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Biology Reflective Assessment Curriculum

A Thesis submitted in partial satisfaction of the requirements  
for the degree Master of Arts

in

Teaching and Learning: (Curriculum Design)

by

Cheryl Ann Bayley

Committee in charge:

Rachel Millstone, Chair

Cheryl Forbes

Christopher P. Halter

2011

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Chair

University of California, San Diego

2011

## **Dedication**

This thesis is dedicated to my son Liam and my husband Roman for their love and support. This work is also dedicated to my science students who have taught me so much.

## Epigraph

*"Liberating education consists in acts of cognition, not transfers of information"*

~Paulo Freire

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# ABSTRACT OF THE THESIS

## Biology Reflective Assessment Curriculum

by

Cheryl Ann Bayley

Master of Arts in Teaching and Learning: (Curriculum Design)

University of California, San Diego, 2010

Rachel Millstone, Chair

Often students and educators view assessments as an obligation and finality for a unit. In the current climate of high-stakes testing and accountability, the balance of time, resources and emphasis on students' scores related to assessment have been slanted considerably toward the summative side. This tension between assessment for accountability and assessment to inform teaching strains instruction and educators' ability to use that information to design learning opportunities that help students develop deeper conceptual understanding. A substantive body of research indicates that formative and reflective assessment can significantly improve student learning.

Biology Reflective Assessment Curriculum (BRAC) examines support provided for high school science students through assessment practices. This investigation

incorporates the usage of reflective assessments as a guiding practice for differentiated instruction and student choice. Reflective assessment is a metacognitive strategy that promotes self-monitoring and evaluation. The goals of the curriculum are to promote self-efficacy and conceptual understanding in students learning biology through developing their metacognitive awareness.

BRAC was implemented in a high school biology classroom. Data from assessments, metacognitive surveys, self-efficacy surveys, reflective journals, student work, a culminating task and field notes were used to evaluate the effectiveness of the curriculum.

The results suggest that students who develop their metacognitive skills developed a deeper conceptual understanding and improved feelings of self-efficacy when they were engaged in a reflective assessment unit embedded with student choice. BRAC is a tool for teachers to use assessments to assist students in becoming metacognitive and to guide student choice in learning opportunities.

## **I. Introduction**

Assessment is one of the most important yet overlooked aspects in science curriculum design. Effective assessment practices are integral to informing teaching and learning, as well as measuring and documenting student achievement. In the current climate of high-stakes testing and accountability, the balance of time, resources and emphasis on students' test scores have been slanted considerably toward the summative side. Unfortunately, this imbalance has led to a cycle of even more standardized testing of students and an emphasis on breadth rather than on depth in instruction. When science test scores fail to improve, often the reaction is to increase the cycle of testing and test preparation, covering large amounts of content in a superficial way. Research indicates that formative and reflective assessment can significantly improve student learning. Yet this same research shows that the features of formative assessment that affect student achievement are missing from many classrooms (Black, 2003).

This curriculum addresses the need to recognize and enhance students' multiple opportunities to learn, which include pedagogically directed learning assessments (Black, 2003). Optimal opportunities to learn exist when science teachers are aware of the variety of ideas students are likely to bring to the classroom and are able to see the connections between students' thinking and the content standards targeted by state and national governing groups. With this knowledge, educators can provide learning experiences that build a bridge between the two. What is effective strictly for the purpose of external accountability may not effectively serve instructional planning and decision making. A rich repertoire of reflective and formative assessment techniques provides the ongoing feedback and stimulus needed for deep thinking that a high-stakes test scheduled once or

twice a year cannot provide in time, for instance, to inform instruction and affect learning. In this and many ways, teachers who use assessments that de-emphasize the summative side, a learning environment that fosters deep thinking, and students who use reflection while learning are the keys that connect assessment, instruction, and learning.

This curriculum examines support provided for students through assessment practices in a biology classroom. This investigation incorporates the use of reflective assessments as a guiding practice for differentiated instruction. Reflective assessment is a metacognitive strategy that can provide a metacognitive experience by promoting self-monitoring and evaluation. Reflective assessment is used in this curriculum to facilitate differentiated instruction through student choice. Differentiated instruction is instruction that is adapted to meet the diverse needs of individual learners. This allows for all students to learn science. This curriculum proposes the use of metacognitive strategies such as reflective assessment to promote self-efficacy and conceptual understanding for students learning biology.

## **II. Assessment of Need**

### **Science Nationwide**

Science achievement in the nation is at a critical tipping point. The Pew Research Center and the American Association for the Advancement of Science (AAAS) demonstrated evidence of the current state of the nation's scientific literacy. Only 55% of Americans in their survey knew why stem cells differ from other kinds of cells; just 46% knew that atoms are larger than electrons. And concerning the issue of global warming the gap between scientists and the public was vast: 84% of scientists, but just 49% of Americans, think human emissions are causing global warming (Pew Research Center, 2009; AAAS, 2009). These statistics demonstrate the lack of translation of science education to general public knowledge.

According to the Trends in International Mathematics and Science Study (TIMSS) (International Association for the Evaluation of Education Achievement, 2007) and the National Assessment of Educational Progress, the United States is falling behind other developed nations in science achievement. This assessment is an international math and science test given to fourth and eighth grade students in 47 countries. The assessment consisted of multiple-choice questions, free-response items, and a questionnaire. In 2007, the United States ranked eleven out of 47 countries in eighth-grade science scores (TIMSS, 2007). The United States had higher science scores than many developing nations, but ranked in the lower tier amongst developed nations. In 1995, the average eighth grade science score was 513 out of 1000. The United States showed an increase of 8 points in eighth grade science scores for a score of 520 in 2007 (TIMSS, 2007). These

figures show a slight increase however they maintain the status quo in international science achievement overall. As one of the wealthiest countries in the world, the United States ranks below many developed countries in science achievement.

Nationally, science scores have not changed in the past two decades. The United States Department of Education administers the National Assessment on Educational Progress (NAEP). NAEP science tests, comprised of multiple-choice and open-ended questions, are given to fourth, eighth, and twelfth-grade students. Eighth- grade students showed no change in science scores from 1995 to 2005 (NAEP, 2005). Twelfth-grade performance in science exhibited a decline from 1995 to 2005. Despite a 3 point increase for eighth grade Black students, the achievement gap between White and minority students remained the same in both grades. Among all evaluated groups, the percentage of students performing at proficiency has remained unchanged for eighth-graders with only 29 to 30 percent of them achieving proficiency. Unfortunately, the level of students performing at proficiency has declined slightly for twelfth-graders. While only 21% achieved proficiency in 1995, that number has decreased to 18 in 2005. Of specific interest to this study, the Life Science portion of the NAEP test mirrored this pattern with eighth-graders maintaining the same level of proficiency and twelfth-graders slightly declining between 1995 and 2005 (NAEP, 2005).

Since 2002, there has been a de-emphasis on science instruction in the elementary level in the context of No Child Left Behind Act (NCLB). The federal government's role changed dramatically with the passage of NCLB (McGuinn, 2006). NCLB mandates that all students and subgroups reach hundred-percent proficiency by the year 2014. Science assessments were required by NCLB starting with the 2007-2008 school year when one



grade began being tested at each of the elementary, middle school, and high school levels. No target levels of achievement were set for science, however this creates potential consequences for other subjects such as science since mathematics and reading remained priorities before 2008. Since 2008, mathematics and reading are still weighted more on the overall school's rating (United States Department of Education, 2002).

As a result of NCLB, science education has suffered because of demands on schools to emphasize math and reading (Froschauer, 2006; Mundry, 2006). A 2006 report from the Center on Education Policy (CEP) presented a four-year study showing that schools were decreasing instructional time in non-assessed areas because of NCLB. The report indicated that seventy-one percent of the school districts surveyed reported that they have reduced elementary school instructional time in at least one other subject to make more time for reading and mathematics. In some case study districts, low achieving students receive double periods of reading or math, or both, sometimes missing certain subjects such as science altogether (CEP, 2006).

Even before NCLB, many in education considered elementary science to be a non-priority school subject (Spillane, Diamond, Walker, Halverson, & Jita, 2001). Although researchers have provided a number of rationales for the limited science instructional time in the elementary level (Finson and Beaver, 1994; Plourde, 2002; and Lee and Houseal, 2003), the CEP has indicated that the changes directed by NCLB created another factor which seems to worsen the problem. These changes have negative consequences as students reach upper grades.

### **Science in California**

According to NAEP data, nine states showed an increase in science performance from 2000 to 2005. California was one of those states with an increase from a score of 129 to 136. While headed in the right direction, NAEP found that over a 10 year span there was actually a decrease, from a score of 138 in 1996 to 136 in 2005 (NAEP, 2005). This trend of decreasing or stagnant scores in the nation is also observed at the state level.

The California Department of Education (1998) provides state standards for each subject in high school. There are 5 major biology strands aligned to state standards, each assessed with an end-of-course state exam (CDE, 1998). The state exam is graded on a five-level scale: advanced, proficient, basic, below basic and far below basic. This assessment is administrated once and the results are communicated to the schools months after the test. On the 2009 Biology California state test (CST), performance results ranged from 20% advanced, 22% proficient, 33% basic, 13% below basic and 12% far below basic for the state of California. The previous year's test performance results ranged from 16% advanced, 26% proficient, 33% basic, 13% below basic to 13% far below basic (CDE, 2008). Although there was an increase in the number of students who scored advanced on the biology CST, the overall percentage of advanced and proficient students remained the same at 42%. Therefore, less than half of the students in California score at least proficient on the biology CST after a year in biology class.

Although there are limitations to this exam's assessment of achievement, it can be used as a tool or indicator for analysis on science achievement. California, as well as the nation, is consumed with standardized testing, but is this testing improving achievement? One test alone such as the California State Exam does not provide enough feedback or day-to-day information about student achievement for teachers to maximize learning

(Stiggins, 2002). In addition, many teachers are focused on learning for tests and not for their teaching for maximizing learning.

### **District Science Achievement**

Further investigation into science achievement can be examined at an urban school district in Southern California with a large population of English Language Learners. In the last decade, this district in which I teach has mandated the use of district summative assessments twice a semester. During the 2009-2010 year, the district increased its mandate to 4 assessments a year, therefore increasing the number of summative tests that mimic the state standardized testing. Questions of importance related to this increase include the usage of summative assessments and frequency which calls for a deeper analysis. It is helpful to conduct such analyses at the local level, where the interpretations allow for both direct observation and analysis of data. First hand experience and comparative data hold a greater validity because a local subject can render more valid data.

On the Biology California State Exam (CST), the 2009 test performance results for this district ranged from 15% advanced, 25% proficient, 39% basic, 12% below basic to nine percent far below basic. The previous year test performance results ranged from 11% advanced, 26% proficient, 38% basic, 14% below basic to 12% far below basic (CDE, 2009). A 4% gain can be observed in the advanced scores. Overall, however, the scores have remained stagnant, demonstrating a need for reassessment of policy and science teaching methodology.

At Cougar High School, an urban high school located within 5 miles of the Mexican border, useful evidence can be collected about the science achievement of a

largely Latino population. Students' 2009 Biology CST test performance results ranged from 5% advanced, 18% proficient, 45% basic, 19% below basic to 13% far below basic. The previous year's test performance results ranged from 3% advanced, 20% proficient, 41% basic, 21% below basic to 15% far below basic (CDE, 2009). The school's annual scores remained flat and are lower than the district and state performance scores.

### **Conclusion**

Curricular design increasingly focuses on standardized test preparation, placing a heavy emphasis on summative assessments which become central to the learning experience. These assessment practices create an environment of anxiety in which learning becomes something students demonstrate in isolated and high-stakes circumstances. These practices are not conducive for meaningful and integrated opportunities for learning and assessment. The results of the Biology CST at Cougar High School demonstrate the gap between assessment and meaningful learning improvement since "teaching to the test" has failed to return positive results. Considering these statistics, there is a substantial need to improve education for science students by maximizing effective teaching strategies. Indeed, rather than developing assessments to encourage learning, science education has come to emphasize learning for the sake of assessments with little success. Considering these statistics, there is a substantial need to improve education for science students by maximizing effective teaching strategies.

Research shows that successful assessments articulate clear objectives, accurately reflect student achievement, build student confidence, provide descriptive feedback, adjust curriculum and provide student self-assessment tools (Stiggins, 2002). These characteristics can be found in reflective assessments (Zemelman, Daniels and Hyde,

2005). Reflective assessment is the usage of authentic, higher-order activities, ethnographic information in the classroom and formative assessments as tools for students to understand their own metacognition. Although testing in the classroom has been misguided and overused, reflective assessments can be a valuable tool to facilitate learning, provide feedback and guide student choice in science. This curriculum includes the use of metacognitive strategies such as reflective assessment to promote conceptual understanding and self-efficacy through student choice among students learning biology.

### **III. Literature Review**

#### **Metacognition**

Flavell (1979) was the first to use the term *metacognition*, describing it as one's knowledge concerning one's own cognitive processes or anything related to them. Metacognition is often described as "thinking about thinking" and reflection (Schoenfeld, 1987). Metacognition have connections to cognitive psychology, which examines the way in which people think and process information. Flavell (1979) stated that metacognitive experiences help students assess where they are in their learning. Reflective assessment, with its focus on self-monitoring and evaluation, is therefore a metacognitive strategy. Reflective assessment is the usage of authentic, higher-order activities, ethnographic information in the classroom and formative assessments as tools for students to understand their own metacognition. Higher-order activities are real problem solving, reading whole books, story writing, scientific inquiry, portfolios and performance tasks. Ethnographic sources in the classroom can come from observations, interviews, artifacts and questionnaires (Zemelman, Daniels and Hyde, 2005). The potential for reflective assessment to impact student achievement lies in its ability for a curriculum that facilitates a cycle of thinking about thinking in the daily classroom setting.

Metacognition includes two components, self-awareness and self-regulation of learning and understanding (Flavell, 1979). While there are numerous definitions of metacognition (Kauffman, Ge, Xie, & Chen, 2008), a common description for metacognition is "knowledge and regulation of one's own cognitive system" (Brown, 1987). It involves knowledge about one's thinking, how to use strategies, and the self-

regulatory components of planning, evaluating, and monitoring (Jacobs & Paris, 1987). When learners engage in the metacognitive process, they are involved in planning, monitoring, evaluating, and selecting strategies with an awareness and knowledge of the resources they need (Gordon, 1996). Metacognition can be increased in classrooms by improving knowledge and regulation of cognition and creating environments that promote metacognition. Diverse achieving students can benefit from metacognitive/self-regulative skills (Manning, Glasner, & Smith, 1996).

Self-regulated learning (SRL) (Butler, D.L., & Winne, P, 1995) promotes metacognition by supporting students in setting goals, self-monitoring, regulating their actions, and controlling their cognitive efforts and attention (Pintrich, 2000). SRL involves the learner as an active participant in the construction, modification, and/or enhancement of knowledge, all of which are part of metacognition. Self-regulated learners have skills that lead to an awareness of what they know and/or don't know and how to correct their state of not knowing. Such self-regulation is essential for reflective assessments.

Teaching a student to understand what it is that he or she is thinking and to build the skills to verify his or her opinions is what Dewey (1933) believed to be the purpose of education. Dewey believed that individuals need to participate in reflective thought; they need to find out what they believe and then have the ability to prove it. A directed type of journaling, reflective journals also called learning logs, can provide attention to cognitive strategies such as paraphrasing, summarizing, and creating graphic organizers (Anderson & Krathwohl, 2001). Students using reflective journals tend to display greater awareness and control of their thinking processes, suggesting a greater degree of

metacognition, and they report performing significantly better on final exams than control group students (McCrindle & Christensen, 1995). Used as a diary, reflective journals contain material that serves to inform future instruction and provide an authentic performance assessment.

Regulation of cognition involves activities that control and regulate a person's thinking and learning which includes planning, monitoring, and evaluation (Schraw & Moshman). Several researchers use the term "monitoring accuracy" when referring to the process of accurate self-assessment and achievement. Monitoring accuracy is also labeled "calibration of performance" (Nietfeld & Schraw, 2002; Nietfeld, Cao, & Osborne, 2005).

SRL has been effectively used in several contexts to enhance student learning. White and Manning (1994) learned from their high school classroom study that self-regulated learning interventions helped to create higher levels of self-guidance and better teacher ratings on pedagogy. Students who have skills that lead to more self-guidance have more awareness of what they know and/or do not know and how to improve their current knowledge. Robert Marzano found that using reflective journals as a platform for students' self-assessment can then facilitate student engagement (Marzano, 2006).

Research points to particular teaching practices as effective for developing students' metacognitive strategies (Williams, Blythe, White, Lin, Gardner, & Sternberg, 2002). Explicit metacognitive instruction is found to help students gain control over the how and when of cognition (Zimmerman, 1986; Zimmerman 2000) and also facilitates higher order thinking skills. Instructional practices that teach metacognitive practices by actively involving learners in developing an awareness of how to monitor and control



appropriate and effective strategies, are likely to be effective in increasing students' academic performance (Chiu, Chow, & McBride-Chang, 2002; Bransford, 2000; White & Frederiksen, 1998).

Rather than merely exposing students to metacognitive strategies, teachers who provide explicit instruction to students make metacognitive strategies clear while integrating higher order or scientific thinking skills into the content. Explicit teaching of metacognition has been found to be more effective than letting students figure out the scientific process skills for themselves (Williams, Blythe, White, Lin, Gardner, & Sternberg, 2002). Additionally, it is beneficial to know when to use a metacognitive strategy.

### **Metacognition and Assessment**

A component of reflective assessments incorporates formative assessment, which focuses on providing immediate feedback by acting upon student understanding during the course of instruction. Formative assessment has been linked to increased student achievement (Black & William, 1998; Wang, Haertel & Walberg, 1993; Yin, 2005; Yin, Tomita, & Shavelson, 2008). Whereas summative assessments signify the end of a unit, formative assessment was first defined by Scriven (1991) as an assessment designed to assist students in making improvements to their learning and to guide teachers' instruction.

The term formative assessment or “assessment for learning” (Black & William, 1998) can be used to describe all activities that learners and teachers use for the purpose of assisting the learners in discovering where they are in their learning, where they are going, and how to get there. Black and William's (1998) assessment for learning serves

its formative function when evaluative information is fed back to the learners, and the subsequent activities in which they engage lead directly to learning. Black and William (1998) stress the importance of student involvement in the assessment process. This is another missing piece in summative assessment. When students actively assess their own work through formative assessment, this builds students' "learning to learn" skills by emphasizing the process of teaching and learning, and involving students as partners in that process. It also builds students' skills at peer-assessment and self-assessment, and helps them develop a range of effective learning strategies. Students who are actively building their understanding of new concepts rather than merely absorbing information and who are learning to judge the quality of their own and their peers' work against well-defined criteria are developing invaluable skills for lifelong learning.

Gipps (2002) offers a set of guiding principles for teachers' classroom strategies that are informed by social discourse and socio-cultural theories of learning (Gipps 1999, 2002). Teachers who use collaborative grouping and social methods combined with formative assessments create the most effective learning experience according to Black & William (1998).

Feedback, formative assessments and classroom culture combine to form a fruitful environment for reflective assessment. Classroom assessment that provides students with clarity about their learning goals and feedback about their learning (Black & William 1999; Wiggins, 1998), support students' independent evaluation of their own work and helps them take more responsibility for their learning (Shepard, 2001; Fountas & Pinnell, 1996; Feldgus & Cardonick, 1999). Feedback can demonstrate successful examples of task performance and the criteria for scoring these tasks, help students

understand processes involved in accomplishing high quality work, and identify the specific steps they can take to improve their work. Involving students in their own learning often requires changes in teachers' existing practices and the type of classroom culture they promote. Without a collaborative class culture, the formative assessments will not have their intended effects (Black & William, 1998; Torrance & Pryor, 1998). Through collaborative working partnerships learners are able to build up their knowledge by working together to understand new concepts (Bayer, 1990; Vygotsky, 1978).

### **Self-Efficacy**

Self-efficacy is commonly defined as the belief in one's capabilities to achieve a goal or an outcome. Students with a strong sense of efficacy are more likely to challenge themselves with difficult tasks and be intrinsically motivated. Over the past five decades, theorists have changed their approach to the study of human motivation. External or extrinsic motivators seen are considered to be less effective forms in favor of a close consideration of the importance of internal or intrinsic motivators (Ormrod, 1999). Intrinsic motivation exists when the source of motivation lies within the individual or student. Tasks that are intrinsically motivating fulfill a want rather than a need (Brophy, 1998) and are experienced by the student as enjoyable or worthwhile (Ormrod, 1999). Intrinsic motivation focuses on positive elements of motivation such as the delight of an intellectual discovery, pride in a job well done, and an appreciation for what is being learned (Covington & Dray, 2002). Intrinsic motivation is one element among many that contribute to learning.

Classroom assessments often fail to genuinely motivate students to learn because they can fail to motivate them intrinsically. Instead, summative assessments tend to be

extrinsically motivating since the motivation is based more on the desire for a grade versus the desire to learn. In the following section I will discuss some key motivational factors which include: pragmatic goals/needs as a motivator for learning; choice as a motivator for learning; self-efficacy as a motivator for learning; and self-regulated learning as a motivator.

