PEER-LED TEAM LEARNING
LEADER TRAINING

LINKING BRAIN GROWTH AND THE DEVELOPMENT OF SCIENTIFIC REASONING SKILLS: IMPLICATIONS FOR CURRICULUM DEVELOPMENT

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A good curriculum design requires much more than a careful sequencing of the subject matter of the course. Science education research has shown us that we can also facilitate the development of reasoning ability by structuring our courses properly (Lawson, 1993; Lawson, Abraham & Renner, 1989; Renner & Marek, 1990). Many studies have, in fact, found that students exposed to inquiry-based curricula demonstrate positive gains on standard measures of reasoning ability and academic achievement (Leonard, 1983; Renner & Lawson, 1975; Schneider & Renner, 1980). Perhaps the most impressive results are the studies by Shayer and Adey (1992, 1993) that found long-term positive effects on academic achievement not only in science and mathematics, but in English as well, as a result of inquiry instruction in science courses.

Formal scientific reasoning ability can be defined as the set of logical operations an individual uses to test hypothetical causal propositions. These operations include controlling variables, proportional reasoning, combinatorial reasoning, probabilistic reasoning and correlational reasoning. Under Piagetian intellectual developmental theory, this set of logical operations constitutes the higher-order thinking skills attributed to an individual at the formal operational stage. At the previous stage in Piaget's four-stage theory, known as concrete operational, an individual also has a characteristic set of thinking skills which include the ability to describe, seriate and classify (Good, Mellon & Kromhout, 1978).

Support for Piaget's developmental theory comes from both biological and psychometric brain research that shows growth spurts that coincide with the four stages of intellectual development. Measurements of brain weight and skull circumference have established the series of spurts and plateaus that occur during childhood and adolescence (Epstein, 1978). Furthermore, brain growth during adolescence is primarily centered in the prefrontal lobes as seen by increases in length of the pyramidal neurons and increases in prefrontal lobe myelinization (Blinkov & Glezer, 1968). Psychometric measures designed to test prefrontal lobe activity have found notable regressions in inhibiting ability, planning ability, and mental capacity from the ages of 10 to 13 years. It is suggested that the maturation of the prefrontal lobes during adolescence is required for an individual to have the capacity to develop formal scientific reasoning abilities (Lawson & Kwon, 2000). Interestingly, a fifth brain growth spurt has been hypothesized at the age of 18, beyond the previous spurt at age 14 to 16 years that has been associated with the transition from Piaget's concrete to formal operational developmental stages. What this final brain growth represents is unclear, but current research suggests that it is linked with the ability for hypothetico-deductive reasoning on theoretical or abstract concepts (Lawson, Drake, Johnson, Kwon & Scar- pone, 2000).

Research at the college level has found that only a little more than 25% of freshman chemistry students demonstrate formal scientific reasoning ability. A further 50% are transitional while almost 25% of the students show no evidence of higher-order thinking skills at all (Cracolice, 1994). This last group of students clearly represents a significant proportion of the failure and attrition in science courses because scientific reasoning ability is required so that higher-order scientific concepts can be understood. The central mandate therefore becomes designing curricula that facilitates the development of higher- order thinking skills.

Lev Vygotsky was a Russian psychologist who, along with Piaget, has had an important influence on the constructivist theories of learning. His ideas on the social construction of knowledge have gained acceptance, given the number of curricula that now incorporate cooperative learning methods. In Vygotsky's Mediated Learning, peer collaboration is a key element that prompts the use of higher-order thinking skills (Strang & Shayer, 1993). Each student brings to the discussion his/her set of thinking skills and actively participates in resolving any potential conflict arising from previous alternative conceptions. In this way each student can engage his/her current reasoning abilities, but also be provoked to develop higher- order reasoning abilities from the interaction with more able peers.

Vygotsky has termed the range between what an individual can do alone versus what he/she can do with assistance as the Zone of Proximal Development. It is within this zone that the development of higher-order thinking skills can occur. A curriculum based on Vygotsky's Mediated Learning requires students to be placed in an inquiry (data to concepts) environment with materials that explicitly contrast currently held conceptions and encourage peer collaboration.

One curriculum initiative firmly based on Mediated Learning is Peer-Led Team Learning (Gosser et al., 2001). Here, students work in groups to solve challenging inquiry-oriented exercises. The interaction between the students is facilitated by a peer leader who functions to prompt students to expand beyond their current reasoning abilities.

Science education and neurophysiological research have made significant advances to the theory of human intellectual development. While many questions remain to be answered, it is clear that we can effect positive changes. We can facilitate gains in students' scientific content knowledge, while at the same time helping them to make developmental advances.

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Cite This Article as: Cracolice, M.S., Monteyne, K. (2012). Linking Brain Growth and the Development of Scientific Reasoning Skills: Implications for Curriculum Development. Peer-Led Team Learning: Leader Training. Online at http://www.pltlis.org.
Originally published in *Progressions: The Peer-Led Team Learning Project Newsletter*, Volume 2, Number 4, Summer 2001.