ability to adapt successfully to different environments, it does have its limits. The brain may be unable to recover from a seriously deprived environment during a critical brain development period. In one study, kittens raised in a cylindrical environment that had no horizontal lines could not see horizontal lines when they matured (Blakemore and Mitchell 1973).

It’s probably safer to generalize from rats to mice than from rats to human beings. For example, a rat brain will fill a thimble, while a human brain will fill a three-pint container. The forebrain occupies 45 percent of the rat brain’s mass compared to 85 percent in humans; frontal lobes occupy about 5 percent of the rat’s brain compared to 30 percent of the human brain; the cortex matures in about a month in a rat compared to 10+ years in the human brain. And rats don’t have to contend with 30-year mortgages and adolescent children...

Still, researchers expect to find related patterns of plasticity in humans when they develop the technology to monitor growth in specific areas of the human brain—with rat/human differences probably occurring in location and degree of plasticity. Indeed, Diamond compared Albert Einstein’s preserved brain with those of normal people and discovered significantly more glial support cells in the angular gyrus, an important area of the neocortex that integrates sensory data and processes conceptual and symbolic thought (Diamond 1985).

The enriched environment research is important for educators, even with the caveats suggested above. The neural connections that transfer chemicals are fundamental to all brain activity, and the enrichment research indicates that the basic set of connections the mammalian brain uses to regulate interactions with its environment can maintain its plasticity and vigor throughout life if stimulated to do so. Since neurons will thrive only in an environment that stimulates them to receive, store, and transmit information, the challenge to educators is simple: define, create, and maintain an emotionally and intellectually stimulating school environment and curriculum.

Creating an Enriched School Environment and Curriculum

Educators aren’t surprised by such a challenge; it’s a fundamental tenet of our profession. Still it’s reassuring to know that brain researchers are getting closer to providing support for our belief that a stimulating school...
Highlights of Research on Brain Development

Researchers have found that brain development of rats is greatly affected by the environment in which they live. The cortices of rats from enriched social settings are thicker and heavier; they are better equipped for learning. Rats' brains are not nearly as large or complex as ours, but their overall mammalian brain development pattern resembles that of humans. The enriched environment research suggests that an emotionally and intellectually stimulating school environment and curriculum contributes to the brain growth of students. The findings can be interpreted as showing that adults who design educational activities must be sure the activities are as involving to the students as they are to the adults, and must not confuse sheer activity (which is not necessarily stimulating) with meaningful stimulation.

Researchers also point to the effects of tender care in the development of intelligent rats, confirming the need for a caring environment in schools.

environment and curriculum can positively affect the development of our students' brains. But it's also somewhat unsettling to think of the possible negative developmental effects of a boring school, bereft of stimulation. Researchers found significant general corticar improvements after only a few days when they moved rats from a less stimulating to an enriched environment (Diamond in Hopson 1984), but they also found that an otherwise normal cat was blinded for life in an eye that was covered for only a few days during a critical period of visual development (Hubel 1970).

We can think of a classroom as an artificial environment, somewhat analogous to the enriched/social, caged, laboratory environment in the plasticity studies. Although critics can argue that a school lacks the direct stimulating challenge of the natural world, it is an efficient way to deal with the complexities of passing on socially significant information that doesn't generally come up in family discussions. Further, more than 80 percent of the waking hours of a child and adolescent are spent outside school in family and peer environments that range from stimulating to impoverished, from social to solitary. Thus, the research design of the brain plasticity studies presents educators with something interesting to contemplate—a set of three interacting models of educational environments.

Many educational theorists have proposed over the years that we should move students out of the classroom into the natural world—or at least that we should develop the curriculum around classroom simulations, role playing, field trips, and other activities that parallel the experiences and problem-solving challenges of the natural world. When done correctly, the oft-maligned extracurricular program probably gets as close to real problem solving as anything else we do in school—by using metaphor, play, and limited adult domination in a nonthreatening, informal setting to explore the dimensions, tactics, and strategies of problem solving. One thinks of Piaget's view of play as the serious business of childhood and the Duke of Wellington's comment that the Battle of Waterloo was won on the playing fields of Eton.