### **Pragmatic reasons/goals as intrinsic motivators for learning**

We know from learning theory that ideas are best discovered when students see a need or a reason for their use. (Bransford, Brown, & Cocking, 2000). Students are motivated by the desire to attain certain goals, therefore a close relationship exists between motivation and the goals that drive it. Their motivation to achieve their goals influences their actions and the consequences they deem reinforcing (Ormrod, 1999). The term, goal orientation, refers to students' reasons for engaging in academic tasks (Anderman, Austin, & Johnson, 2002). Goal orientation is theorized as a series of binaries by Ames, (1992) and is seen to include social goals by Blumenfeld (1992). The figure below shows the binaries proposed by Ames and grouped according to their primary source of motivation.

**Table 1:** Ames's (1992) Goal Orientation Binaries

| Intrinsically Motivating |        | Extrinsically Motivating |
|--------------------------|--------|--------------------------|
| Learning                 | Versus | Performance              |
| Task Involvement         | Versus | Ego Involvement          |
| Mastery Goals            | Versus | Performance Goals        |

Mastery goals are set with a desire to achieve competence by acquiring new knowledge or mastering new skills; performance goals come from a desire to appear capable of performing and to receive favorable judgments from others (Ormrod, 1999). With a mastery goal students are oriented toward trying to understand their work, improving their level of competence, or achieving a sense of mastery based on self-referenced standards; with a performance goal, students focus on ability evidenced by doing better than others, by surpassing basic standards, or by achieving success with little effort (Ames, 1992). Ames and Archer (1988) found that students who had an emphasis on mastery goals in the classroom reported using more effective strategies, preferred challenging tasks, demonstrated a more positive attitude toward the class, and had a stronger belief that success follows from one's effort. Students who had performance goals as guiding ideals tended to focus on their ability, evaluating their ability negatively and attributing failure to lack of ability. Specific motivational processes are related to these two types of goals in classroom settings.

### **Choice as an intrinsic motivator for learning**

Instilling intrinsic academic motivation into instruction has been found to be an effective component of lesson design and pedagogy. Contextualization, personalization, and choice produce dramatic increases in intrinsic motivation as well as depth of engagement in learning, amount of learning, and perceived competence of the learner (Cordova & Lepper, 1996).

### **Self-efficacy as an intrinsic motivator for learning**

Bandura (1986) defines self-efficacy as "people's judgments of their capabilities to organize and execute courses of action required to attain designated types of

performances" (p. 391). Learners form ideas about their self-efficacy from their actual performances, observational experiences, forms of persuasion, and physiological responses (Schunk & Pajares, 2002). In our culture, as children get older, many of them begin to attribute their successes and failures to intelligence and/or natural talent, factors they believe to be stable and beyond their control (Ormrod, 1999). If students are usually successful at school activities, they come to believe that they have high ability and develop a high sense of self-efficacy for academic tasks. If students often experience failure in school activities, especially if they attribute it to low natural ability rather than low effort or poor strategies, they often develop low self-efficacy for academic pursuits (Schunk, 1991). Self-efficacy, then, has close ties to social cognitive theory, which examines humans' learning based on interactions between behaviors, beliefs, and environmental conditions (Bandura, 1986).

### **Self-regulated learning as an intrinsic motivator**

Like students who work to achieve mastery goals, those who engage in self-regulated learning focus more on internal processes than on external forces and outcomes. Self-regulated learning is active learning in which students assume responsibility for motivating themselves to learn with understanding (Brophy, 1998). It is a constructive process that occurs when students set goals for their learning and then attempt to monitor, regulate, and control their cognition, motivation, and behavior as they work to achieve those goals (Pintrich & Zusho, 2002). More specifically, self-regulated learning includes the following elements: self-motivation, goal setting, planning, attention control, application of learning strategies, self-monitoring, and self-evaluation (Ormrod, 1999).

Students who can monitor and direct or change their own cognition, motivation, behavior and environment are more likely to be successful in academic settings (Pintrich & Zusho, 2002). Perry (2002) found that specific teacher actions promote self-regulated learning. These include giving students choices, chances to control levels of challenge, opportunities to evaluate their own and others' learning and feedback and evaluation of a non-threatening and a mastery-oriented nature. Reflective assessments provide these elements of self-efficacy.

Self-efficacy is commonly defined as the belief in one's capabilities to achieve a goal or an outcome. Students with a strong sense of efficacy are more likely to challenge themselves with difficult tasks and be intrinsically motivated. These students will put forth a high degree of effort in order to meet their commitments, and attribute failure to things which are in their control, rather than blaming external factors. Self-efficacious students also recover quickly from setbacks, and ultimately are likely to achieve their personal goals. Students with low self-efficacy, on the other hand, believe they cannot be successful and thus are less likely to make a concerted, extended effort and may consider challenging tasks as threats that are to be avoided. Thus, students with poor self-efficacy have low aspirations which may result in disappointing academic performances becoming part of a self-fulfilling feedback cycle (Bandura, 1986; Margolis and McCabe, 2006).

Perceived self-efficacy is defined as people's beliefs about their capabilities to produce designated levels of performance that exercise influence over events that affect their lives. Self-efficacy beliefs determine how people feel, think, motivate themselves and behave. Such beliefs produce these diverse effects through four major processes. They include cognitive, motivational, affective and selection processes.

### **Teaching Strategies for Student Self-efficacy**

Student-centered instruction, as opposed to teacher-centered education maximizes student learning. Small group work alongside the explicit teaching of cooperative and collaborative skills have long been recognized as essential instructional components for developing successful learners (Bransford, 2000). Cooperative groupings provide opportunities to recognize, explore, and build on academic strengths and weaknesses in non-threatening settings, leading to students' increased monitoring of cognitive processes (Johnson & Johnson, 1989; Kagan, 1990). Teaching methods that integrate curriculum objectives with adolescents' needs for physical movement and social interaction such as these are prevalent in classrooms across the country. Collaborative classrooms with an appreciation of students' cultural capital can facilitate motivation.

The development of self-efficacy, values, and goals directly impacts learning. These constructs affect the degree to which students attend to learning tasks and activities as well as the amount of effort they dedicate to completing them. Self-efficacy directs choice, performance, and, ultimately, success in academic achievement. Reflective assessments benefit from inherent motivation gained through student goal setting, socio-cultural groups and student choice.

### **Conceptual Understanding**

Reflective assessments are motivational tools for students which lead to conceptual change in a student's scientific knowledge and understanding of the natural world (Zemelman, Daniels and Hyde, 2005). Science achievement can be conceptualized as being composed of four types of knowledge - declarative knowledge ("knowing that"), procedural knowledge ("knowing how"), schematic knowledge ("knowing why"), and



strategic knowledge ("knowing about knowing") (Li, 2001; Li, Ruiz-Primo, & Shavelson, 2006). Science curricula and instruction might often be aimed at conceptual change, but they do so through declarative and procedural knowledge. Gains in declarative and procedural knowledge, however, may be more akin to conceptual accumulation than conceptual change. In other words, conceptual understanding may be desired or desirable, but most curricula and assessment focus on conceptual accumulation rather than conceptual understanding and they do so by emphasizing declarative and procedural knowledge. In order to affect conceptual change, curricula need to tap into students' prior knowledge. The struggle to replace knowledge with alternative ideas, or help knowledge evolve into scientifically-sound knowledge must occur by invoking students' experience. Scientific conceptual understanding is aimed at identifying students' not-quite-scientific understandings, their origins, and their structures (Duit & Treagust, 2003).

Since the 1970s, research in science education has shown that some of the best academic achievers complete their courses with poor understanding of fundamental concepts, and retain serious misconceptions after formal instruction. They are not able to apply in different contexts what they had learned in the examples and end-of-chapter problems in their textbooks. It appears that understanding of concepts does not necessarily accompany the ability developed during instruction to reproduce factual or procedural knowledge. The fact that good academic results can be achieved without genuine conceptual understanding calls into question the methods used for obtaining academic results (McDermott, 1984).

There is now evidence that even good students don't always display a deep understanding of what's been taught even though conventional measures certify success (Wiggins & Mctighe, 1998). Further, in most educational settings testing focuses predominantly on the recall of information from textbooks and class presentations. Rarely are students assessed in ways requiring them to demonstrate deeper understanding. Wiggins goes on to discuss how correct answers offer inadequate evidence for understanding or good test results can hide misunderstanding.

Although teaching for understanding is not always a primary focus in a course, there is little doubt that it is more valuable than rote learning. It is important to clarify what is meant by conceptual understanding or teaching for understanding. A student who has achieved understanding has more than just textbook knowledge, and skills to solve problems at the end of each chapter. Understanding involves sophisticated insights and abilities that may be exposed in a variety of ways and contexts. Understanding is what endures after details are forgotten; it is what is retained and may be applied in unfamiliar situations. The very nature of concepts, principles, key ideas and processes requires them to be understood rather than just be learned for application in a few contexts so that familiarity may give the impression of understanding. Familiarity with some subject matter, and knowledge and skills do not automatically lead to understanding because success may be achieved by memorizing or frequent practice. Even in training programs, or physical education courses, the teaching of specific skills without explanations and justification for the reason something is done in a certain way, may result in more skillful and more knowledgeable students. However, more permanent changes in the students are not achieved by integrating new information with previous knowledge and relating it to

previous experience. By ignoring students' prior knowledge and using assessments that do not address understanding result in superficial and contextual learning. Therefore the assessment of understanding requires different methods from the more traditional tests which are designed predominantly to gain evidence for factual knowledge and problem solving skills (Wiggins & Mctighe, 1998).

The type and content of the assessment used in a course have an influence on the curriculum used by teachers and students. Often teachers and students hesitate to spend time on what is not going to be assessed, and work towards achieving good test results assuming that only test results are used in the recognition of success.

Many teachers claim to teach for understanding, but their teaching and assessment methods, and the outcomes in most students, irrespective of academic success, do not reflect their intentions. Assessment methodologies, such as reflective assessment, that promote the development of understanding are not as easy to develop as those based on traditional methodologies. In addition resources to support such alternative assessment methodologies are not as readily available. After all, any teacher from any discipline can write a set of questions, mark students' responses right or wrong and count the correct answers for each student.

Methodologies for the assessment of understanding would allow students to reveal their partial understandings, their misunderstandings, their misconceptions, and their alternative ways of viewing a situation. Understanding can be developed and evoked only through multiple methods of assessment (Wiggins & Mctighe, 1998).

Understanding is something that can be achieved gradually and with effort, and it is a matter of degree. The continuum of understanding ranges from naive to

sophisticated, and from simplistic to complex, as opposed to merely right or wrong. To understand means not just knowledge of more difficult things but also the ability to offer qualifications and conditionals. This understanding must show various kinds of understanding due to diverse points of view people have of the same situation. Conceptual understanding involves using learning in new ways and it implies the ability to think and act flexibly with what one knows; this constitutes understanding. A distinction must be made between a superficial or borrowed opinion and an in-depth, justified understanding of the same idea (Wiske, 1997).

Wiggins and McTighe (1998) produced a working definition of the complex nature of understanding, by identifying six key component abilities—six different but overlapping and integrated facets: Explanation, Interpretation, Application, Perspective, Empathy and Self-knowledge.

Hewson and Hewson (1984) describe three conditions that must be met for a student to begin to integrate a new concept: it must be first seen as intelligible, plausible, and fruitful. Teaching strategies can follow once these three conditions have been met. They speculate that the first phase of conceptual change is integration, as new concepts are integrated with existing ones. This is followed by differentiation, as existing conceptions are defined and shown to be separate from more scientific ones. What follows is an exchange of old conceptions for new ones as students see that old conceptions are not plausible and new conceptions are more explanatory. Finally, the student can link the new conceptions with their experiences (Hewson, 1984).

Referred to as misconceptions by some (Wandersee, Mintzes, & Novak, 1994), the conceptions students bring to the class independent of instruction are also known as

naive conceptions (Champagne & Klopfer, 1984), nonscientific beliefs (Lawson & Weser, 1990), preinstructional beliefs (Chinn & Brewer, 1993), intuitive knowledge (Vosniadou, Ioannides, Dimitrakopoulou, & Papademetriou, 2001), and alternative frameworks (Carey, Evans, Honda, Jay, & Unger, 1989). The idea is to recognize that a student's prior knowledge is embedded in a system of logic and justification. Conceptual understanding is facilitated by students' usage of metacognitive strategies such as reflective assessments to understand their prior knowledge to fit current scientific understandings.

### **Conclusion**

Current educational reform, grounded in constructivist philosophy, locates the student/learner in the center of learning. In keeping with this educational philosophy, reflective assessments incorporate metacognition, self-efficacy, and conceptual understanding for students to self-assess and facilitate their choices. Traditional science curricula and assessment encourage learning for assessments rather than creating assessments to facilitate metacognitive learning. The next chapter will review science assessments and curricula, many of which lack reflective assessments despite their grounding in constructivist philosophies. Many, if not most, assessment practices have remained traditional even while serving reform curricula.

#### **IV. Biology Curricula Review**

A traditional approach to teaching and curriculum in the high school classroom emphasizes factual information where the student is a passive recipient of knowledge transferred by the teacher or textbook (Cuban, 1982; Goodlad, 1984). This traditional approach is used in biology classes (Penick, 1995), and does not appear to have changed much since these studies from Cuban and Goodlad, despite research pointing to different beneficial approaches. Even teachers using innovative curricula have tended to lecture and assign students to read and answer questions based on the text much of the time (Gallagher, 1967; Penick, 1995). Supovitz and Turner (2000) found that teachers in higher poverty schools, as defined by the number of students on free and reduced lunch, reported lower reliance on curriculum that supports an investigative and reflective classroom culture.

The current reform movement in science education advocates a change from the traditional transmission model of education to an inquiry model where students build their understanding from experiences, reflection, investigation and discussion. In addition, many traditional curriculum units and textbooks are structured for assessment of learning (Black, Harrison, Lee, Marshall, & William, 2003) versus assessment for learning (Keeley, 2008). Learning for assessments encourages teaching to the test while assessment for learning incorporates assessments into learning.

This chapter explores the current limitations of state-adopted biology textbooks in facilitating reflective assessment and constructive learning. The curricula reviewed are Prentice Hall Biology (Pearson, 2007), Sweetwater Union High School District Biology Curriculum Unit (Sweetwater Union High School District, 2006), and Glencoe's Biology:

A Community Context (McGraw-Hill, 1998). These curricula are all aligned with the California content standards, but vary in their teaching and learning approaches. The chapter goes on to investigate these curricula through the constructs of self-efficacy, motivation and conceptual change.

### **Prentice Hall Biology Curricula**

Prentice Hall Biology (Pearson, 2007) is aligned to the California State Standards (California Department of Education, 1998) and is organized around chapters aligned to these standards. Each chapter has three to four sections. The textbook begins with content on the scientific method, and then continues to ecology, cellular biology, cellular energetics, molecular biology, genetics, evolution, organisms and physiology. Each section begins with a guide for reading which includes the key concepts in question format, the vocabulary terms for the section and a reading strategy for the section. Throughout each section there are occasional labs for building science skills and building content knowledge. In addition, there is generally one checkpoint question per section to be utilized by the reader to think about the reading. At the end of each section are questions that demonstrate the recall information of the chapter. Finally, there are section reviews at the end of each chapter that pose higher-level questions.

**Metacognition.** As discussed previously, Flavell (1979) stated that metacognitive experiences such as “thinking about thinking” help students assess where they are in their learning. Teaching a student to understand how they thinking and process information in order to possess the skills to verify their opinions is what Dewey (1933) believed to be the purpose of education. Dewey believed that individuals need to participate in reflective thought by finding out what they believed and justify their ideas. The Prentice Hall

textbook is based upon students reading a chapter and then answering questions that recall factual information from the chapter. In addition, the reading strategies recommended at the beginning of each section involve recall strategies. For example, in the first section of the textbook, the reading strategy guides the reader to list the steps of the scientific method. While some questions at the end of each chapter do encompass more critical thinking, there is a lack of posed, guided opportunities for the learner to think about their thinking. The learner is drilled to read the content and recall the material. The core of the curriculum is focused on independent student work that lacks the instructional approaches that facilitate metacognition and long-term conceptual understanding. The teacher's guide does however suggest that teachers address misconceptions and build science skills through strategies such as comparing and contrasting.

**Conceptual understanding.** Prentice Hall's curriculum includes end-of-the-unit exams and is in the process of developing formative assessments. However, the textbook's curriculum lacks diagnostic exams and guided opportunities to illicit prior knowledge from the reader to facilitate conceptual change. The textbook's assessments are focused upon the learner's knowledge at the end of the chapter readings. The Prentice Hall curriculum lacks a monitoring system for the learner to track their own progress and to metacognitively reflect on their learning and progression throughout the unit.

**Self-Efficacy.** The Prentice Hall curriculum is not centered upon engaging activities or student choice, which are two key components for promoting motivation and self-efficacy (Deci, 1996; Zemelman, Daniels and Hyde, 2005). Some of the chapters contain an inquiry lab in the teacher guide that is centered on student engagement. There



is also a section called “Issues in Biology” which offers occasional questions that facilitate student choice on a research issue in biology. These two curricular activities are side-notes to the textbook however. The curriculum primarily requires students to read the chapters and answer questions. In addition, there are worksheets that complement each chapter and an end-of-unit summative assessment. The Prentice Hall curriculum does not allow for student choice and lacks a foundation in engaging activities. In these ways the textbook does not cultivate self-efficacy.

### **Biology: A Community Context (BACC)**

BACC is a biology curriculum designed to meet the National science standards (National Department of Education, 1996). It is different from traditional curricula. It is designed to be more student-centered, to be more inquiry oriented and to have greater emphasis on a few central concepts rather than covering the whole content of biology (Leonard, Speziale, & Penick, 2001).

The BACC textbook is half the size of other typical high school biology texts. The reading level is appropriate for average 9th and 10th grade students (Leonard, 2001). Far fewer vocabulary words are introduced than in typical traditional biology textbooks. Text questions focus on analysis and interpretation of the activities, not factual information from the reading.

The student textbook is divided into 8 units designed around themes, problems and inquiries. The 8 units are: “Matter and Energy,” “Ecosystems,” “Populations,” “Homeostasis,” “Inheritance,” “Behavior and the Nervous System” and “Biosphere.” Important biological concepts are returned to and developed in multiple inquiries, often in several units. A unit begins with an inquiry lab and guided inquiries. The labs are

followed with readings, group discussions and extended activities. A typical unit organization is illustrated in Table 1.

**Table 2:** BACC Unit One Example

| Unit 1: Matter and Energy for Life      |
|---|
| Initial Inquiry                         |
| The Biology of Trash                    |
| Guided Inquiries                        |
| 1.1 A Trash Audit                       |
| 1.2 Composting                          |
| 1.3 Decomposition Through Contamination |
| 1.4 Mystery Bags                        |
| 1.5 Modeling Biological Molecules       |
| 1.6 What Lives in Compost?              |
| Conference                              |
| Extended Inquiries                      |
| Congress                                |
| Forum                                   |
| Summary of Major Concepts               |
| Suggestions for Further Exploration     |

The BACC curriculum intentionally reduces the number of concepts introduced so that students can experience inquiry which generally takes longer than more traditional direct instruction (Leonard, Speziale, & Penick, 2001). BACC does not include some traditional biology content and omits much of the detail found in more traditional high school texts. For example, BACC does not include discussions of electron configuration, specific information about different kinds of chemical bonds, discussion of condensation and hydrolysis reactions or detailed information about the structure and function of cell organelles. BACC also does not contain plant and animal dissections and much of the detailed knowledge of taxonomy, anatomy and physiology included in traditional biology courses. Instead the textbook focuses on studying fewer concepts with more investigations and student-centered activities. There is far more emphasis in BACC on

doing and discussing investigations and on the nature and process of science than in traditional curricula and far less emphasis on vocabulary and factual material.

**Metacognition.** BACC advances a curriculum in which students actively build meaning from experiences and social interaction rather than passively receiving knowledge. The focus is on the students actively investigating biological processes and discussing their ideas. In the first part, “Exploration,” students begin with concrete experiences, ask questions, make predictions and make observations. The teacher's role in the BACC curriculum is to create a classroom climate where students experiment, communicate and think (Leonard & Penick, 1998). Many of the activities in BACC promote metacognition, but there is a lack of explicit teaching of metacognitive awareness and reflective journaling.

**Conceptual understanding.** BACC curriculum adds layers to the typical summative assessment at the end of the unit by eliciting prior knowledge and promoting conceptual change. During a reading component, questions focus on analysis and interpretation of the activities, not on factual information from the reading. Two sets of self-check questions are provided for groups to further develop the concept, the second set requires more sophisticated analysis about, for instance, the role of science and scientists in society. There are also companion conferences that focus on scientific communication students write and present an abstract of one of their investigations in the curriculum. Then the class decides on an investigative plan. Each group of students is assigned research and role to play in the simulation. In addition, a multiple choice summative assessment is provided for each unit. These additional assessments allow for a

more reflective process than traditional methods, but there is a lack of reflective journaling on assessment and tracking of the learner's progress.

**Self-Efficacy.** BACC's constructivist curriculum is consistent in content and pedagogy with the National Science Standards, in that it requires students to engage in reflective inquiry. As a result, the curriculum affords more opportunities for the students to connect with the content thereby increasing student motivation and self-efficacy. BACC offers students choices in investigative approaches for experiments and lab reports. Students can select topics of interest and investigative questions to research, thereby supporting student motivation and self-efficacy.

### **Sweetwater Union High School District Biology Curriculum Unit**

The Sweetwater Union High School District Biology Curriculum is aligned to district and California State Science standards (California Department of Education, 1998). The curriculum focuses a great percentage of its attention to vocabulary acquisition techniques. The curriculum also recommends pedagogical techniques which permit students to conceptualize and visualize biological processes since much of the information in biology concerns processes which cannot be seen. This curriculum recommends that laboratory work be a vital component in the science experience and should comprise approximately 40% of instructional time. Acquisition of quantifiable data, manipulation of the data through graphs, and formulation of conclusions based on results are also key components of the curriculum. This curriculum has four summative assessments that mimic the state standards test.

**Metacognition.** The Sweetwater biology curriculum uses a combination of the adopted textbook, laboratory activities and real-world/authentic experiences. The

textbook is designed around dense facts and readings. The laboratory activities are step-by-step or “cookbook” experiments with given procedures that students follow to suitable outcomes. For example, the first recommended lab is called “What causes phenol red to change color?” It involves mixing 6 different pre-determined substances and then students figure out which substances cause the chemical to change color through the scientific method. There is a lack of guided deep reflective thought opportunities. Other activities are included such as role-playing and literacy strategies such as Venn diagrams. These elements do not support metacognition fully in a science classroom but could be more conducive to metacognitive thinking processes if they were inquiry-based and involved more reflective thinking. Also, the focus on summative assessments in this curriculum neglect to facilitate the monitoring process for metacognition.

**Conceptual understanding.** This curriculum has some embedded graphic organizers that elicit prior knowledge and create connections between vocabulary words. In addition, there are some literacy strategies used in the genetics section that ask for students’ personal experiences and connections to the content.

The Sweetwater district curriculum offers standards-aligned multiple choice tests for each major unit that serve as summative assessments. This form of assessment shares similar deficiencies with the Prentice Hall assessments because again, they focus on learning for assessments rather than on assessing to learn. There is a lack of diagnostic and formative assessments with reflective journaling or metacognitive thinking strategies that facilitate conceptual understanding in this curriculum.

## Conclusion

The curricula reviewed do not incorporate all of the elements of metacognition, self-efficacy and conceptual understanding. Table 2 summarizes the three curricula reviewed according to organization, strengths of curriculum and needs of curriculum.

**Table 3: Overview of Biology Curricula**

| Name of Curriculum  | Organizational Overview of Curriculum   | Strengths of Curriculum  | Needs of Curriculum  |
|---|---|--|--|
| Prentice Hall Biology (Pearson, 2007)   | Content Readings<br>Follow-up Questions<br>Unit Experiment<br>Issues in Biology<br>Multiple Choice Questions and Assessments<br>Summary and Extension Questions | Standards-Based  | Promotion of Self-Efficacy: Student choice and engagement<br><br>Promotion of Conceptual Understanding<br><br>Metacognitive Strategies                     |
| Glencoe's Biology: A Community Context (McGraw-Hill, 1998)  | Initial Inquiry<br>Guided Inquiries<br>Content Readings<br>Extended Inquiries<br>Class Discussion<br>Summary<br>Further Exploration                             | Standards-Based<br><br>Promotes Self-Efficacy<br><br>Promotes Conceptual Understanding | Metacognitive Strategies<br><br>Promotion of Conceptual Understanding Through Reflective Assessments   |
| Sweetwater Union High School District Biology Curriculum Unit (Sweetwater Union High School District, 2006) | Content Readings<br>Unit Experiments<br>Literacy Strategies<br>Multiple Choice Questions and Assessments<br>Summary and Extension Questions                     | Standards-Based<br><br>Promotes Conceptual Understanding through Literacy Strategies   | Promotion of Self-Efficacy: Student choice and engagement<br><br>Promotion of Conceptual Understanding Through Assessments<br><br>Metacognitive Strategies |

Although the Prentice-Hall and BACC are both textbooks, their curriculum guide is philosophically different. The Prentice-Hall model, which is similar to the Sweetwater District curriculum, follows a traditional model of reading a chapter, answering questions, performing an experiment and taking a test. The Prentice-Hall curriculum does not facilitate the constructs of metacognition, self-efficacy and conceptual understanding. The BACC curriculum structures their units according to inquiry-based instructional strategies which foster metacognitive thinking and student self-efficacy, but it lacks an in-depth reflective assessment that leads to conceptual understanding. Metacognition, conceptual understanding and student self-efficacy are all constructs found in the research to be beneficial in facilitating learning and effective teaching. In the next chapter, a curriculum is outlined in which these three elements are combined in a *Biology Reflective Assessment Curriculum*.

## ***V. Biology Reflective Assessment Curriculum***

My recollections as a middle school and high school student are filled with memories of cramming for some type of unit test which represented the culmination of one unit, and the commencement of the next. Later in college, the summative unit test was replaced with the even higher stakes midterm and final. Fast forward to my own experience as a teacher evaluating different curricula and again much of the same is repeated; a pervasive focus on summative assessments, the majority of which take the form of multiple-choice exams. Reeves (2001) used a medical analogy to contend that if learning-oriented, formative assessments are like physical examinations, the summative assessments I've described are comparable to autopsies. Summative exams are intended to evaluate learning, not to inform learning. Indeed, in practice they identify learning failures after-the-fact. Instead, there is a need to assess student progress throughout the school year while there is still time to implement interventions that increase student learning.

*Biology Reflective Assessment Curriculum (BRAC)* relies on the constructs of metacognition, self-efficacy and conceptual understanding to promote students' understanding of their learning and to help them regulate their own metacognition. In order to accomplish these outcomes, *BRAC* has three goals. Through reflective assessment, *BRAC* seeks to enhance students' own learning through self-reflection, deepen their conceptual understanding of biology, and develop their self-efficacy in learning. The teaching practice of reflective assessment measures students' current understanding and in turn provides immediate and useful feedback to students. The assessments in this biology curriculum include reflective activities that require students to



use metacognitive skills to work independently and collaboratively. The curriculum concludes with a culminating natural selection task that applies metacognitive strategies to biology content.

*BRAC*, which can be adapted to any discipline, encourages students to engage in activities that require them to assess their learning and create goals as they study evolution. The collaborative component of the curriculum asks students to consult with classmates about their goals and curriculum choices to relearn or further their learning through a selection of differentiated lessons. Student learning is assessed and the unit is evaluated based on five sources of data: reflection journals, surveys, observations, culminating task and assessments. The curriculum, then, uses formative assessments throughout the study of evolution. This chapter provides an overview of the goals, educational constructs, and curricular activities of the Biology Reflective Assessment Curriculum that relies on such ongoing reflexive and formative assessment.

## **Goals**

The overarching goal of *BRAC* is for students to reflect on their own processes of learning biology in order to become both thoughtful learners beyond the science classroom and learners who generalize their insightful abilities into habits. Through *BRAC*, students are asked to apply reflective thinking to their learning and to develop their conceptual understanding of biology so they develop self-efficacy as learners.

**Goal 1: learning and applying metacognition.** The first goal of *BRAC* is for students to learn reflective strategies. Students learn in a powerful way when they are asked to think about and explain how they are learning. Metacognition, or thinking about thinking, may increase learning outcomes. Moreover, by engaging students in the

consideration of the processes and strategies that help them learn, they may be more apt to replicate those outcomes independently (Flavell, 1979).

**Goal 2: developing conceptual understanding.** The second curricular goal of *BRAC* is for students to develop their conceptual understanding of evolution. In order to understand the concepts of evolution, students choose class and curriculum activities. Reflective assessments are used as tools for students to make their choices. Students reflect upon assessments and choices while they connect their learning experiences to a conceptual understanding of evolution.

**Goal 3: promoting self-efficacy.** The third goal of this curriculum focuses on helping students promote their self-efficacy. Self-efficacy will be used as an indicator of motivation. Specifically, self-efficacy is measured through student work, journal responses, survey responses and behavioral observations. A student's self-efficacy can be enriched through this empowerment of selection and self-knowledge. For example, students in the *BRAC* classroom will set learning goals and choose from a collection of learning strategies to improve their conceptual understanding

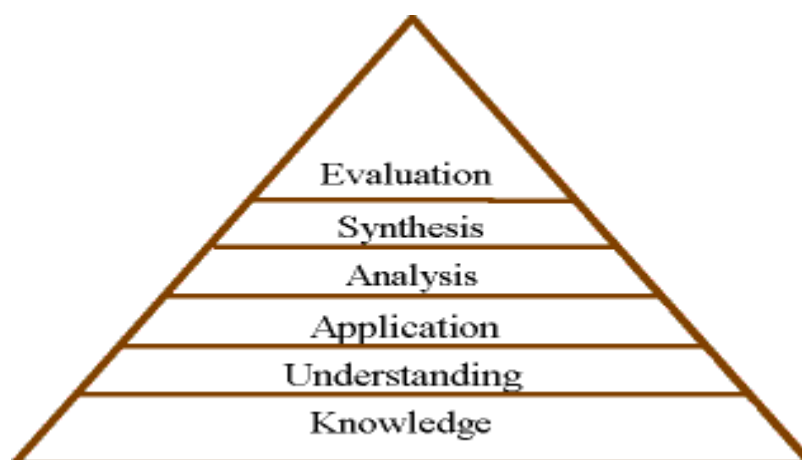
## **Constructs**

The education constructs of metacognition, self-efficacy, and conceptual understanding are embedded in *BRAC*. As examined in Chapter Four, these educational constructs are valuable parts of student learning yet have not been completely incorporated into the existing state-adopted curricula

**Metacognition.** Metacognitive strategies are foundational to this curriculum, which regularly prompts students to observe models and practice metacognitive strategies. Students learn concepts through inquiry labs, readings and activities while

reflecting on their learning using quick writes, graphic organizers and quizzes. Students formulate their own goals and choose successive activities in an ongoing or new topic. Their choice of topics is based on their level of understanding which is self-assessed using Bloom's taxonomy (Bloom, 1956).

Bloom (1956) developed the concept of the cognitive domain. This includes the recall or recognition of specific facts, procedural patterns, and concepts that serve in the development of intellectual abilities and skills (Smith, 1970). There are six major categories, which progress in complexity. That is, the first one must be mastered before the next one can take place. Figure 1 is a representation of Bloom's taxonomy.



**Figure 1:** Bloom's Taxonomy (Schultz, 2005)

After using Bloom's taxonomy as a tool to identify their level of understanding, they select a new activity from among a bank of activities differentiated for level based on Bloom's hierarchy. Students write about their learning and choices in their journals.

**Self-Efficacy.** Self-efficacy is commonly defined as the belief in one's capabilities to achieve a goal or an outcome. Students with a strong sense of efficacy are more likely to challenge themselves with difficult tasks and tend to be intrinsically motivated. These

students will put forth a high degree of effort in order to meet their commitments, and attribute failure to things under their control, rather than blaming external factors. Self-efficacious students also recover quickly from setbacks, and are ultimately likely to achieve their personal goals (Bandura, 1986 & Margolis and McCabe, 2006).

*BRAC* works best in a classroom where the teacher and students have developed a culture that promotes students' sense of self-efficacy. This kind of environment instills mutual respect between teachers and students from the beginning of the school year so students understand that the classroom is a safe and considerate environment that is focused on learning. In this curriculum, students build on their knowledge, create learning goals in their journals and communicate goals to other classmates in a courteous setting. Next, students are encouraged to choose tasks that allow for learning at their level and interest. The assessments used in *BRAC* are low-risk and are used as guides for learning. The low-stakes environment encourages risk-taking and communication which are important for student self-efficacy.

**Conceptual understanding.** Conceptual understanding is achieved when students develop more than just textbook knowledge and skills to solve problems at the ends of chapters, but when they develop a deeper understanding of the material. Conceptual understanding is what endures after details are forgotten, and it may be applied in unfamiliar situations. The very nature of concepts, principles, key ideas and processes requires them to be understood rather than simply learned. Learning in this sense refers to a basic understanding of the topic and application of that understanding in a limited number of contexts. Simple familiarity with subject matter and related skills does not automatically lead to conceptual understanding because success may be achieved by

memorizing or frequent practice. Traditional tests are designed predominantly to gain evidence of factual knowledge and problem-solving skills, but they fail to expose a lack of conceptual understanding. Therefore the assessment of conceptual understanding requires methods other than traditional tests such as performance tasks (Wiggins and McTigue, 1998).

In *BRAC*, students demonstrate their conceptual understanding through assessments such as graphic organizers, quick writes, quizzes and a culminating task. In addition, students write regularly in their journals in order to record and observe the development of their conceptual understanding of evolutionary relationships.

### **The Curricular Activities of *BRAC***

*BRAC* is comprised of three phases that can be intertwined and used simultaneously during implementation. Phase 1 occurs pre-implementation and is an introduction to self-reflection and supportive learning strategies. During Phase-1 students carry out a variety of activities to support their learning in Phases 2 and 3. In Phase 2 students learn the principles of Bloom's taxonomy and how to use it as a tool to diagnose their levels of understanding. Phase 3 begins by learning or re-learning metacognitive strategies that encompass the stages of planning, monitoring and evaluating.

Phase 1 describes the period prior to the formal implementation of *BRAC*. In the first phase, foundational strategies are taught which help to lay the groundwork for later instruction. This phase incorporates curriculum that elicits students' prior knowledge and allows students to share their thinking. The list of preparatory activities is aligned with the curriculum's goals in Table 3.

**Table 4:** Phase 1 of *Biology Reflective Assessment Curriculum*

|           | Activities                                | Goal 1: learning and applying metacognition | Goal 2: improving conceptual understanding | Goal 3: developing self-efficacy |
|-----------|---|---|--|----------------------------------|
| Phase one | K-W-L                                     | X   | X  |                                  |
|           | Double-entry science interactive notebook | X   | X  | X                                |
|           | Think aloud                               | X   | X  |                                  |
|           | Cornell notes                             | X   | X  |                                  |
|           | Socratic seminars                         | X   | X  | X                                |
|           | Talk to the text                          | X   | X  |                                  |
|           | Pro-con grid                              | X   | X  |                                  |
|           | Science analogies                         | X   | X  |                                  |
|           | Reading inventory                         | X   |  |                                  |

During Phase Two, students learn the principles of metacognition, Bloom's taxonomy and how to use Bloom's taxonomy as a tool to diagnose their levels of understanding of the content using assessments. Table 4 summarizes activities for Phases Two and Three as they align with curricular goals.

**Table 5:** Phases 2 and 3 of *Biology Reflective Assessment Curriculum*

| Phase   | Activities                          | Goal 1: learning and applying metacognition | Goal 2: improving conceptual understanding | Goal 3: developing self-efficacy |
|---------|-------------------------------------|---|--|----------------------------------|
| Phase 2 | Bloom's connections                 | X   | X  |                                  |
|         | Bloom's questioning techniques      | X   | X  |                                  |
|         | Being metacognitive mini-lessons    | X   |  |                                  |
| Phase 3 | Planning - reflection journal       | X   | X  | X                                |
|         | Monitoring-individual learning plan | X   | X  |                                  |
|         | Monitoring – learning portfolio     | X   | X  | X                                |
|         | Evaluation - culminating task       | X   | X  | X                                |

Phase 3 incorporates the three stages of metacognition: planning, monitoring and evaluating. Initially, students write about their learning in their journals using embedded evolution content assessments as guiding tools during the planning stage. Then they develop goals, and receive and give consultations on their action plans to relearn or extend their learning with collaborative groups. Next, during the monitoring phase, students develop a learning plan and create a record of their work in a learning portfolio. Lastly, the evaluation phase involves students demonstrating their knowledge and reflection abilities through a culminating task. These stages help students pose study questions for themselves, explore the consequences of their decisions and actions, reflect on how they learn, and check for conceptual understanding.

### **Conclusion**

BRAC embeds assessments as a tool for learning. In this curriculum, formative assessments guide students in selecting their next instructional steps during the process of learning biology. Instead of employing a summative assessment alone, students use assessments to gather feedback and reflect upon their learning. As a result, this curriculum results in differentiated instruction that cultivates conceptual understanding and self-efficacy through fostering metacognition.

## **VI. Implementation of *Biology Reflective Assessment Curriculum***

### **Setting**

I currently teach biology at Cougar High School located in an urban, low-income school district. This district is comprised of thirteen high schools and eleven middle schools. The district includes both high-performing schools and program-improvement schools. Some of the schools have reached the state's target goal of 800 on the Academic Performance Index (API) and some are far below the target API.

**Description of school setting.** Cougar High School is located within two miles of the U.S.-Mexican border near a municipal airport and a higher education center. The school enrolled 2,501 students in 2008-2009. Nearly 75% of the students qualified for free- or reduced-price school meals, and 94% qualified for Title One federal funding. Title One supplemental funds aim to bridge the gap between low-income students and other students. This U.S. Department of Education program provides financial assistance to schools with high percentages of low-income and at-risk children to help ensure that all children meet challenging state academic standards.

The student body is 92% Latino, 4% Filipino, 2% African-American and 2% from other groups. An average of 13% of the student body is new each year. English Language Learners, comprise 46.5% of the students. 13% of the students are in the Special Education (IEP) Program, and 15% of the students are placed in the Gifted/Talented (GATE) program. The majority of the teaching staff holds a single subject secondary credential in their content area. The average classroom size in science is 26.



Students at this high school perform below both the state average and the state's target goal of 800. The API score increased from 651 to 655 in 2009. Twenty-five percent of the ninth grade students scored proficient or better on the English standards-based tests compared to the 50% state average. The ninth grade students scored proficient or better on the Algebra One standards-based test at the same rate as the state average, 11%.

This high school provides systems for additional academic support. Students are able to receive tutoring after school in math, English, science and history. For students who do not meet proficiency on district assessments, math and English tutoring are required. Students can also make up credits from failed classes through a program that occurs before school called credit recovery.

The classroom operated within district, state and federal contexts and these contexts influenced several aspects of this project. Outside pressures from the classroom included District-mandated assessments and intervention in addition to state and federal testing. At Cougar High School, students were required to take a district content test every eight weeks that mimicked state and federal testing. Students who did not meet proficiency standards were assigned mandatory tutoring interventions through the administration and teachers. As a result, these assessments had high-stakes association for students rather than providing a more productive and non-threatening environment to identify and correct problems in learning and instruction. Maximizing diagnostic information concerning students' errors in understanding would have encouraged feedback and promoted active reflection that enhances learning. Unlike the existing

system of assessment, *BRAC* capitalized on using reflective assessments as a tool to guide student choice and facilitate metacognition.

Another factor that affected the design of this curriculum was the wide range of abilities in the classroom. The biology students ranged from students who were classified as English Language Learners, Special Ed and Gifted. In order to meet the needs of all abilities and learning styles in the classroom, *BRAC* used a variety of instructional strategies and assessment methods. This curriculum implemented a mixture of learning approaches that were selected by students.

Student choice and interests were central components of *BRAC* because of the demographic of students and their learning context. These aspects are generally beneficial components of any curriculum design, but can be especially useful for an underachieving student population which is sometimes subjected to over-testing and drilled instructional practices in the classroom.

**Description of classroom setting.** I taught the *BRAC* to one of my biology classes. This biology class had a range of students from ninth to twelfth graders. Many of the activities were implemented from the beginning of the school year and used periodically as students moved through the curricular units. The high school has a modified block schedule. Monday through Thursday students have two-hour blocks and on Fridays the schedule is a traditional six-period day. I taught this curriculum each week on Tuesdays and Thursdays (in two-hour blocks) and on Fridays (a 55 minute period).

### **Teaching and Learning Prior to Implementation – Phase 1**

Phase 1 describes the period prior to my formal implementation of this curriculum. In Phase 1, I taught foundational strategies which helped to lay the

groundwork for later instruction. Since effective curriculum elicits students' prior knowledge and allows students to share their thinking, these foundational strategies included a K-W-L chart (Ogle, 1986). A K-W-L elicits prior knowledge by asking students what they already know (K), then asks them to set goals specifying what they want (W) to learn by collaborating as a classroom unit or within small groups, and lastly asks students to discuss what they had learned (L) upon completion of the unit.

K-W-L was an introductory strategy that provides a structure for learning what students know about a topic, what they want to know, and finally what has been learned and is yet to be learned. Students categorized information about the topic that they expected to use. Students applied higher-order thinking strategies which helped them construct meaning from what they read and helped them monitor their progress toward their goals. Different columns were added to a K-W-L chart for extension questions and metacognition. I asked my students to add an "H" column in order to elaborate on How they learned information in the "L" column, a metacognitive task.

Other tools I used throughout the school year for introducing new topics were double-entry notebooks and dialogue journals (Staton, 1987). Double-entry science notebooks facilitated writing through a student-teacher written conversation in such a way that students could determine what they knew or did not know about a topic. The entire left and right pages of the journals were used for different purposes. The right page of each journal was for notes taken about information in a lecture, a book or a video. On the entire right page of the double-entry journal, students might be prompted to select words, short quotations, or other passages or features of the text that interested or confused them or that elicited a strong response. They recorded the word, quotation or

brief passage, either verbatim or in paraphrased form. The entire left page of the notebook was reserved for students' expression of information in their own way and could even include song lyrics or poems. This is where students recorded their reactions, interpretations, reflections or other responses to the text segments or features they selected. These entries could influence learning by revealing problems, questions, connections, and concerns.