When a few mature rats were placed into an enriched environment with a group of younger rats, the mature rats played with the toys and dominated the environment. They were stimulated by the environment and developed thicker cortices, but the brain development of the less-involved younger rats wasn't positively affected by what was a potentially stimulating environment (Diamond 1985). These experimental results could find their human representation in classroom projects, extracurricular activities, athletics, and childhood experiences with ballet, piano, and little league, for instance, which stimulate the fantasies of teachers, coaches, and parents but not the youngsters who need to interact with such valuable experiences in non-threatening ways that will stimulate their interest and problem-solving skills.

What role then should teachers play in a classroom that purports to stimulate? John Dewey (1938) commented on the folly of mature adults who work in classrooms with immature children, but who don't use their maturity to enhance the children's experience. To use one's maturity, though, doesn't mean to dominate. If we define the most mature person in a social setting as the person in the group who is the most able to adapt to the needs and interests of others, teachers ought to adapt to their students whenever possible and not always expect their students to adapt to them.

It isn't enough to create an environment that merely keeps students busy. Rats placed into a small cage that was furnished only with a running wheel kept active by using the wheel but experienced no measurable increase in cortical thickness (Diamond in Hopson 1984). Shades of continual drudgery with workbooks and long division problems! Years of research have found patterns of positive cortical effects only in changing, stimulating, social environments.

Suggested Readings on Brain Plasticity


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Perhaps the most complex educational issue to come out of the human educational projections of this thought-provoking body of research, though, is the problem of trying to define a normal human environment—beyond the basic properties of being social, changing, and stimulating. Rats flourished best in their normal outdoor habitat. What is the normal habitat of contemporary children and adolescents—the environment that probably has the best potential for developing their brain to its maximum?

It may well be that the contemporary classroom and the out-of-school world that many students experience are closer to a natural human habitat than we care to admit. Many families already live in a human version of the enriched social rat cage, with a daily rearrangement of toys sent via TV and consumer technology. It sounds terribly depressing at first thought, and we tend to fling away at our indoor civilization and its electronic artifacts. On the other hand, I can't think of anything from my childhood that did more to develop my eye-hand coordination than a joystick on a video game that was totally designed and produced by a local 4th grade class. Today I watched 5th graders composing reports directly on classroom word processors. Who knows what tomorrow will bring?

We romanticize the stimulation of a free and idyllic life in the great outdoors, but a great many people live very regulated lives that occur principally in the limited indoors, and many of these do seem to make the best of it—enriching their lives in ways that nourish the human spirit. It's important to remember that the enriched social rat cage did result in significant growth over the impoverished environment. A major challenge educators face is to create the human equivalent: to create enrichment in an environment that has a high potential for impoverishment.

When pressed to draw practical classroom applications from her years of research with mammalian brains, Diamond smiled and replied that teachers ought to approach their assignment with a commitment to provide students with tender loving care. Tender loving care in the rat studies means that researchers gently handle rats when they work with them: researchers have discovered that this simple act in itself positively extends the lifespan of the animals and, in turn, affects their cortical development. Diamond leaves it to educators to discover the human equivalent to her rat care, but she believes that each person should be treated as an individual, with every effort made to bring forth the best in that person.

The three interrelated concepts that make up her phrase tender loving care will engender a multitude of stimulating thoughts in educators. Diamond's suggestion is simple, but as Dewey once said, simple and easy aren't the same thing.

Perhaps Dewey and Diamond put their finger on the characteristic of teaching that can make it such a creative, optimistic, and stimulating profession with a great potential for maintaining an educator's own brain plasticity throughout a career. It's the continual search for deeper meanings in simple systems that stimulates imaginative educators to work with their students to create an enriched social environment within classroom walls.

Unfortunately, the plasticity research provides only the broadest of guidelines at this point about how educators should organize the classroom environment. We'll have to work at it, and both educators and students will be the better for the effort.

References


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