I frequently used the think-aloud as a strategy to model metacognition and to collect observations about students' higher-level cognitive processes as proposed by Ericsson & Simon (1984). Think-alouds are known to improve children's metacognitive abilities (Baumann, Jones, & Seifert-Kessell, 1993), model and assess thinking of students who speak English as a second language (Mangubhai, 1990), and allow students to reflect on their own thinking processes (Baker & Brown, 1984). I modeled by saying aloud what I was thinking when reading, solving problems, or responding to questions. I demonstrated think-alouds to model practical ways of approaching difficult problems while bringing to the surface the complex thinking processes that underlie reading comprehension, problem solving, and other cognitively demanding tasks. Students then demonstrated the process of verbalizing their inner dialogues and thought processes. As a result, this practice helped students gain insight into their thinking and allowed both teacher and student to diagnose their strengths and weaknesses.

To help students begin to be more aware of their thinking processes they were provided with sentence starters, such as: So far, I've learned\_\_\_\_; This made me think of\_\_\_\_; That didn't make sense because \_\_\_\_; I think \_\_\_\_ will happen next; I reread that

part because\_\_\_\_; I was confused by\_\_\_\_; I think the most important part was\_\_\_\_; That is interesting because\_\_\_\_; I wonder why\_\_\_\_; and I just thought of\_\_\_\_\_.

I also used Cornell Notes each week prior to the implementation of a new topic (Pauk, 1962). Students would record, question, recite, reflect and review when taking Cornell Notes from a textbook. Cornell Notes helped students take detailed and organized notes on materials from textbooks and class. They also allowed students to be actively engaged during note-taking, helped them to strengthen their writing skills, and to summarize and reflect on what they learned. I asked students to divide the paper into two columns. The right column was three-fourths the size of the page and was used for recording notes from a book or lecture. The left column was used for writing questions during and after the lecture or reading. Students wrote questions to clarify meanings, reveal relationships, establish continuity, and strengthen memory.

I encouraged students to review the information in their Cornell Notes by reading the notes aloud, putting them into their own words, and answering their own questions. At the end of the students' notes there was a section for a summary or reflection. I asked students to reflect on the material by asking questions including those I modeled such as: "What's the significance of these facts?" "What principle are they based on?" "How can I apply them?" "How do they fit in with what I already know?" and "What other questions do I have?"

I also used pro-con grids to help students clarify their own thinking and access their prior knowledge (Thomas, 1993). Two to three times a semester students wrote down the pros and cons of an issue or question that they posed themselves or which the teacher or another student posed. The issues were typically controversial requiring

students to consider topics such as genetic engineering. Pro-con grids facilitated student discussions. Students learned to analyze data and make their own informed decisions by developing the ability to weigh competing factors and examine both sides of an issue.

In addition to using grids, students created analogies to build conceptual bridges between what was familiar and what was new. I used analogies to introduce students to concepts that represented complex, difficult-to-visualize systems with interacting parts. For example, I compared protein synthesis in a cell to shoe production in a factory. On an almost-daily basis, I modeled how a particular scientific concept or process resembled more familiar and recognizable concepts and processes.

I used additional strategies to help students read the text such as a reading inventory, talking to the text and reading survey (Schoenbach, R., Greenleaf, C., Cziko, C., & Hurwitz, L.1999). At the beginning of the year, students took a reading survey and in the double-entry science notebook they began a list of strategies that help them understand written text. Although the list was different for each class, there were similar strategies such as rereading the text. I added to this list throughout the year based on the strategies students discovered and found useful. One specific strategy I taught was talking to the text. Students would have a “conversation” with the text using pictures, words or symbols. As a student thinks of a question or discovers a new idea, the student writes along the text of the reading. The purpose was for the reader to be actively involved in the text in their own way as they read.

### **Implementation – Phases 2 and 3**

**Day 1** Day 1 consisted of students filling out surveys and my introduction to Bloom’s taxonomy and metacognition. One survey obtained students’ initial beliefs about

evolution before they began learning the concepts of evolution in the classroom. Given the sensitive nature of this topic, I felt it was important to learn what I could about student beliefs about evolution. Since I was new to this school, I began by asking my science colleagues their opinions about typical student beliefs regarding evolution. Most of my colleagues said that students do not disagree with evolution and accept it or come into the class without a strong opinion about the subject. The contradiction to my colleagues' opinions was evident immediately before I passed out the surveys when one student asked, "Are we going to learn about how humans came from monkeys?" This idea seemed to be a common idea in the classroom.

After taking the pre-unit evolution survey, I asked students to take two surveys online in the computer lab. One survey was a metacognition survey, thinking about one's own learning survey, and the other was a self-efficacy survey. Both are located in the appendix. Both surveys contained statements that followed with a self-rating that ranged from Almost Never to Almost Always. I also administered a written-response metacognitive survey.

Next we discussed the learning objectives using classifications from Bloom's taxonomy. Then I distributed a short reading on Tree Frogs. We read the learning objective associated with this reading and then together we read the article. Following this reading I asked how these tree frogs would be studied in their natural environment. Then students read sample assessments and graded them based on Bloom's rubric. They recorded their scores on the assessment and then discussed them with their groups. I provided the correct scores for each sample assessment. Students wrote about this use of Bloom's taxonomy and whether they thought it would be helpful for future assessments.

They also described their insights regarding potential ways that they could relearn or further their learning once there was an understanding of the material. Lastly, the students answered an anticipatory evolution vocabulary sheet.

**Day 2.** The next day began with the content of evolution through a lab and ended with an activity using Bloom's taxonomy. The warm-up was a K-W-L on evolution. I asked students to fill in the K portion of the chart and then share with their partners. Then students came to the board to write information from their own K-W-Ls to share with the class. Next I asked students to write questions in the W portion of the chart and share with their partners. Students asked questions such as "What is evolution?" and "Why do we have to learn about evolution?"

Subsequent to the K-W-L chart, students performed and designed a natural selection lab. In this lab, students acted as birds that were competing for resources with other birds. They created lab analysis questions based on Bloom's taxonomy for other lab groups. After the lab we discussed natural selection through sexual selection. Students generated questions for discussion and classified their questions using Bloom's taxonomy.

After the lab and natural selection analysis questions, I assessed students' understanding of natural selection through a quick-write. Students wrote on the following in their reflective journals: "How well do you understand natural selection?" "Give an example of natural selection." "What helped you to understand natural selection?" and "What helps you to learn new ideas?" For homework, students were assigned to complete Cornell Notes for the related chapter in the textbook.



**Day 3.** The warm-up for Day 3 was a discussion in which I posed a question: “What is science and what is not science to you?” I asked students to write examples and discuss their warm-up with their partners. Then I asked six randomly selected students to write one thing from their warm-up on a T-chart on the board. The T-chart was a giant “T” on the board and contained two columns: Science and Not Science. Some common terms for science were: nature, animals and microscopes. Initially there were not many common answers for the column under Not Science, although two of the most common answers were religion and evolution. Later we had a discussion on students’ choices for what is science and we deduced that science included observable phenomena such as animals, but it also required evidence.

Defining what science is not was more difficult for students. I posed some questions about things I had seen on TV. I said, “I sometimes watch shows where they hunt ghosts or aliens. Is this science?” There was definitely a mixed response to this question. Students argued that these shows used machines and experiments to find ghosts. My student Misael said: “Yes, ghosts are science, they have taken photos of them.” After much debate, we put aliens and ghosts to the test of whether they were observable and if there was evidence for them. We finally put the two in the category of something that is not science and classified them as beliefs based on the lack of evidence. In order for something to be explained through science, it needs to be repeatable and substantial evidence needs to exist. For example, the class discussed how ghosts may be real, but are not something repeatable that can be studied such as a plant growing. A student asked, “What about religion?” and many students responded that it would be classified as a belief.

After the warm-up and beliefs T-chart, I passed back the natural selection assessments with the learning objective from the previous day. Students practiced grading their own assessment and another student's quick-write using a Bloom's rubric. Then I asked students to write in their journals about why they chose the scores they had given themselves and their partners. At that point, I distributed the scores based on the rubric to the students and asked them to examine the choices I provided to relearn the material or further their learning about natural selection. These choices varied from completing an online lab to creating an illustration of natural selection depending on where each student fell on Bloom's taxonomy. The rubric was on a scale of zero to three. For example, if a student scored a 1 which corresponds to the remember level of Bloom's taxonomy, that student was given suggested choices such as a vocabulary building exercise. Next students developed a learning plan based on the instructional choice they felt best suited their learning of natural selection. They recorded this plan in their journals and then began working on it. At the end of class, I asked students to respond to the following questions: "How did Bloom's taxonomy help or not help you understand your own learning?" and "How can it help or not help you make decisions for activities after an assessment to help you further your learning?" Their homework was to finish this instructional choice based on their learning plan.

**Day 4.** The next day I directed students to perform a natural variation lab. Students collected data on each other's height, arm and leg dimensions and analyzed the variation within the class population. After the lab, students worked in groups to create lab analysis questions using Bloom's taxonomy, and then each group shared their questions with other groups. We ended the lab with a discussion of the importance of

natural variation in a population in order for natural selection to occur. This discussion was facilitated by student-generated questions classified according to Bloom's taxonomy. I assessed the students through a quick-write and assigned Cornell Notes on natural variation.

**Day 5.** The following day I passed back the assessments on natural variation with a score. Students then developed a learning plan with an instructional choice in their reflective journals. Students spent most of the day relearning or furthering their learning on natural variation, which was based on their instructional choice.

After students worked on their instructional choice, we discussed the learning portfolio and culminating performance task. For the learning portfolio, I asked students to begin thinking about which pieces of work from this unit would best represent their learning throughout the unit. I also gave the requirements for the performance task to the class. The performance task combined a case study on evolution and the application of the natural selection concept to the students' personal lives, often referenced in the culminating task as "my hood." Lastly I carried out a mini-lesson on metacognition that involved student journal responses and a class discussion. Students responded in their journals to these questions: "What is metacognition?" "When have you been or not been metacognitive in your own life?" and "What was the outcome?"

**Day 6.** I administered a ten-question, multiple-choice assessment on natural selection and natural variation to identify any changes students had made in their instructional choices. We discussed metacognition again, and then students began their first outline of the culminating task and found examples of natural selection in their own lives.

**Day 7.** I returned the scored assessments and asked students to reflect in journals about their learning progress. Students also developed a learning plan with their own selected instructional choice. I allocated forty-five minutes for students to complete their instructional choice. As a class, we reviewed a cartoon and reading that distinguished Darwinism from Lamarckism, and then the class participated in a competition in which students were given a puzzle. The puzzle was comprised of Darwin and Lamarck's ideas through a cartoon depiction. Students had to match the correct ideas with cartoons. Finally, I asked students to finish their instructional choice for homework if they were not able to finish the assignment in class.

**Day 8.** At this point, students had developed a basic understanding of the concepts of natural selection and natural variation. The next idea I introduced was the origins of variation and how variation is maintained or destroyed. I began with a cartoon about mutations. In the comic, a small dinosaur is born with bones slightly lighter than his brother and sisters due to a mutation in his DNA. His family thinks he is a freak, but when a predator attacks he has a slight advantage to escape. He survives and his genes continue on. After this comic, students shared their thoughts with each other and then they performed the tiger lab. In the tiger lab, students play the role of tigers who face population genetics problems when they have a homozygous recessive gene for fur color. The recessive allele or gene is a deadly gene for the tiger yet throughout the students' experience in the lab these deadly alleles will be maintained through heterozygous individuals. This idea was not directly instructed, but hopefully discovered throughout the course of each student's lab experience. At the end of the lab, students were assessed

through a quick write. The class ended with a short story from Africa about malaria and sickle cell anemia called “A Mutation Story.”

**Day 9.** I passed back assessments with a rubric score and students reflected in their journals about their learning progress. Students also developed a learning plan with their own selected instructional choice. I allocated forty minutes for students to perform their instructional choice.

**Day 10.** Students began Day 10 with a short multiple-choice quiz on mutations, natural variation and the heterozygote advantage. The next evolution concept we learned is often referred to as genetic drift. This idea illustrates how variation in alleles and genes in a population can be affected by random events such as natural disasters. I had students perform a genetic drift lab. In this lab, students were able to study two island simulations that they manipulated through random forces. Their results demonstrated genetic drift. After the lab, I assessed students through a quick-write.

**Day 11.** I returned the quick-writes with a rubric score and students reflected in their journals about their learning progress. Students also developed a learning plan with their own selected instructional choice. I allocated one hour for students to perform their instructional choice.

**Day 12.** The last concept we discussed before the culminating task was fossils as evidence of evolution. Students performed a fossil inquiry lab where they played the role of paleontologists and made conclusions based on their findings. In addition, we discussed significant fossil evidence and how the age of fossils is measured. I did not have an assessment for this concept, but I did give the district’s multiple-choice exam of thirty questions on all concepts of evolution.

**Day 13.** I asked students to begin working on their culminating task. The first part of the culminating task involved a case study on a fictional animal population that experiences changes. The students interpreted those changes through evolutionary concepts. The second portion of the performance task asked students to write and illustrate examples of natural selection in their own lives.

### **Summary and Conclusion**

Overall, *BRAC* was implemented productively for many reasons based on observations and collected data that will be discussed in further detail in the next chapter. First, students who had greater gains on conceptual understanding had a higher metacognitive awareness and feelings of improved self-efficacy after the implementation. Second, students reported it was easier to stick with their plans and accomplish their goals in science class after the implementation. Third, students felt more competent when problems arise in science class. Fourth, students' beliefs in evolution became more aligned with scientific concepts and understandings after the implementation. Students' commonly misstated understandings of evolution changed. Finally, students' reported an increased ability to choose specific learning strategies depending on the task on which they were presented.

Phases 2 and 3 of the curriculum encompassed approximately 4 weeks of instruction that was devoted to the scientific ideas of evolution. In addition, phase 1 was taught continually throughout the school year.

Overall, *BRAC* was successfully implemented with these students based on several pieces of data. Students met the goals of the curriculum and even demonstrated

improvement in metacognition, conceptual understanding and self-efficacy through the science curriculum. These findings will be discussed in more detail in the next chapter.

## **VII. Evaluation of *Biology Reflective Assessment Curriculum (BRAC)***

### **Goals**

The three goals of *BRAC* were first, for students to learn about metacognition through reflective strategies and to write about their learning in journals; second, for students to understand the concept of evolution; and third, for the curriculum to help students develop self-efficacy. Throughout the evolution unit, students used assessments as a guide for their learning choices while connecting learning experiences to their conceptual understanding of evolution.

*BRAC* was implemented in one of my biology classes. My data sources were field notes, surveys, journals, student work, assessment comparisons, and rubric assessments of a class of 26 high school biology students. All quantitative survey data were from the entire class.

**Goal 1: Learning about Metacognition.** I administered a metacognitive survey prior to and subsequent to the implementation of *BRAC* to rate students' levels of metacognitive awareness. Throughout the implementation of *BRAC*, I measured the number of metacognitive statements used in students' reflective journals and recorded statements made in class during whole-group and small-group discussion. Finally, I measured the number of metacognitive statements used in the culminating task and compared this measurement to earlier assessments.

**Goal 2: Conceptual Understanding of Evolution.** In order to evaluate conceptual understanding, I compared students' assessment scores to metacognition, beliefs about evolution and self-efficacy. I compared the student's assessment score with



their demonstrated level of metacognitive awareness, their belief system, and their self-efficacy ratings on the survey.

**Goal 3: Developing Self-Efficacy.** I measured the accomplishment of the third goal using three data sources: a self-efficacy survey, field notes, and excerpts from their reflective journals. I administered the self-efficacy survey both before and after the implementation. My field notes recorded students' attitudes, responses, levels of participation during the lesson, student body language, student engagement in the activity and the amount of time engaged in writing. Finally, I compared excerpts from students' reflective journals that related to self-efficacy at the beginning, middle and end of the curriculum.

## **Findings**

### **Finding 1: Students developed metacognitive awareness.**

Students appeared to have learned more metacognitive skills as a result of the BRAC curriculum. Students who had higher assessment scores had higher metacognitive awareness and students also reported selecting more learning strategies after the implementation. It is difficult to observe the development of metacognition. As a result, the data for this finding were based on multiple sources: pre- and post-metacognitive surveys, assessment scores, reflective journals and field notes.

**Metacognitive awareness and assessment.** There was a slight connection between higher assessment scores, which reflect conceptual understanding, and student responses of higher metacognitive awareness on the quantitative metacognitive survey. Generally students with a higher self-identification of metacognitive awareness had higher assessment scores. Eighty-eight percent of the students who scored a 3 and above

on assessments also had an on-average higher metacognitive rating, above a 4 on a 5-point scale. For example, Student 1 averaged 3 on a 4-point scale for assessments and 4.25 on the quantitative metacognitive survey. Both scores fall into the higher range of the class. Table 5 summarizes and compares the average assessment scores with the post-metacognitive survey self-ratings throughout *BRAC*. Students who scored higher on the assessments would generally rate themselves at a higher metacognitive awareness level on the post-survey.

**Table 6:** Assessment Scores vs. Post-Metacognitive Survey Self-Rating

| Average assessment<br>Scores | Post-metacognitive survey<br>rating average |
|------------------------------|---|
| 3 and above                  | 3.97  |
| 2                            | 3.21  |
| 1 and below                  | 3.04  |

However, the reflective journals and the written metacognitive surveys did not demonstrate as direct a connection between metacognitive awareness and assessment scores.

A classification of students' metacognitive awareness was generated based on the student journal responses. Students' reflective journals were a venue for them to express their thoughts on their own metacognition and self-efficacy throughout the unit. Journal responses were classified according to three levels: high, average and low, where high indicated metacognitive awareness greater than the group average.

One common problem with this kind of self-report is deciding which journal responses involve more metacognition. The heuristics used to judge the metacognitive processes were based on studying four main components: planning, information

management, monitoring and evaluation. Planning consists of asking oneself questions about the material before beginning to solve a problem and organizing time to best accomplish goals. Information management is drawing pictures or diagrams to help understanding while learning and trying to translate new information into one's own words. Monitoring is asking oneself periodically if one is meeting the goals. Finally, evaluation involves summarizing what one has learned after solving a problem, and asking oneself if one had considered all options. Based on these criteria, I rated and averaged the reflective journals responses as high, average and low and summarized the findings in Table 6. While the data from the reflective journals do not completely support the previous findings from metacognitive survey results, they do show a slight trend in which students with higher metacognitive awareness had higher assessment scores.

**Table 7:** Reflective Journal Responses

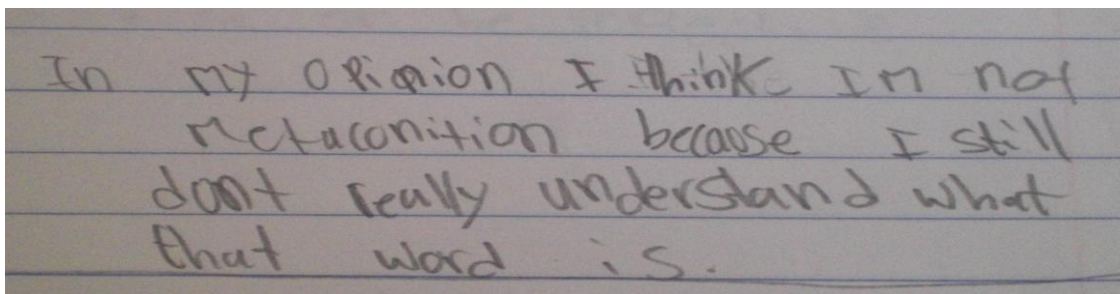
| Average<br>cognition rating | Assessment<br>scores 3 and<br>above | Assessment<br>scores 2 | Assessment<br>scores 1 and<br>below |
|-----------------------------|-------------------------------------|------------------------|-------------------------------------|
| High                        | 13%                                 | 15%                    | 4%                                  |
| Average                     | 50%                                 | 63%                    | 38%                                 |
| Low                         | 37%                                 | 22%                    | 58%                                 |

In my field notes, I also measured the number of metacognitive statement stems used during class discussions and group time for each student. I had a list of student names on a clipboard and I recorded each time a student used a metacognitive stem statement during a class discussion or when students were in their groups. Then I tallied the total of number of statements and compared the students with the highest usage of stem statements to assessments scores throughout the unit. There was no connection

between students who scored higher on assessments and students who used more metacognitive stem statements.

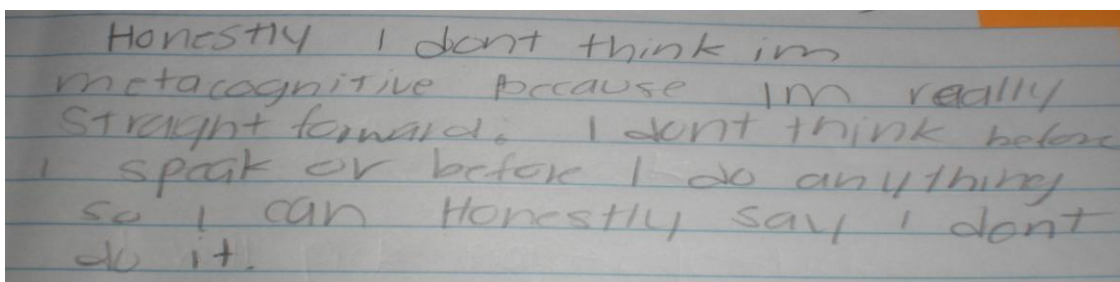
From the literature we know that students who have been taught metacognitive (self-regulated learning) skills learn better than students who have not been taught these skills (B. J. Zimmerman & Schunk, 2001). Students with good metacognitive skills are better critical thinkers, problem-solvers, and decision makers than students without these skills (Bransford, 2000). The research on metacognition suggests that using metacognitive strategies in the classroom can lead to more conceptual understanding, and the survey data from this implementation supports this research.

However, after four weeks of implementation, conflicting findings emerged between the data from the metacognitive surveys and the field notes. In addition, there was divergence between students' journal reflections and my field notes. The reflection journals and metacognitive surveys supported the idea that higher metacognitive awareness is connected with higher assessment scores, but my recorded field notes did not support this finding. A potential explanation for the lack of connection being shown in the reflective journals and field notes relates to the time period of the implementation. Learning about metacognition and its tools takes time and practice. The implementation of *BRAC* was over the course of five weeks. This may have not been enough time to develop students' metacognitive awareness. A majority of the students stated they had no knowledge of the word metacognition before this unit. Also, many students felt they had limited practice as reflective thinkers in the classroom. Figure 2 shows a student expressing difficulty with metacognition.

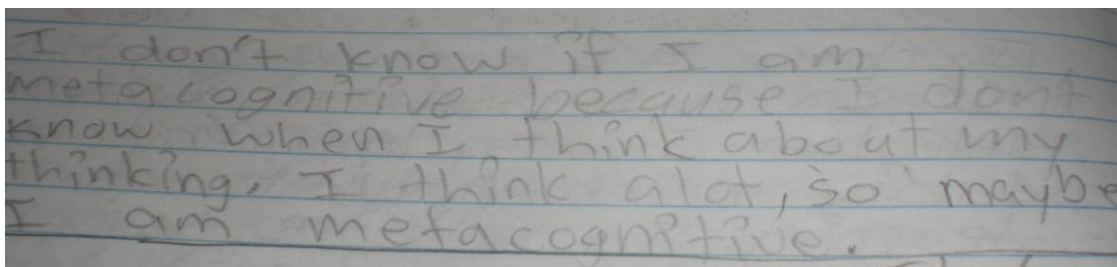


**Figure 2:** Student journal entry 1

From the beginning of the unit, the idea of metacognition was a complex concept for some students to grasp. Throughout the unit, as the ideas of reflection and metacognition became more of a practice through assessments and choice, some students felt their metacognitive awareness was low because they were only beginning to understand the concept of metacognition. For example Figures 3 and 4 show the entries of two students who scored in the upper range of assessments in the class. They rated themselves as having lower metacognitive awareness or indicated they were not sure of their metacognitive awareness in reflective journal entries which were written near the end of the curriculum unit. These students may have been more critical of themselves.



**Figure 3:** Student journal entry 2

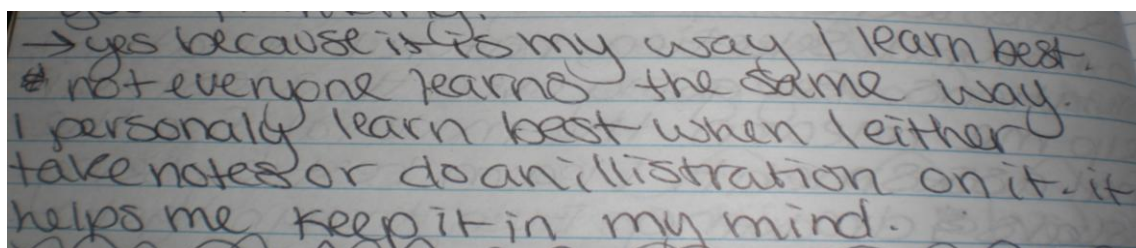


**Figure 4:** Student journal entry 3

*Students select more learning strategies.* I found that students reported an increased ability to choose specific learning strategies for themselves. The metacognitive ability to select and use particular strategies in a given context for a specific purpose means that the learner can think and make conscious decisions about the learning process. Evidence for this claim comes from reflective journals, field notes and the metacognitive surveys. Some of the greatest gains in pre- and post-survey questions involved how students used learning strategies in the classroom. Before the implementation, students responded with an average rating of 3.29 to the statement, “I have a specific purpose for each strategy I use.” After the implementation the rate was 3.95. Another strategy response stated, “I find myself using helpful learning strategies automatically.” Prior to the implementation, the average rating was 2.81 and afterwards it was 3.58. There were other strategy statements that demonstrated this same trend.

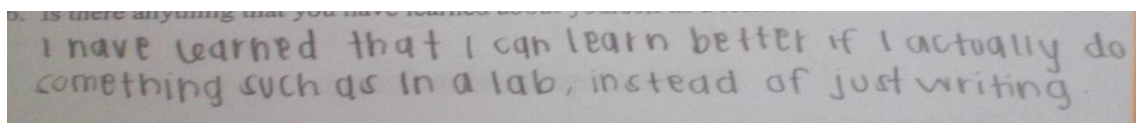
In addition to the pre- and post-survey, I also measured the choices students made during class using my field notes and by analyzing student responses in their reflective journals. At the beginning of the implementation a majority of the students chose a similar assignment. The assignment was to use their books and take notes in some form. Eighty-three percent of the students chose to perform a book assignment. Near the end of the implementation the ratio of choices amongst students had become more stratified. On

the last assignment 27% of students chose the book assignment, 19% selected a hands-on activity, 19%, an expressive illustration, 7%, an internet extension, and 27% chose a vocabulary building activity. Both my field notes and students' reflective journals demonstrated an increase in their variety of choices at the end of the implementation of *BRAC*. The following are examples of student responses on their strategy choice near the end of the unit:



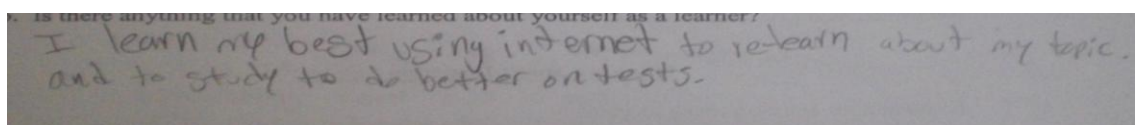
→ yes because it is my way I learn best. not everyone learns the same way. I personally learn best when I either take notes or do an illustration on it. it helps me keep it in my mind.

**Figure 5:** Student response 1



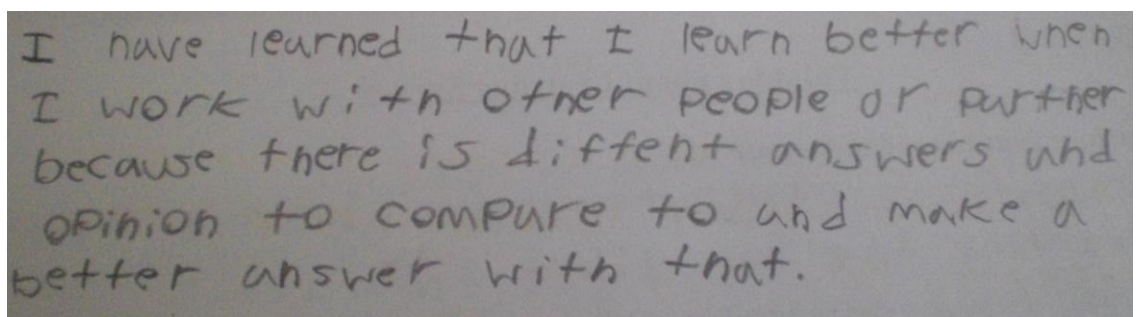
I have learned that I can learn better if I actually do something such as in a lab, instead of just writing.

**Figure 6:** Student response 2



I learn my best using internet to re-learn about my topic. and to study to do better on tests.

**Figure 7:** Student response 3



I have learned that I learn better when I work with other people or further because there is different answers and opinion to compare to and make a better answer with that.

**Figure 8:** Student response 4

This finding connects with my first goal of developing students' metacognition. A target of this curriculum was for students to choose a strategy to relearn or further their learning on a topic related to evolution. Students' belief that they improved their ability to choose appropriate learning strategies as a result of *BRAC* shows a potential increase in metacognitive awareness. Educational research finds that teaching metacognitive practices by actively involving learners in monitoring and controlling appropriate and effective strategies are likely to be effective in increasing students' academic performance (Chiu, Chow, & McBride-Chang, 2002; Cocking et al., 2000; White & Frederiksen, 1998). Making metacognitive strategies clear while integrating higher order or scientific thinking skills into the content has been found to be more effective than letting students figure out the scientific process skills for themselves (Williams, Blythe, White, Lin, Gardner, & Sternberg, 2002). *BRAC* incorporated different strategies and student choice to facilitate learning. The combination of options, feedback and reflection in *BRAC* may have allowed students to improve their use of strategies in learning.

**Finding 2: Students develop self-efficacy.** In this second finding, students seemed to increase feelings of self-efficacy. Self-efficacy is also a difficult construct to observe so multiple data sources were used as evidence. This finding was based on student responses to the pre- and post-self-efficacy surveys as well as their reflective journals and my field notes. The data supports that students increased their ability to direct their own learning and persist in science class.

***Students directed their own learning.*** I found that students seemed to direct their own learning in science class after the implementation. This finding most directly addresses the third goal of my curriculum, the goal of developing a sense of self-efficacy.



One of the data sources for this finding were responses to self-efficacy survey statements such as, “I feel in charge of making things happen in science class.” Initially this statement had an average rating of 1.81 on a 5 point scale. At the end of the implementation the rating was 2.28. Another statement on the survey that increased after the implementation stated, “I spend time planning things I want to do in science class.”

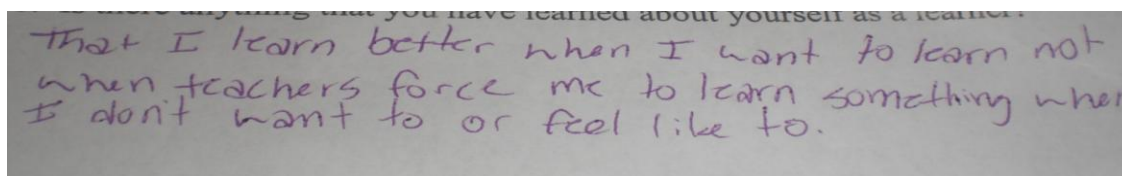
Student self-efficacy surveys generated findings similar to those generated by students’ reflective journals. I recorded the number of times students directed their own learning during the cycles of *BRAC*. There were approximately 12 cycles of *BRAC* that involved an inquiry lesson, an expansion lesson, an assessment and a relearning or extension component. During these cycles students had opportunities to direct their learning and be in charge of curriculum choices in biology class. After an assessment I recorded whether students selected their own choice or had the teacher select their method. During the implementation, students directed their own learning nearly 100% of the time, meaning that they selected their choice to relearn or further their learning after an assessment.

Another method of studying students’ self-direction and propensity to plan for their own learning was through my journaling of student statements and questions concerning the planning stages of relearning or extending their learning of an evolution topic. I compared the number of statements that illustrate self-direction and planning from the beginning of the implementation to the end of the unit. For example, when Student 2 examined her choices for extending her learning of natural selection she concluded, “I want to go on the internet to find more examples of natural selection.” I, in

turn, recorded these statements. After an assessment I would record statements from students and classify statements into self-direction and non-self-direction.

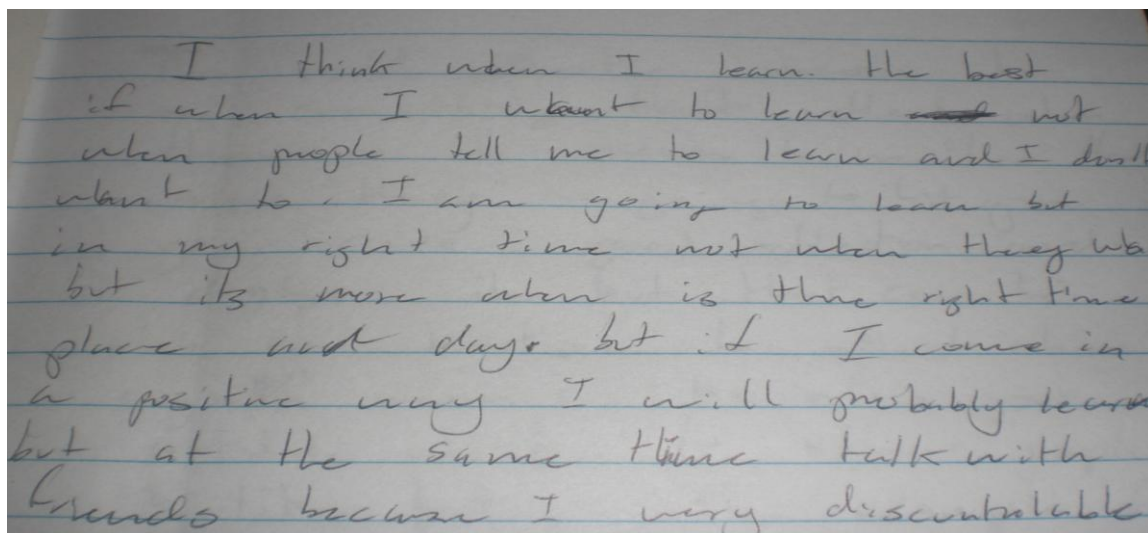
During the course of the implementation, no change was recorded in student statements about directing their own learning. My own observations and opinion of student direction was that it became easier for students to make choices and plan their course of action to understand evolution concepts. While I found no change in student statements related to self-direction, nonetheless, I observed that it became easier for students to make choices and plan for relearning evolution concepts. While all of my research methodology didn't account for this, other methods such as a continuous student reflection on how they plan in reflection journals might yield a closer connection between research and practice.

At the end of the implementation, students responded to a post-survey that asked if having choices affected them as learners and what they learned about themselves as learners. Student responses reflected, in some cases, the importance of student motivation and genuine curricular interest. For example, Figure 5 emphasizes this student's ability to learn better if there is less of a forced feeling from the teacher. Potentially, choice in the curriculum can alleviate this constraint and consequently encourage more self-direction in learning.



**Figure 9:** Student response 5

Figure 6 provides another example of a student expressing the importance of self-direction in learning and points to the positive connection between levels of motivation and students' genuine interest in the curriculum.



**Figure 10:** Student response 6

According to Deci (1995), student choice can promote self-efficacy. This curriculum was designed to provide students with opportunities to make informed decisions about their curriculum choices. As a result, student choice was at the heart of this curriculum. This possibly allowed students to take charge of their learning and feel more self-efficacious about their learning experience.

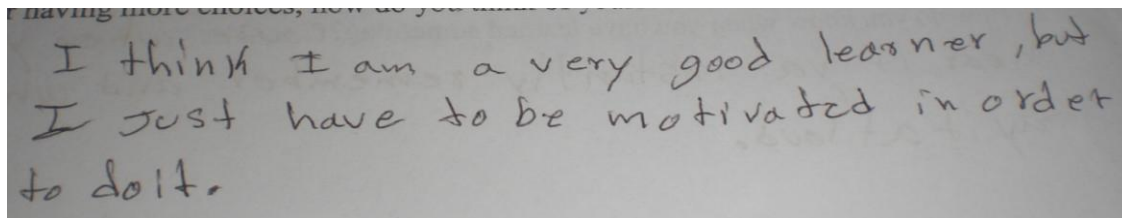
***Students increased their academic persistence.*** As evidenced by their reported ability to stick with their plans and accomplish their goals in science class, I found that students had an increased sense of persistence-related self-efficacy after the *BRAC* implementation. They also reported feeling more competent to persevere when problems arose in science class such as not knowing how to complete a lab. This increased sense of efficacy was indicated from student answers on the self-efficacy survey and the reflective

journals. An example of a question posed to students was, “When a problem arises, I can usually find more than one way to solve it in science class.” The survey at the beginning of the implementation returned an average rating of 2.59 and after the implementation the rating was 2.89. Another statement students were asked to reflect on was, “I am smart and I able to figure things out when something unexpected happens in science class.” The average rating on the pre-survey was 2.85 and on the post-survey it was 3.08. Although the difference in ratings is slight, this finding does support research findings that providing students with choice can increase their confidence and interest in the subject, therefore affecting student self-efficacy.

Two pieces of data that also support this finding were the collection of field notes of students’ on-task versus off-task behaviors and the number of students who followed through on their completion of their assignments. I recorded on-task and off-task behaviors ten times per class at the beginning, middle and end of the implementation. Observations were made of students’ attention, on-task/off-task, cooperation, disruption and participation. When I compared students off-task and on-task behaviors at the beginning of the implementation and the end of the implementation there was an increase in students’ on-task behaviors. At the beginning of the implementation, student on-task rate was at 86%. At the end of the implementation the student on-task rate was 100%.

Students also had a higher assignment completion rate at the end of the implementation than they did at the beginning. The student-chosen assignments in the curriculum unit had a completion rate of 57% in the beginning of implementation compared to a 77% completion rate at the end of the curriculum unit. Thus, the three sets of data support the hypothesis that students given choices in their assignments feel

motivated to persist and stick with completing them. At the end of the implementation, students responded to a post-survey that asked questions about how having choices affected them as learners and what they learned about themselves as learners. For example in Figure 7, the following student stressed that she is a good learner, but that motivation is key to her learning successes.



**Figure 11:** Student response 7

Students who can monitor and direct or change their own metacognition, motivation, behavior and environment are more likely to be successful in academic settings (Pintrich & Zusho, 2002). In an academic setting, student motivation can play a role in students' persistence with learning, completion of assignments and projects, and resulting assessments. *BRAC* may have had an influence on students' diligence and perseverance in completing their assignments, practicing on-task behavior and feelings of motivation to persevere and learn throughout the unit.

***Self-efficacy and assessment.*** In addition to a connection between assessment scores and self-metacognition ratings, students who felt more self-efficacious on the surveys had higher assessment scores. Fifty-five percent of the students who scored a 3 and above on assessments also had an average higher overall self-efficacy rating, that is, above a 4 on a 5-point scale. Table 6 summarizes and compares the average assessment scores throughout *BRAC* with the post overall-self-efficacy survey self-ratings. If

students scored higher on the assessments, they would generally rate themselves with higher feelings of self-efficacy on the post-survey.

**Table 8:** Assessment Scores vs. Overall Self-Efficacy Survey Self-Rating

| Average assessment scores | Overall self-efficacy survey rating average |
|---------------------------|---|
| 3 and above               | 4.2   |
| 2                         | 3.76  |
| 1 and below               | 3.5   |

In assessing students' self-efficacy ratings, I studied their reflective journals and coded their final entries based on a 3-point scale of *high*, *average* and *low* for self-efficacy. I rated responses with the code of *high* when students described their learning experience as very effective as in the statement, "I am a really good learner now." Average responses were composed of descriptions of some improvements such as "I am more focused." Low responses showed no feelings of self-efficacy or improvement. Table 7 summarizes the relations between assessment scores and self-efficacy reflective journal ratings. While a slight connection can be observed between higher levels of self-efficacy and assessment scores, overall field notes on self-efficacy did not show a connection between assessment scores and evidence of self-efficacy. I recorded on-task and off-task behaviors ten times per class at the beginning, middle and end of the implementation. In my observations of students' attention, on-task/off-task, cooperation, disruption and participation, there was not a strong correlation between higher percentages of positive behaviors and higher assessment scores.

**Table 9: Reflective Journal Responses**

| Average self-efficacy rating | Assessment scores 3 and above | Assessment scores 2 | Assessment scores 1 and below |
|------------------------------|-------------------------------|---------------------|-------------------------------|
| High                         | 7%                            | 7%                  | 0%                            |
| Average                      | 63%                           | 50%                 | 42%                           |
| Low                          | 20%                           | 43%                 | 58%                           |

Data from student surveys suggested students who had higher feelings of self-efficacy had higher assessment scores as shown in Table 8. In addition, reflective journals corroborate this finding from the student surveys. Therefore, metacognitive training, which increases self-efficacy, can increase students' self-confidence and sense of personal responsibility for their own development. This is consistent with the literature in that increased self-confidence and a sense of increased personal responsibility may provide motivation for learning according to past research (McCombs & Marzano, 1990; Schunk, 1990). Metacognitive training can increase students' motivation to learn. Training in metacognitive skills may enhance students' sense of self-efficacy, thus increasing their motivation to learn (Bandura, 1986; Hofer & Yu, 2003; Sperling, Howard, Staley, & DuBois, 2004).

**Finding 3: Student beliefs aligned more closely with scientific concepts.**

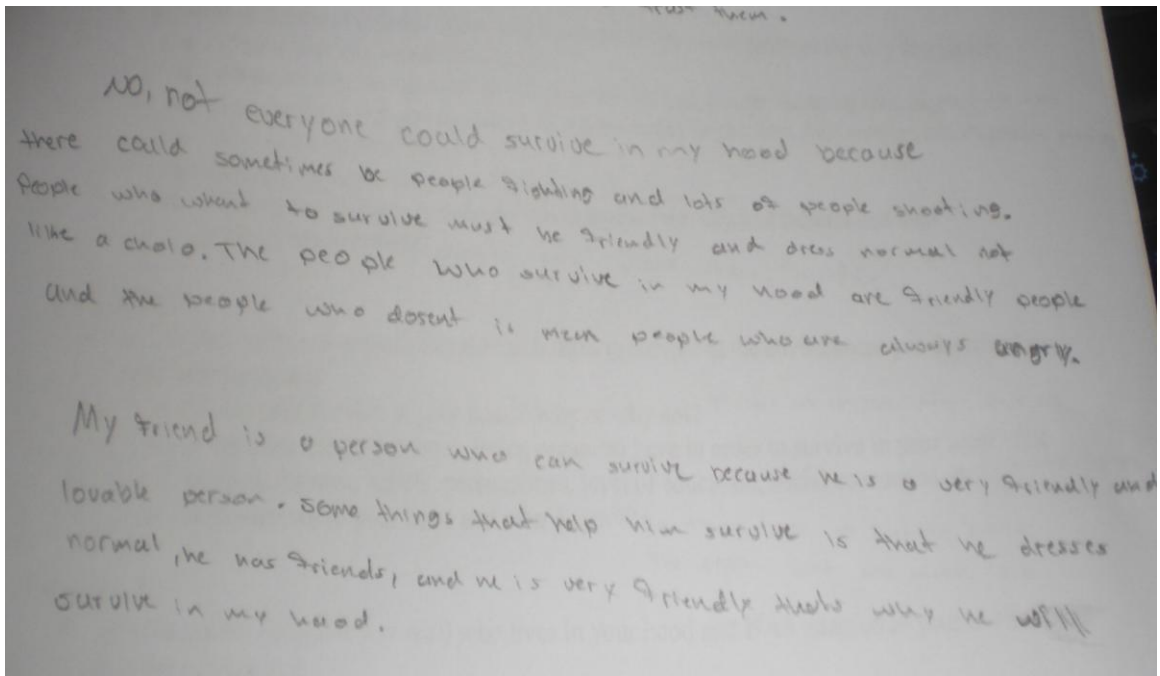
Student beliefs about evolution became more aligned with scientific concepts as a result of *BRAC*. The evidence collected was a before-and-after evolution-beliefs survey, field notes and students' reflective journals. This finding connected with my second goal, to support students' reflection on their conceptual understanding of evolution. After the implementation their beliefs became more aligned with scientific concepts and

understandings. As a result, students' common misunderstandings of evolution changed, \ which can be an expected after studying any subject for a period of time. The beliefs survey functioned like a pre- and post-test, although these types of data allowed for analysis of how the implementation could have affected beliefs.

When we began this unit, students were encouraged to share their prior understandings of and beliefs about evolution in a pre-survey, reflective journals, KWLs and in an initial classroom discussion. Although the majority of students responding to the pre-survey (55%) expressed beliefs about evolution that aligned with current scientific thought, many of the student responses in their KWLs and reflective journals stated that evolution is simply a belief and goes against their religion. After the implementation, the percentage of beliefs aligning with current science rose to 72%. Contributing to this rise, the statement, "There is actually very little evidence for evolution." was rated false by 68% of students before the implementation and 75% after the implementation.

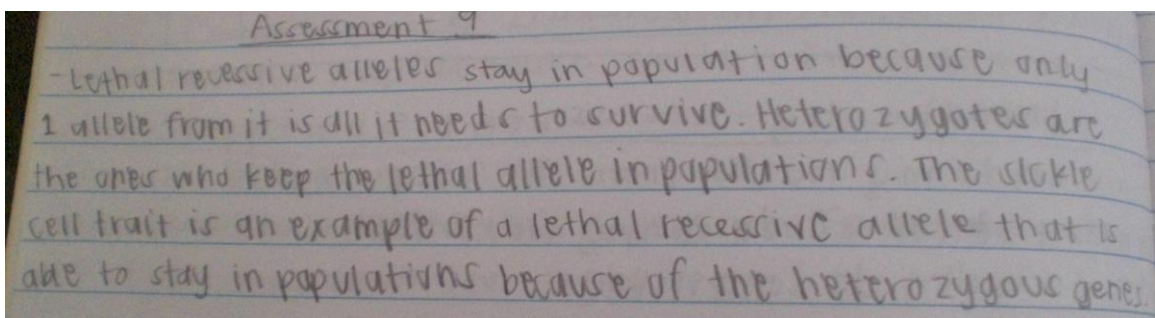
At the end of the curriculum unit, students participated in a performance task that evaluated their knowledge of evolution. On this performance task, students achieved 77% accuracy on evolution concepts. Figure 8 is an example of two paragraphs of a student performance task where the student applied the idea of natural selection to their own environment and neighborhood. The student used concepts of survival and demonstrated his knowledge of natural selection through an example of two types of people who are and are not naturally selected in his environment.



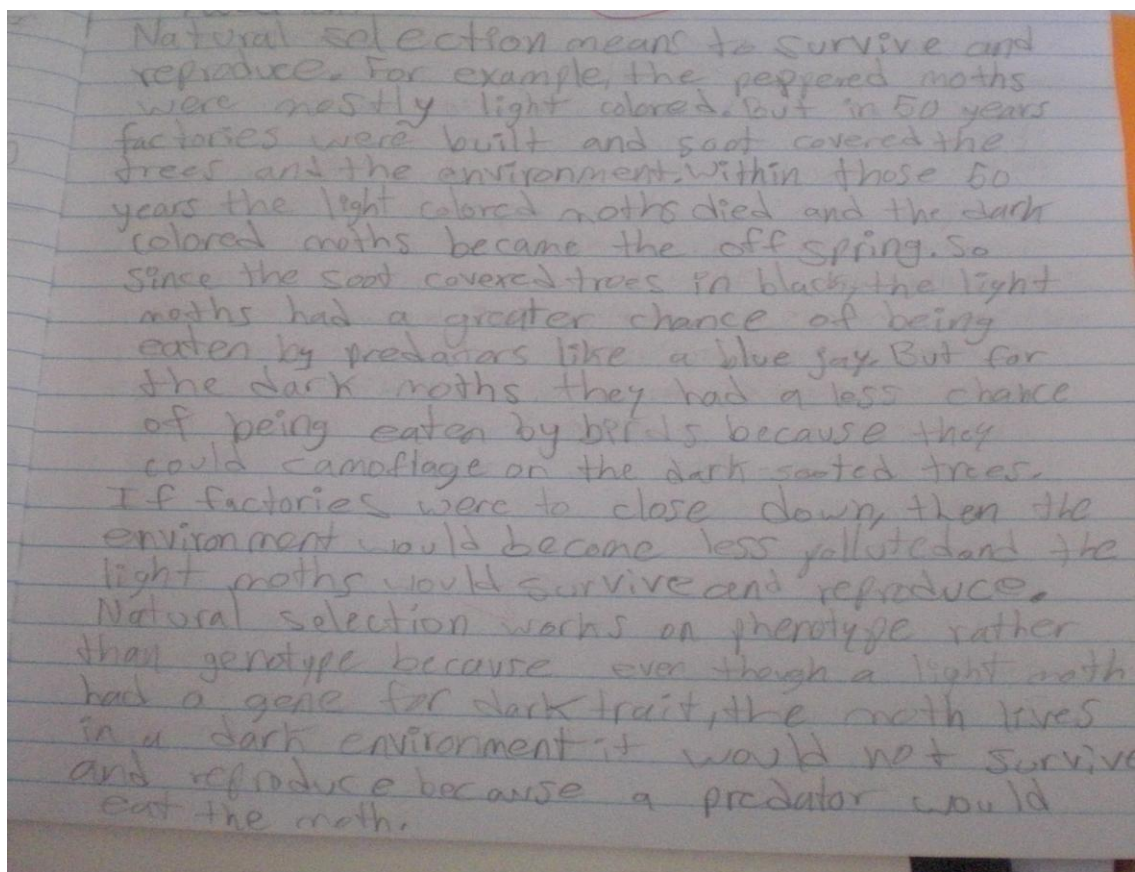


**Figure 12:** Student response on performance task

In addition to evaluating student work, I examined student accuracy on evolution statements. I recorded only statements and not questions in my field notes, and marked them as either misconceptions or as true. At the beginning of the unit, there were less accurate statements than at the end of the unit as evidenced by the culminating task. The following are examples of quick-write assessments, conducted near the end of the unit, that demonstrate an understanding of evolution.



**Figure 13:** Student quick write: maintaining lethal recessive alleles in populations



**Figure 14:** Student quick write: natural selection

**BRAC and state testing.** California state testing (CST) took place near the end of the school year. Table 9 is a summary of my CST scores in the class that had a full implementation of *BRAC*. These scores are compared to the rest of my classes that employed most of the elements of *BRAC*. They are also compared to the whole school- and district-average biology scores. These averages do not include accelerated, honors or advanced placement classes. The fourth and fifth column display English Language Arts (ELA) scores from the year before and compares them with 2010 biology scores.

**Table 10: CST Scores**

| Sample   | Sample size | 2010 Biology CST scaled score | 2009 ELA CST scaled score | Difference (10 Bio CST-09 ELA CST) |
|--|-------------|-------------------------------|---------------------------|------------------------------------|
| <i>BRAC</i> teacher (full implementation)      | 26          | 359                           | 335                       | 24                                 |
| <i>BRAC</i> teacher (elements of <i>BRAC</i> ) | 131         | 366                           | 333                       | 33                                 |
| Cougar high school                             | 558         | 326                           | 337                       | -11                                |
| Entire district                                | 5675        | 342                           | 367                       | -25                                |

A higher than average score was observed in all classrooms where *BRAC* was implemented compared to the school and district average. In addition, among 13 high schools in the district, Cougar High School ranks as the second lowest scoring high school yet students exposed to *BRAC* surpassed the district's average CST scores. This suggests that *BRAC* may have influenced higher CST scores. Although state testing and multiple choice tests provide a narrow window into conceptual understanding, it does provide some evidence for possible deeper learning.

Often students increase their knowledge of a subject after participating in content curriculum units. As a result, this finding of increased content knowledge is not unexpected and surprising, but it does provide possible evidence for conceptual understanding due to *BRAC*. In addition, this finding supports existing research which indicates that using metacognitive strategies in the classroom can lead to more conceptual understanding.

The students who achieved conceptual understanding have more than just textbook knowledge and skills to solve problems at the end of each chapter. Their understanding involved sophisticated insights and abilities that were evident by the

changes in their belief structures on the nature of science. As Wiggins and McTighe (1998) point out, understanding is what endures after details are forgotten; it is what is retained and may be applied in unfamiliar situations. The very nature of concepts, principles, key ideas and processes requires them to be understood rather than only learned for application in a few contexts so that familiarity may give the impression of understanding.

### **Summary and Discussion**

The overall goal of *BRAC* was for students to re-evaluate the traditional usage of assessments in science classrooms. Based on the data, *BRAC* enhanced student metacognitive skills. In addition, this curriculum appeared to develop student self-efficacy and conceptual understanding in evolution.

If encouraged, the subject of evolution is inherently suited to a rich discussion of background experiences and conflicting societal ideas. This year of teaching evolution in a high school biology class definitely led to vivid conversation about evolution concepts. My sense is that fully implementing *BRAC* in a biology class led to less unproductive confrontation and supported deeper reflection on evolution. As a result of giving students more time to reflect and write out their thoughts not only about evolution, but about how they developed as learners, I observed more optimal reactions than I observed in other years. The amount of time given to this subject was also increased so this may have been a factor as well.

Although establishing a causal connection between *BRAC* and student decisions and actions is not definitive, a combination of the research, data from the implementation of *BRAC* and my observations in the classroom contribute to a deduction that developing

students' metacognitive skills plays a role in student self-efficacy and conceptual understanding.

## VIII. Conclusion

According to a favorite classroom science figure, Albert Einstein (as cited in Comer, 2004, p. 5) defined insanity as, “doing the same things over and over again and expecting different results.” His words seem so obvious, but many teachers, including myself, both unintentionally and intentionally tend to repeat the same curricula in the hope that the outcomes will change. In response, I developed *BRAC* to address the stasis I’ve found in both the content and application of assessments in current science curricula. In addition to my own desire to embed assessment and choice into my classroom, I aspired to examine the manner in which assessment is used in common science curricula.

One of the benefits of science classrooms is the amount of engaging and interactive activities that can be incorporated into the classroom. In the original design of this curriculum I sought to make assessments a more likable and positive component of classroom experience much like experiments and projects. However, my field notes and my students’ reflective journals during the implementation do not reflect this initial hope. As a result, I have learned that the one-dimensional desire to make assessments more engaging is not my main objective, but instead I want to make tools such as assessments more useful for students to guide their learning. Engagement can be a component, but the objective should be to facilitate more learning for my science students.

The most visible change I have experienced after this implementation was flexibility in my classroom. Allowing more choice was very liberating and enjoyable for students. The assessments that guided these choices allowed me to feel confident that my students were making more informed choices in the classroom. Letting go of this control enhanced the quality of instruction I provided for my students.

Prior to this implementation, I used strategies in the classroom that embedded reflective learning activities. I would allocate more time for students to reflect on how they learn best or what allowed them to learn a concept in the best way. Throughout this unit I provided reflective journals where students continually recorded their levels of metacognitive awareness. Prior to this implementation, I would only use double-entry notebooks for students to reflect, but most of the time these notebooks were used more for content and were less about their own learning. Introducing a separate space just for student progress or knowledge on their learning seemed very beneficial. I could see this benefit in my students' comments, questions and classroom discussions. Students seemed to have a better and more honest view of their learning strengths and weaknesses.

I would like to continue *BRAC* in my classroom in the future. If teachers were to use aspects of the curriculum or the reflective assessments in their classrooms, I would offer the following suggestions in order to receive the maximum benefit of incorporating reflection and choice with assessments. First, the design and development of the curriculum requires a great deal of time to provide the amount of choices that align appropriately with Bloom's taxonomy. When first implementing *BRAC*, teachers would be advised to plan for this time investment. While the initial time to implement *BRAC* is considerable once the choices and curriculum are created they can be reused in following years. For example, in this curriculum I developed instructional assessments and choices aligned with labs from an evolution unit; now I can use this curriculum again and I am hoping to expand it to my genetics and ecology units.

A second suggestion arises from my experience with the actual classroom implementation of *BRAC* which can be difficult to manage. Prior to implementing

BRAC, most of my assignments were similar to each other in nature except for the culminating tasks or projects. Throughout the implementation of *BRAC*, however, students participated in completely different activities from online labs to a hands-on activity simultaneously. This variation in instructional activity resulted in issues with accountability and follow-through on some of the choices. The teacher not only has to be aware of what to look for in one activity, but in multiple activities simultaneously. To better accomplish this, teachers need to be very organized in the classroom and have the resources prepared before each class.

When I repeat this curriculum in the future, I plan to begin *BRAC* at the beginning of the year. Bloom's taxonomy and the assessments allow for students to be more aware of their own strengths and weaknesses. In addition, I would want to incorporate more choice from the beginning of the school year and continue it throughout the year. This experience has taught me that more choices and less control do not compromise learning or structure in the classroom. Students still learned the content, but they learned it in their way. If I were to continue further research in this area, I would like to research how grouping students can influence and be incorporated into reflective assessments and student choice.

I often start many of my classes with a posed question connected to the content that might vary from how to pass a lie detector test to why we snore and end with a memorable take-home message that connects to the beginning question. After this research experience in my classroom, my take-home message is to revise and reflect. Despite the benefit I feel I have gained from incorporating more student reflection and



choice into my classroom, a greater benefit is my own progression towards reflection and my personal development towards becoming a teacher-researcher.

Recently, the National Science Teachers Association (NSTA) has changed its position to include the importance of research on teaching. I would like to further my classroom research by expanding and exploring teaching methods that would extend my examination of *BRAC*. For example, I would like to use more varied assessment methods that allow students to choose the low-risk, formative assessments they prefer.

Experiencing student's positive reaction to having more choice has encouraged me to investigate methods of student assessment and learning that allow students to exercise greater control. In order to achieve diversified curriculum, I would also explore the usage of electronic portfolios and incorporation of more technology instead of using paper portfolios for the collection of student work. Lastly, I would like to use different research data collection methods in order to achieve a broader perspective on collected evidence. For example, I would like to identify and implement more data collection methods for self-efficacy. By persisting to explore different pedagogical and research techniques in the classroom, I will continue to develop as a practitioner and researcher while my students benefit from research based practices.

## **Appendix A. *Biology Reflective Assessment Curriculum***

By: Cheryl Bayley

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# **Section 1**

## **Introduction**

Letter to Teacher  
Tips for Implementers  
Letter of Consent

## Letter for Teacher

*Biology Reflective Assessment Curriculum (BRAC)* is a metacognitive curriculum that incorporates the usage of assessments to guide student choice. *BRAC* relies on the constructs of metacognition, self-efficacy and conceptual understanding to promote students' understanding of their learning and to help them regulate their own metacognition. In order to accomplish these outcomes, *BRAC* has three goals. Through reflective assessment, *BRAC* seeks to enhance students' own learning through self-reflection, deepen their conceptual understanding of biology, and develop their self-efficacy in learning. The teaching practice of reflective assessment measures students' current understanding and in turn provides immediate and useful feedback to students. The assessments in this biology curriculum include reflective activities that require students to use metacognitive skills to work independently and collaboratively. The curriculum concludes with a culminating natural selection task that applies metacognitive strategies to biology content.

The overarching goal of *BRAC* is for students to reflect on their own processes of learning biology in order to become both thoughtful learners beyond the science classroom and learners who generalize their insightful abilities into habits. Through *BRAC*, students are asked to apply reflective thinking to their learning and to develop their conceptual understanding of biology so they develop self-efficacy as learners.

*BRAC*, which can be adapted to any discipline, encourages students to engage in activities that require them to assess their learning and create goals as they study evolution. The collaborative component of the curriculum asks students to consult with classmates about their goals and curriculum choices to relearn or further their learning through a selection of differentiated lessons. Student learning is assessed and the unit is evaluated based on five sources of data: reflection journals, surveys, observations, culminating task and assessments. The curriculum, then, uses formative assessments throughout the study of science, but can be adapted to any subject. *BRAC* relies on such ongoing reflexive and formative assessment.

*BRAC* is comprised of three phases that can be intertwined and used simultaneously during implementation. Phase 1 occurs pre-implementation and is an introduction to self-reflection and supportive learning strategies. During Phase-1 students carry out a variety of activities to support their learning in Phases 2 and 3. In Phase 2 students learn the principles of Bloom's taxonomy and how to use it as a tool to diagnose their levels of understanding. Phase Three begins by learning or re-learning metacognitive strategies that encompass the stages of planning, monitoring and evaluating.

Phase 1 describes the period prior to the formal implementation of *BRAC*. In the first phase, foundational strategies are taught which help to lay the groundwork for later instruction. This phase incorporates curriculum that elicits students' prior knowledge and allows students to share their thinking. During Phase Two, students learn the principles of

metacognition, Bloom's taxonomy and how to use Bloom's taxonomy as a tool to diagnose their levels of understanding of the content using assessments. Phase 3 incorporates the three stages of metacognition: planning, monitoring and evaluating. Initially, students write about their learning in their journals using embedded evolution content assessments as guiding tools during the planning stage. Then they develop goals, and receive and give consultations on their action plans to relearn or extend their learning with collaborative groups. Next, during the monitoring phase, students develop a learning plan and create a record of their work in a learning portfolio. Lastly, the evaluation phase involves students demonstrating their knowledge and reflection abilities through a culminating task. These stages help students pose study questions for themselves, explore the consequences of their decisions and actions, reflect on how they learn, and check for conceptual understanding.

BRAC can be adapted for any subject and timeline. My hope is that you enjoy the curriculum and find the tools useful for teaching and learning.

## Tips for Implementers

Biology Reflective Assessment Curriculum uses assessments as tools for metacognition. This curriculum fosters metacognitive awareness to develop conceptual understanding and self-efficacy. To cultivate such a curriculum: classroom culture, environmental factors and curriculum design need to be supported.

### Classroom Culture

- **Collaborative Environment:** BRAC works best in an environment that facilitates cooperative learning and grouping because students share thoughts and reflections with other students. Reflection with assessments is a key component so respect and collaboration are essential.
- **Active Involvement:** Students will be involved in different activities or instructional choices at the same time so it is important to have discussed expectations during differentiated instruction.

### Environmental Factors/Classroom Setting

- **Space:** Students will be working on different instructional choices after reflections and assessments. It is helpful to have work centers set up for the different activities and instructional choices.
- **Organization:** Since students will be working on different activities to relearn or further their learning after reflections so it is useful to have a fluid plan to have students transfer from individual reflections to possible group work or other activities depending on their instructional choice.
- **Technology/Supplies:** In order to facilitate the different choices, providing technology is a helpful way to allow different methods of learning. For example, online labs and searches can be useful tools for relearning and furthering learning in a content area.

### Curriculum Design

- **Student Choice:** It is helpful to have an intentional and laid out plan of the different instructional choices that will be provided for students before each lesson. This component of the curriculum design requires a great deal of time to lesson plan.
- **Differentiated Instruction:** Choice for students can increase self-efficacy, but differentiating by level and ability is important to take into account when planning content choices for students after assessment reflections.
- **Assessments:** Different types of assessments should be used so students can demonstrate their learning. Examples of assessments include: quick writes, concept maps, culminating tasks, projects, quizzes, oral reports, etc.

## **Section II**

### **Overview Materials**

Overview of Curriculum

Standards in Curriculum

Example Timeline of Curriculum

Letter of Consent



### Overview of Reflective Assessment Curriculum

| Evolution Lessons  | Assessments   | Reflective Activities  | Differentiated Instructive Curriculum Choices  |
|--|---|--|--|
| <p>1. Prior Experience Activities: think-aloud techniques, double-entry journals, concept maps, quick writes and cornell notes. 2. Introduce Big Idea: Evolution, How can the genetics of populations change through time? 3. Natural Selection Lab 4. Natural Variation Lab 5. Mutations in the Environment 6. Tiger Lab 7. Genetic Drift Lab 8. Comparing Reproductive and Geographic Isolation 7. Fossils as Evidence</p> | <p>1. Quick Writes<br/>2. Concept Maps<br/>3. Quizzes</p> | <p>1. Activity one: Reflection Journal<br/>2. Group Collaboration<br/>3. Individual Learning Plans<br/>4. Learning Portfolio<br/>5. Culminating Task</p> | <p>1. Independent Learning with textbook<br/>2. Pair Share Activity<br/>3. Computer Research<br/>4. Lab/model simulation<br/>5. Review of concept with vocabulary building</p> |

**Curriculum State Standards**

|  |
|--|
| 7a. 8a. Students know why natural selection acts on the phenotype rather than the genotype of an organism. Students know how natural selection determines the differential survival of groups of organisms.  |
| 7c. Students know why alleles that are lethal in a homozygous individual may be carried in a heterozygote and thus maintained in a gene pool.  |
| 8b. Students know new mutations are constantly being generated in a gene pool.   |
| 7b. 8c Students know variation within a species increases the likelihood that at least some members of a species will survive under changed environmental conditions. Students know a great diversity of species increases the chance that at least some organisms survive major changes in the environment. |
| 8d. Students know the effects of genetic drift on the diversity of organisms in a population.  |
| 7d. Students know reproductive or geographic isolation affects speciation.   |
| 7e. Students know how to analyze fossil evidence with regard to biological diversity, episodic speciation, and mass extinction.  |

### Example Timeline of Curriculum

| Day                  | Topic/Assessment  |
|----------------------|---|
| 1<br>(2 hour block)  | Metacognitive Strategies<br>Pre-Belief Survey/Self-Efficacy<br>and Metacognitive Survey<br>Bird Beak Inquiry Natural<br>Selection Lab/Quick Write |
| 2<br>(1 hour block)  | Metacognitive Strategies<br>Review/Reflective   |
| 3<br>(2 hour block)  | Natural Variation Inquiry<br>Darwinism vs. Lamarckism<br>Lab/quiz   |
| 4<br>(2 hour)        | Metacognitive Strategies<br>Review/Reflective<br>Mutations/Concept Map  |
| 5<br>(1 hour block)  | Metacognitive Strategies<br>Review/Reflective   |
| 6<br>(2 hour block)  | Metacognitive Strategies<br>Review/Reflective   |
| 7<br>(2 hour)        | Tiger Lab(Maintaining Deadly<br>Alleles)/Quick Write  |
| 8<br>(1 hour block)  | Metacognitive Strategies<br>Review/Reflective   |
| 9<br>(2 hour block)  | Reproductive vs. Geographic<br>Isolation Activity/Quick Write<br>Assessment/Reflection  |
| 10<br>(2 hour block) | Genetic Drift Inquiry Lab/Quick<br>Write  |
| 11<br>(1 hour block) | Metacognitive Strategies<br>Review/Reflective   |
| 12<br>(2 hour block) | Fossil Record Inquiry<br>Lab/concept map  |
| 13<br>(2 hour block) | Warbels Inquiry/Case Study<br>Performance Task  |
| 14<br>(1 hour block) | Post-Belief Survey/ Self-Efficacy<br>and Metacognitive Survey   |

## Five Week Sample Syllabus for Phases Two and Three in a High School Biology Class Meeting Five Hours a Week on a Block Schedule

### Week 1

Day 1 (2 hours): Distribute release form. Class Activity: Bloom's Taxonomy of understanding with sample student assessments (see appendix). Discuss learning objectives with classifications through Bloom's Taxonomy and how these objectives can be assessed and used as a tool for student understanding. Have students use the Bloom's rubric to grade the sample assessments. Distribute an engaging, short reading with a learning objective to read as a class. Perform a short assessment such as a quick write. Students practice assessing their quick write and others using the rubric and learning objective. Explain possible instructional choices students can make after assessments. In class journal "How did Bloom's taxonomy help or not help you understand your own learning? How can it help or not help you make decisions for activities after an assessment to help you further your learning?" Pass out Evolution Belief Survey, metacognition survey, self-efficacy survey and evolutionary pretest. Homework: Anticipatory Evolution Vocabulary Terms (see appendix)

Day 2 (2 hours): Perform and design Natural Selection Inquiry Lab. Students create and practice creating lab analysis questions based on Bloom's for other lab groups. Discuss Natural Selection through sexual selection. Students generate questions for discussion and classify questions through Bloom's. Assess natural selection through a quick write. Students write in reflective journals "How well you do you understand natural selection? Give an example of natural selection. What helped you to understand natural selection?"

What helps you to learn new ideas?” Homework: Cornell Notes on district required chapter

Day 3 (1 hour): Pass back assessments with the learning objective. Students grade their assessment and another student’s quick write. Students reflect in journals. Students work in groups of three for group consultations with guiding questions. Explain developing a learning plan with instructional choices. Students work on learning plan and begin their instructional choice to further their learning in natural selection. Homework: Finish instructional choice.

## Week 2

Day 4: Perform Natural Variation Lab with student created lab analysis questions through Bloom’s. Discuss the importance of natural variation in a population through student generated questions classified through Bloom’s. Assess through a concept map.

Homework: Cornell Notes on Natural Variation

Day 5: Discuss learning portfolio and culminating performance task. Carry out mini-lesson on metacognition (see appendix). Students write in their journals “What is metacognition? When have you been or not been metacognitive in your own life? What was the outcome?” Pass back assessments with rubric score. Perform group consultations. Develop learning plan with selected instructional choice. Perform instructional choice. Homework: Finish instructional choice.

Day 6: Pass out multiple choice assessment. Perform second mini-lesson on metacognition. Homework: Begin first outline of culminating task and finding examples of natural selection in their own lives.

## Week 3

Day 7: Pass back assessments with rubric score. Students reflect in journals. Develop learning plan with selected instructional choice. Perform instructional choice. Explain cartoon, reading and puzzle on Darwinism vs. Larmarckism. Homework: Venn Diagram on Darwin vs. Larmarck.

Day 8: Read mutation cartoon. Perform and design tiger inquiry lab. Assess students through a quick write. Homework: A mutation story

Day 9: Pass back assessments with rubric score. Students reflect in journals. Develop learning plan with selected instructional choice. Perform instructional choice. Homework: Finish instructional choice.

#### Week 4

Day 10: Pass out multiple choice assessment. Develop learning plan with selected instructional choice. Perform instructional choice. Perform genetic drift lab. Assess students with a quick write. Homework: Finish instructional choice.

Day 11: Pass back assessments with rubric score. Students reflect in journals. Develop learning plan with selected instructional choice. Perform instructional choice. Homework: Finish instructional choice.

Day 12: Begin learning about fossils as evidence for evolution. Perform Fossil Inquiry lab. Pass out district multiple choice test.

Day 13: Pass back assessments with rubric score. Begin culminating task. Homework: Culminating Task.

Day 14: Pass out Surveys.

Dear Parents,

As your child's science teacher, I am looking for ways to improve the education of your child. Currently, I am participating in a Masters program at the University of California at San Diego that focuses on ways to improve teaching in my classroom. I am working on a curriculum development study that will include the activities we already do in class along with activities that are designed to improve the reflection and learning skills of students.

During this study your child will be taking time to reflect on his or her own learning. If a student chooses not to participate in this project, he or she will still be required to complete the normal school work, I will not use her or his work or reflection responses in my study. A student's decision not to participate in this study will in no way affect her or his grade or relationship with me or the school.

During this study students' work, surveys and teacher observations will be used for analysis. These recordings will never be shown in a public forum. The only people who will have access to the raw data are my MA committee and me. In September 2010 when I complete my MA, the raw data will be destroyed. In addition, students' written responses may be used as examples. The names of the students and the name of the school will be changed in the final report of this study, and will remain anonymous. If you have any questions or concerns about this activity, please feel free to contact me using the information below. Thank you for your help.

Sincerely,  
Thank you  
Cheryl Bayley

**If you agree to your student participating in this study, you do NOT need to return this form.**

[ ] I DO NOT give permission for my student to participate in this study.

Child's Name (please print) \_\_\_\_\_

Parent Signature \_\_\_\_\_ Date \_\_\_\_\_

Again, if you are not opposed to your student's participation, you do not need to do anything. If you would not like for your child to participate, please return this form by \_\_\_\_\_.

## **Section III**

### **Inquiry Labs/Activities**

Natural Selection Lab

Natural Selection Sample Lesson Plan

Peppered Moth Lab

Recessive Allele (Tiger) Lab

Genetic Drift Lab - Island Simulation



## NATURAL SELECTION LAB

### **Introduction:**

Natural selection is an important process underlying the theory of evolution as proposed by Charles Darwin. It is sometimes called, “Survival of the fittest”, which is fairly easy to comprehend. Individuals whose characteristics are well suited to their constantly changing environment survive and reproduce. Individuals whose characteristics are not well suited to their constantly changing environment either die or leave fewer offspring. This lab will help you appreciate the effects of natural selection within a population over time.

### **Objective:**

The purpose of this lab is to set up a simple simulation of natural selection in a predator-prey system. Students will play the role of predators and see who is better adapted to their environment.

### **Materials:**

1. Pasta or Beans, paperclips, small straw tubes
2. Four feeding structures (spoons, forks, knives, chopsticks)
3. Cups (paper or plastic)
4. Eager hungry predators

### **Procedures:**

(Students will feed individually)

1. As predator, each student will be assigned one of the four feeding structures: spoon, fork, knife, or chopsticks. These variations represent genetic and phenotypic differences in the population. All individuals have identical mouths (cups).
2. Beans and other food will be spread out in an area representing the habitat of the predators.
3. Students will be given 45 seconds for every trial, which represents each generation, to capture as much food as possible with their assigned feeding structure.
4. After each 45 second feeding session, students will count the number of food captured and record it in their data table. There will be four to five feeding sessions.

### **Pre-lab Questions:**

#### **Key Terms to Understand: (define)**

#### **Natural Selection, Predator, Prey, Adaptation**

1. Which predator will have the best chance of surviving? Why?
2. Make a prediction by ranking the predators according to which will survive the longest. (1=best, 4=worst)

**Predators:**

Spoons\_\_\_\_\_

Forks\_\_\_\_\_

Knives\_\_\_\_\_

Chopsticks\_\_\_\_\_

**Additional Instructions:**

-Begin hunting when the instructor says to begin and continue until you are told to stop. The prey (beans, etc.) must be picked up with the feeding apparatus (spoon, fork, knife, chopsticks) and placed in the mouth (cup). No scraping or pushing of the prey into the mouth is allowed. You must hold the bottom of the cup flat against the table.

-When told to stop hunting, count and record the number of each type of prey you captured. We will total the number of prey for every feeding structure. This will allow us to see which predators were most successful.

-After Generation 0, an environmental change will occur (such as a drought) reducing the prey types to one single type.

-Predator types which capture less prey than others are not successful hunters and natural selection might remove them from the population. After two generations, the least successful predator type will be considered extinct. Those who are extinct will be given new feeding structures and will join the more successful predator population, representing offspring.

-After each generation and the restructuring of the predator populations, predators will again be allowed to hunt for 45 seconds and the procedures will be repeated. This will be done for five generations total.

-Data tables will be filled out as we work through the exercise.

**Post Lab Discussion Questions:**

1. In the first round when there were different types of prey to choose from, which predator type appeared to be the most successful or best adapted to feeding based on your data?
2. After the environmental change, did the competition between predator types increase, decrease or stay the same? Why?
3. Which predator type appears to be the best adapted to feeding on this one type of prey population? Why? Based on your data, explain why that group is considered the best adapted.
4. Which predator type appears to be the least adapted to feeding on this one type of prey population? Why? Based on your data, explain why that group is considered the best adapted.
5. Why do you think it is important to have different types of adaptations among predators?
6. In your own words, explain what natural selection is and how this lab demonstrates the role of natural selection in populations (both predator and prey).

## NATURAL SELECTION

|            | Generation<br>0 | Generation<br>1 | Generation<br>2 | Generation<br>3 | Generation<br>4 |
|------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| Spoons     |                 |                 |                 |                 |                 |
| Forks      |                 |                 |                 |                 |                 |
| Knives     |                 |                 |                 |                 |                 |
| Chopsticks |                 |                 |                 |                 |                 |

### Data Chart

**Initial Beak Type:** \_\_\_\_\_

**Final Beak Type:** \_\_\_\_\_

## Natural Selection

### Question:

What effect will a change in the color of an environment have on the predators and the prey that live there?

### Hypothesis:

### Research:

Adaptation:

Population:

Genetic Variation:

Natural Selection:

### Materials:

- sheet of white paper
- sheet of newspaper
- forceps (your predatory beak)
- 60 white paper disks (prey)
- 60 newspaper disks (prey)
- watch or clock with second hand
- different colored pencils

### Methods:

1. Work in teams. One person must be the timekeeper/data recorder, the rest are predators.
2. Place a sheet of white paper on your desk and scatter 30 white disks and 30 newspaper disks onto it. Record those numbers in the data chart as generation 1.
3. Predators will now collect as many prey items as possible (using only their beaks) in fifteen seconds. Time keepers start and stop the predators.

4. Count up the number of white paper prey and newspaper prey that are left in the environment. Let the prey items reproduce by adding a disk of the appropriate color for each disk that survived the first round. Record that data as generation 2 in your data chart, scatter the new generation of disks on the environment and begin the next round.
5. Continue for four rounds. Then between generation 4 and generation 5 switch the color of your environment from white paper to newspaper and continue for four more generations.
6. If the total number of prey ever drops below 10 then all but one of the predators die, until the prey population recovers.



3. Use your graphed data to describe what happened to the different colored prey populations in this experiment.
4. Explain how the predators are agents (the cause) of natural selection in this experiment.
5. Tell me whether you accept or reject your hypothesis, and explain why.

### **Natural Selection Lesson Plan**

**Objective:** Students will understand natural selection as a process by which heritable traits that make it more likely for an organism to survive and successfully reproduce become more common in a population over successive generations. It is a key mechanism of population genetic change (evolution).

**Big ideas or concepts:** Why are some individuals or populations more successful than others?

**Resources or materials:**

Mean Genes excerpt – Phelan, pg. 126, 2002

Bowerbird Video clip – 60 minutes cbs news -

<http://www.cbsnews.com/video/watch/?id=3624184n>

The Science of Romance – Time, February 2007

Natural Selection Lab (2 versions, traditional and inquiry)

Materials for Natural Selection Lab

Darwinism vs. Lamarckism puzzle and reading

Assessment rubric

**Preparation:**

1. Read the chapter on sex and cheating in Mean Genes.
2. Have pairs and groups for pair-share and groups prepared before lesson.
3. Give pre-survey for evolutionary beliefs and pre-test prior to this lesson or right before.

**Engage:**

1. Warm-up: Imagine for a moment your significant other forming a deep, emotional bond with someone of the opposite sex. They confide in each other and share long nights of conversations. Now imagine your significant other having a brief, intense sexual fling with another person. Both are unpleasant thoughts to imagine, but what experience brings you more distress and why.
2. Tell students to think about their responses and write them in their warm-ups.
3. Have students pair-share their responses and feelings to a partner.
4. Perform a poll in the class. A common tendency is for the female students to be more distressed by scenario one and male students to be more distressed by scenario two. This is not always the case, but very common and the case in a study with college students at \_\_\_\_\_. (Phelan, 2002)
5. This study is an example of a common evolutionary trend with males and females and sexual selection. It is important to not layout the answer to this question, but pose the question and after learning the principles of evolution do students understand why men and women have different behaviors in romance.
6. Have students create a KWL in their double-entry notebooks.



7. Have students write information they think they know about evolution in the first column on their own.
8. Have students pair-share this information with a partner. Have students come up and write information down on the board in the K column.
9. Have students write information they want to know or they think they should know in the first column on their own.
10. Have students pair-share this information with a partner. Have students come up and write information down on the board in the W column.

**Explore:**

1. Have students perform Natural Selection Lab.

**Explain:**

1. Have students formulate a discussion and conclusion paragraph for their lab reports or answer the analysis question in the natural selection lab.

**Elaborate:**

1. The Science of Romance

**Evaluate:** Quick Write Prompt: Explain how natural selection is a process that occurs in the nature? Also, use the principals of natural selection to explain an example of natural selection from your own experiences or from examples today (lab, reading).

Curriculum Choices after Assessment:

1. Technology – Lab Simulation – extension activity  
[http://www.mhhe.com/biosci/genbio/virtual\\_labs/BL\\_12/BL\\_12.html](http://www.mhhe.com/biosci/genbio/virtual_labs/BL_12/BL_12.html)
2. Independent Study
3. Darwin's Obituary

LONDON NEWS OBITUARIES

20 April 1882

## Charles Darwin, Controversial Scientist, Dies at 73

Yesterday, noted naturalist and controversial scientist Charles Darwin died. Mr. Darwin had been in declining health for several years. He passed at his home in Down (Kent), England.

Darwin was born on February 12, 1809, at Shrewsbury, England. Darwin gained notoriety after publication of the book, *On Origin of Species*, published November 24, 1859. Darwin began his academic career studying medicine at the University of Edinburgh, but soon switched to theology at Cambridge. However, the study of nature was Darwin's calling. "I was a born naturalist," he said of himself. Every aspect of nature intrigued him. He loved to collect, to fish and hunt, and to read nature books. The country town of Shrewsbury, population 20,000, was the perfect place for a "naturalist in training." Darwin's letters and notes give the impression he devoted more time to collecting, hunting and riding than to his prescribed studies at Cambridge. Yet he did well on his examinations, finishing tenth on the list of nonhonors students.

Immediately after graduation Darwin

he described all the places he visited. One of the most intriguing stops was the equatorial Galapagos Islands. Here Darwin studied many unusual plants and animals. When at sea, Darwin spent time reading academic works such as Charles Lyell's *Principles of Geology* which introduced him to the idea of uniformitarian geology and Jean Baptiste Lamarck's arguments for evolutionary thinking. After the five year voyage, Darwin spent his time sorting his collections and sending them to various specialists to be described.

The results of his voyage, the cataloguing of his collections, the ideas of other scientists and philosophers, especially Thomas Malthus's *Essay on the Principle of Population*, and Darwin's ability to think critically led him to the most controversial biological theory ever;

signed on the H.M.S. Beagle as naturalist and gentleman companion of Captain Robert FitzRoy. The good captain had been commissioned to survey the coasts of Patagonia, Tierra del Fuego, Chile and Peru. The Beagle left Plymouth, England on December 27, 1831 and returned on October 2, 1836. While on the voyage Darwin kept a travelogue (Journal of Researches) in which

evolution by common descent and the principle of natural selection. However, Darwin was reluctant to publish this theory. In fact he did not publish it until approached by Alfred Russel Wallace, who had developed the same theory independently. Together they announced the theory in 1858 and Darwin's famous book was published in 1859. If we could look into the future, we would see that the debate started by Darwin goes on and on.

In January 1839 Darwin married his cousin Emma Wedgwood, and in September 1842 the couple moved from London to the village of Down. They had twelve children, eleven of whom survive.

### **Questions for Further Thought**

1. Make a list of facts about Darwin that you learned from the obituary. Can you add others? Should these have been included in the obituary? Why or why not? What facts would you like to know that were not included?
2. How is Lamarck's theory of evolution similar to Darwin's? How does it differ? What do you think Lamarck would say about Darwin's theory? Why? Arrange for a debate to take place between Darwin and Lamarck with students taking the roles of the scientists.
3. What key component is missing from Darwin's theory? Who supplied the answer? When was it discovered? How did this discovery affect scientific criticism of Darwin's theories?
4. It has been said that Darwin was the "Father of Biology." Do you agree with this statement? Why or why not?

5. Several other scientists were involved with Darwin's theory and the controversy that followed. Below you will find a list of those scientists. Choose one and research that person. Then, write an obituary for your scientist and share it with the class. Be sure to include the contribution or controversy associated with each man. Place all the obituaries in an anthology and place it in the media center as a resource for student use.

Charles Lyell  
Richard Owen  
Asa Grey

John Gould  
Alfred Russel Wallace  
Louis Agassiz  
August Weismann

Joseph Dalton Hooker  
Thomas Henry Huxley  
Ernst Haeckel



## Evolution and Gene Frequencies: A Game of Survival and Reproductive Success



### Scenario:

In this population of Bengal tigers, alleles exist as either dominant or recessive. Bengal tigers live high in the mountains of India where the temperature is very cold. The presence of fur is dominant to the absence of fur, which is recessive. Because of this, the homozygous recessive trait is lethal.

### Purpose:

To determine the effect of random mating in a population of tigers possessing a recessive gene.

### Materials:

- 50 dried split peas (green)
- 50 dried corn kernels (yellow)
- 1 paper bag
- 2 Petri dishes (one labeled “living population” & one labeled “RIP”)
- Data Sheet (Included)- to be pasted in your notebook on the left side
- Activity Questions- to be answered in your notebook on the left side
- Writing Utensil

### Hypothesis:

Based on the scenario given, on the **left side of your notebook**, state whether you think the recessive allele will remain in the population of Bengal Tigers after 15 generations. You can start your hypothesis like this:

IF the “no fur” allele is recessive, THEN after 15 generations...

### Procedure:

1. Let the 50 split peas represent the alleles for fur (the dominant allele) and the 50 yellow corn kernels represent the allele for no fur (the recessive allele) in the Bengal tiger population.

2. Let the paper bag represent the deep dark jungles of India where random mating occurs and cannot be witnessed by biology students.
  3. Remember, the homozygous recessive individuals will not survive in the cold climate of India's mountains. Only the homozygous dominant and heterozygous individuals will survive. **On the left side of your notebook**, define what each of the three terms means (homozygous recessive, heterozygous, and homozygous dominant) and tell me how you will know which individual is which by looking at the split peas & corn kernels.
  4. Place the 50 split peas (dominant alleles) and 50 corn kernels (recessive alleles) in the dark jungle bag and shake up (mate) the tigers. **DON'T LOOK!**
  5. Pull out two alleles at a time to represent one offspring that was produced during the mating. If the offspring genotype is either homozygous dominant or heterozygous, the place the alleles in the Petri dish labeled "living population." If the offspring's genotype is homozygous recessive, the place the alleles in the Petri dish labeled "RIP." **WHILE CHOOSING EACH GENOTYPE**, record the number of homozygous dominant individuals, number of heterozygous individuals, and number of homozygous recessive individuals on your data sheet.
- \*\*\* Once in the RIP Graveyard these alleles are no longer able to be passed on to the next generation.
6. Once you have determined the genotype of all offspring, place the alleles of the surviving tigers (which have grown, survived and reached reproductive age) back into the dark jungle and mate them again to get the second generation. **REMEMBER**, the only tigers that survive to this next generation are the homozygous dominant and heterozygous individuals.
  7. Repeat steps 5 and 6 to determine the 3<sup>rd</sup> through 15<sup>th</sup> generation. Remember: all homozygous recessive individuals become part of the RIP Graveyard and therefore cannot reproduce.

**Activity Questions (Answer all questions on the left side of your notebook):**

1. Do your results support your hypothesis? Why or why not?
2. What happened to the number of dominant alleles from one generation to the next? What happened to its frequency?
3. What happened to the number of recessive alleles from one generation to the next? What happened to its frequency?
4. What would happen to the gene frequency of the recessive allele if it became extinct?
5. Why didn't the recessive allele get selected out of the population (meaning, why didn't the recessive allele go away)?

**Data Chart (Cut this chart out and paste in your notebook on the left side)**

| Generation | Total #<br>Homozygous<br>Dominant<br>Individuals | Total #<br>Heterozygous<br>Individuals | Total #<br>Homozygous<br>Recessive<br>Individuals | Total # of<br>Dominant<br>Alleles | Total # of<br>Recessive<br>Alleles | Allele<br>Frequency<br>of Dominant<br>Allele | Allele<br>Frequency<br>of Recessive<br>Allele |
|------------|--|--|---|-----------------------------------|------------------------------------|--|---|
| 1          |  |  |   |                                   |                                    |  |   |
| 2          |  |  |   |                                   |                                    |  |   |
| 3          |  |  |   |                                   |                                    |  |   |
| 4          |  |  |   |                                   |                                    |  |   |
| 5          |  |  |   |                                   |                                    |  |   |
| 6          |  |  |   |                                   |                                    |  |   |
| 7          |  |  |   |                                   |                                    |  |   |
| 8          |  |  |   |                                   |                                    |  |   |
| 9          |  |  |   |                                   |                                    |  |   |
| 10         |  |  |   |                                   |                                    |  |   |
| 11         |  |  |   |                                   |                                    |  |   |
| 12         |  |  |   |                                   |                                    |  |   |
| 13         |  |  |   |                                   |                                    |  |   |
| 14         |  |  |   |                                   |                                    |  |   |
| 15         |  |  |   |                                   |                                    |  |   |

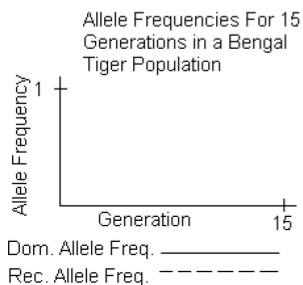
To determine the dominant allele frequency, take the number of times you got the dominant allele and divide that number by the total number of alleles that were used to make up all the genotypes of that generation:

$$\frac{\text{number of dominant alleles}}{(\text{number of dominant alleles} + \text{number of recessive alleles for the generation})}$$

Do the same in order to find the recessive allele frequency.

$$\frac{\text{number of recessive alleles}}{(\text{number of dominant alleles} + \text{number of recessive alleles for the generation})}$$

These frequencies will be decimal numbers (like 0.45 or 0.55). Also, a great way to check to see if you are doing the calculations right is to make sure that the dominant allele frequency + the recessive allele frequency for a single generation equals 1.



#### Plotting the results on a graph:

Using the picture to the left as a guide and the graph paper provided to you, graph the dominant and recessive allele frequencies as they occurred during the 15 generations.  
*Glue graph in your notebook on the left side.*



## Genetic Drift

### Teacher Material

Major Themes:

1. Evolution
2. Population Genetics
3. Chance vs. Selection

California Standards: Evolution

8c. Evolution is the result of genetic changes that occur in constantly changing environments. Students know the effects of genetic drift on the diversity of organisms in a population.

Synopsis:

- In the basic lab, student teams set up two islands composed of equal proportions of genotypic alleles. In this simulation the islands will be bowls, one large and one small. Each bowl will be populated with beans of the same shape and size, but of different colors. Students will blindly sample half of the beans on each island to reproduce and the non-reproducing beans are eliminated. After students have recorded the number and proportion of alleles in each new population, they blindly resample each population again and again record the new proportion of alleles left on each island. After five iterations, the students can stop and compare the initial vs. final proportions of alleles left on each island. Genetic drift should have occurred much more dramatically on the small island than on the large island.
- For an extension of the fundamentals of genetic drift, have your students simulate a bottleneck or founder event by starting with a large population of known proportions of alleles (known number of beans and their colors) and then randomly sample a small number of those beans from the initial population to begin a new population that you can let grow. After four or five generations of growth, you can compare the proportion of alleles in the new population vs. the initial population.

Suggested Time:

- Two class periods
  - Introduce the lab near the end of the period on the day preceding the actual lab activity.
  - Present the problem (small populations and genetic drift) and briefly discuss historic bottleneck and founder events (e.g. California Sea Otters and Galapagos Finches) and ask the students if they thought the current populations were the same as the original populations and whether that was important.
  - For homework, require the students to research this topic in their textbooks, to report on the vocabulary items, and form an hypothesis for the problem.

- On Lab Day, first discuss the meaning and importance of the vocabulary terms, then have students share and justify their hypotheses. Discuss materials and methods, then run the simulation, gather, and collate data.
- For homework, the students will analyze and graph their data, answer the guided discussion questions, and accept or reject their hypotheses with a justification.
- At the beginning of the final day, have the students turn in their reports and then orally report out their findings to the class.

Background Information:

- **Genetic Drift** is basically a random, non-adaptive change in the gene frequencies of a population. It is non-adaptive evolution. It occurs most generally in small populations. For instance, if a small random sample of individuals is separated from a larger population, the gene frequencies (proportion of alleles) in that sample may differ significantly from those in the population as a whole, merely because of the luck of the draw. The **Bottleneck Effect** describes a situation where a large population is drastically reduced in size (by numbers of individuals) due to some natural or anthropogenic disaster and the **Founder Effect** describes the colonization of a new habitat by only a few individuals. In both cases, there is a great likelihood that the new populations contain different proportions of alleles than the initial populations and have probably even lost certain alleles totally from the original gene pool. Also, even without a Bottleneck or Founder event, a small population is more likely to suffer the loss of alleles due to the perturbations of chance than is a very large population. In all cases, the shift in gene frequencies is not in response to natural selection and therefore not necessarily an adaptive change (it won't give the next generation a bigger proportion of better adapted alleles).
- Good examples of Bottleneck events that your students can relate to are the hunting to near extinction of the Pacific Northern Fur Seals and the California Sea Otters. In each case, the population of each species was reduced from tens of thousands to less than a hundred. Once each of these species became protected from hunting, their populations grew, but each new population contains less polymorphism and heterogeneity than their original populations. There are many more cases in the scientific literature; perhaps you know of one that you can share with your students.

## Student Material

### Genetic Drift on Two Different Islands

#### Question or Problem:

- How will genetic drift affect the diversity among the organisms in a small population on a small island vs. a larger population on a large island?

#### Hypothesis (your best educated guess that answers the question or solves the problem):

- 

#### Research (background knowledge used to support your logic):

- Gene
- Allele
- Population
- Random Chance
- Bottleneck Effect
- Founder Effect
- Genetic Drift
- Evolution

#### Materials:

- Big Island Bowl
- Little Island Bowl
- Bean Organisms: Brown, Red, White, Pink, and Black-Eyed
- Data Table

#### Methods:

1. Place ten (10) beans of each color into the Big Island Bowl (Total = 50 beans).
2. Place only two (2) beans of each color into the Small Island Bowl (Total = 10 beans).
3. Record your data in your data table.
4. With your eyes closed (remember that Genetic Drift is random, and not like Natural Selection), sample 25 lucky members from the Big Island (50% of the population) and 5 lucky members from the Small Island (50% of that population) to reproduce.
5. Keep the two groups of breeding beans in separate piles and empty both of the islands of all of the non-breeding beans.
6. Let each breeding bean reproduce one individual of its own kind and place those parents and their progeny (kids) back into their appropriate islands. (The big island should again have 50 beans and the small island should have 10 beans.)

7. Record the new number of each color of bean in your data table under "Year 2".
8. Continue this procedure for three (3) more years (for a total of 5 years).
9. Graph and label your initial and final population data as Pie Graphs.

Data, Observations, and Calculations (charts, graphs, and sketches are good ways to display your data):

- Data Table

| Island       | Color Allele | Year 1 | Year 2 | Year 3 | Year 4 | Year 5 |
|--------------|--------------|--------|--------|--------|--------|--------|
| Small Island | Brown        |        |        |        |        |        |
|              | Red          |        |        |        |        |        |
|              | White        |        |        |        |        |        |
|              | Pink         |        |        |        |        |        |
|              | Black-Eye    |        |        |        |        |        |
|              | Total        |        |        |        |        |        |
| Big Island   | Brown        |        |        |        |        |        |
|              | Red          |        |        |        |        |        |
|              | White        |        |        |        |        |        |
|              | Pink         |        |        |        |        |        |
|              | Black-Eye    |        |        |        |        |        |
|              | Total        |        |        |        |        |        |

- Pie Graphs
  - Initial Big Island Population
  - Initial Small Island Population
  - Final Big Island Population
  - Final Small Island Population

Discussion (acceptance or rejection of your hypothesis justified with analyses, explanations, and inferences of the meaning of your data):

1. Describe how the proportion of alleles (for bean colors) changed over time on each of the islands.

2. Did the proportion of alleles change more on one of the islands than on the other? If so, then try to explain why.
3. Did any alleles go extinct on either of the islands? If so, do you think that losing alleles will help or hurt the population (please explain why)? Can you propose any ways that an island could get extinct alleles back into its gene pool?
4. Natural Selection and Genetic Drift can both cause populations to evolve (change) over time, but they do it differently. Explain how they're different.
5. Tell me whether you accept or reject your hypothesis, and explain why.

Further Questions:

- 1.
- 2.

Evaluation: Write a summary paragraph explaining:

- a. what you learned
- b. why the knowledge is important
- c. what you liked best about the inquiry/experiment
- d. what would improve the activity

## **Section IV**

### **Phase Materials**

#### Phase One

Double-Entry Notebook

Think Alouds

Cornell Notes

Pro-Con Grid

Bloom's Action Words

#### Phase Two

Bloom's Questioning Samples

Reflective Guiding Questions

Metacognitive Stem Statements

#### Phase Three

Reflection Journals

Individual Learning Plan

Culminating Task

## **Keeping Double-Entry Notebooks in Science**

Double-Entry Notebook supplies: DUE by \_\_\_\_\_

- An 8 1/2 x 11 spiral notebook with at least 70 pages
- Pen and pencil with an eraser
- Very helpful to have: Highlighters of different colors &/or colored pencils
- Very helpful to have: Small pair of scissors & a glue stick



Double-entry notebooks will be used in this class to help you understand and remember important concepts. It will be like writing your own personal textbook. This style of notebook uses both sides of your brain to make "sense" of information. Information, which you understand, is easier to recall for assessments.



### **Let's begin.**

- Leave the first 4 pages blank for title page and table of contents.
- Number all the pages: right side pages are odd, left side is even.

#### **Left Page = Output**

*\* even-numbered pages*

The left spiral page shows your understanding of information.

You work with input from the right side *but present it in your own way*. Be creative on this side!

- Brainstorming
- Discovery headlines
- Biography posters
- Mind mapping
- Riddles
- Your questions
- Pictographs
- Cartoons/Doodles
- Poetry & Songs
- Metaphors & Analogies
- Concept Maps
- Venn diagrams
- Dialogues
- Sketches
- Flow chart/Timeline



#### **Right Page = Input**

*\* odd-numbered pages*

The right page in the spiral is for writing down information you are given. When the teacher lectures, or you get input from books, videos or speakers. Use the right side for...

- Time, date, page #'s, etc.
- Thrilling lecture notes :)
- Procedural notes for labs
- Vocabulary words
- Text book notes
- Notes from films or videos
- Lecture guides
- Teacher questions
- Guest speakers
- Other relevant input





## **Keeping Double-Entry Notebooks in Science**

### **The Right Page (Side) of the Notebook is for INPUT**

- **The right page (side) of the notebook is for writing down information you are given.**
  - Always start an input page with a title and date (upper right corner) at the top of the page.
  - The right-side spiral has only odd numbered pages.
  - When the teacher lectures, you take **Cornell notes** on the right side.
  - When you read information or see a video, the notes go on the right side of the notebook.
  - If the teacher answers questions or does sample problems, you write the information on the right side.
  - If you discuss/share ideas with your peers or the class, you write the information on the right side.
  - Any type of informational input you get in class goes on the right side.
- **Other types of input that goes on the right side**
  - Vocabulary words and their definitions
  - Notes for labs and lab instructions, procedures and materials
  - Teacher questions and sample problems
  - Diagrams or equations copied from the board
  - Any other type of **INPUT** you get in class



### **Sample Cornell Notes**

| Subject Title   | Date  | Period |
|---|---|--------|
| Question Column   | Notes Column - factual information  |        |
| Why are plants green?   | Scientists note that plants are green. Many ideas have been proposed to understand plant color.   |        |
| What's photosynthesis?  | Photosynthesis means, "to put together with light" meaning that plants use a process to produce food and energy from light.   |        |
| What does <u>transmit</u> mean?   | Plants are green because they transmit (reflect) green light from organelles called chloroplasts, where photosynthesis happens.   |        |
| Compare & contrast energy intake by plants and animals  | Plants make their own food by absorbing water and carbon dioxide and using the energy of light to convert them into sugar. Animals catch and eat food sources and use oxygen and enzymes to convert it to energy to stay alive. |        |
| Brief Summary of Notes: Photosynthesis is a chemical process in plants that allows them to make energy to live. Plants transmit green light during photosynthesis, so plants look green. In contrast, animals have to find their own food to make energy to live. |   |        |



**\*GLUE** your assignment page on the 1st left hand page of the unit

**Double-Entry Notebook Table of Contents**

Unit \_\_\_\_\_

Name \_\_\_\_\_

Chapters \_\_\_\_\_

Date \_\_\_\_\_

| Left Side Items                   | Page | Right Side Items                  | Page |
|-----------------------------------|------|-----------------------------------|------|
| 1                                 |      | 1                                 |      |
| 2                                 |      | 2                                 |      |
| 3                                 |      | 3                                 |      |
| 4                                 |      | 4                                 |      |
| 5                                 |      | 5                                 |      |
| 6                                 |      | 6                                 |      |
| 7                                 |      | 7                                 |      |
| 8                                 |      | 8                                 |      |
| 9                                 |      | 9                                 |      |
| 10                                |      | 10                                |      |
| 11                                |      | 11                                |      |
| 12                                |      | 12                                |      |
| 13                                |      | 13                                |      |
| 14                                |      | 14                                |      |
| 15                                |      | 15                                |      |
| 16                                |      | 16                                |      |
| 17                                |      | 17                                |      |
| 18                                |      | 18                                |      |
| 19                                |      | 19                                |      |
| 20                                |      | 20                                |      |
| 21                                |      | 21                                |      |
| 22                                |      | 22                                |      |
| 23                                |      | 23                                |      |
| 24                                |      | 24                                |      |
| # Stamps TOTAL for this Section = |      | # Stamps TOTAL for this Section = |      |

Quality Rubric Rating: \_\_\_\_\_ x Value Factor \_\_\_\_\_ = Total Score \_\_\_\_ / \_\_\_\_

**\*GLUE your table of contents on the first right hand page of the unit**

## **Double-Entry Science Notebook Self-Reflection**

### **Reflective Paragraph Directions**

Begin your responses on the last left-hand page of the unit and continue on the facing right-hand page

**Count the # of stamps for the unit & record it first.**

1. Choose 6 items, which represent your best interesting work - 3 from left side and 3 from the right side...
2. In several REFLECTIVE paragraphs, write specific reasons why you chose the items, why they are your best work, and what these assignments reflect about your skills as a student.

**Skills: organization, analysis, logic, creativity, thoroughness, and accuracy of information, ability to put new information together, understanding new concepts, etc.**

***Reasoning that it was "fun" or just that you "liked" it is NOT an adequate reflection.***

- ┌ Indicate your overall rating of your notebook based on the 6,5,4,3,2,1 rubric. What do you think this notebook deserves on an A-F scale? Include several sentences on WHY, using specific details, you've chosen this rating.
- ┌ Using sentences and specifics, respond to the following:
  - What information did you learn that was new to you?
  - Did the notebook help you this term? Explain.
  - Do you plan on keeping the notebook? Explain.
  - What would improve the notebook? Explain.
- ┌ What are your goals for your next science class? List specific areas in which you feel you need to improve or need help improving
- ┌ What improvements or areas to change would you like to see in the class? Explain.
- ┌ **Thank you for your input!**

## **Double-Entry Science Notebook Scoring Rubric**

### **6 Excellent**

- Notebook contents are complete, dated & labeled
- Pages are numbered (odd: RIGHT-side even: LEFT-side)
- Right-side/Left-side topics are correct & contents organized
- Textbook notes/ writing goes beyond basic requirements
- Uses color and effective diagrams
- Notebook is neat and shows attention to detail.
- Shows impressive, in-depth self-reflection about the work.



### **5 Above Average**

- Notebook contents are complete, dated & labeled
- Pages are numbered (odd: RIGHT-side even: LEFT-side)
- Right-side/Left-side topics are correct & contents organized
- Uses color and effective diagrams
- Most areas meet requirements, but don't go beyond.
- Includes most of the traits of a "6", but lacks excellence in all areas.
- Shows in-depth self-reflection.

### **4 Average**

- Notebook contents are complete (at least 90%) dated & labeled.
- Pages are numbered (odd: RIGHT-side even: LEFT-side)
- Right-side/Left-side topics are correct & contents organized
- Uses color and some diagrams
- Information shows a basic understanding of content topics
- Some areas meet requirements, but don't go beyond.
- Shows limited, but real, self-reflection.

### **3 Below Average**

- Notebook contents are complete (at least 80%) dated & labeled.
- Pages are numbered (odd: RIGHT-side even: LEFT-side)
- Right-side/Left-side topics are somewhat organized
- Uses minimal color and few diagrams
- Information shows a limited understanding of content topics
- Few areas meet all requirements.
- Shows some real self-reflection.

### **2 Inadequate**

- Notebook contents are incomplete.
- Some attempt at dating and labeling of entries is made.
- Right-side/left-side is inconsistent and contents are unorganized.
- Information and concepts show only a superficial understanding of the subject matter and/or show serious inaccuracies.
- Notebook is not neatly written, sloppiness prevails.
- Shows little real self-reflection.

### **1 Incomplete**

Notebook turned in, but too incomplete to evaluate.

## Double-Entry Notebook • *Parent Review*

- Schedule a time and place to meet with your parent (or significant adult) when they have time to look at your Double-Entry Notebook, and write some comments.

Dear Parent or Guardian,

Your student has been keeping a Double-Entry Notebook in biology. Please look through their notebook, read their self-reflections/ and respond to the following items.

Thanks for your time and support.



1) The work I/we found most interesting was.... Because.....

2) What does the notebook tell you about your student's learning habits?

3) Comments, questions or concern? Please let me know.

Parent's Name \_\_\_\_\_

Student's Name \_\_\_\_\_

Signed \_\_\_\_\_ Date \_\_\_\_\_

## **Think Alouds using Hands on Learning**

Build an Animal using Clay

### **Think Alouds for Reading Selection**

1. Select a short reading with a beginning, middle, and an end.
2. Tell students that they are about to enter a strange new world, that is the world of your thoughts as a reader. Tell them that your thoughts will not be the same thoughts as theirs.
3. Tell them that reading is not just pronouncing words; it is making meaning out of what the author has written. Tell them that they can improve their reading comprehension.
4. Begin reading the text for a few lines and then alter your voice (raise the pitch, lower the volume, or use an accent) to model what you are thinking. Stop and explain what the voice altering meant and keep this voice altering consistent throughout the Think-Aloud.
5. Keep your thoughts concise and on the focus of the reading. Don't ramble on with personal anecdotes. Comment much more on the text than on your personal connection with the text.
6. Don't over-do the amount of your Think-Aloud thoughts. Once every paragraph or two is about right. Don't interrupt the flow of the reading and lose sight of the textual meaning.
7. Talk to the text and to the author.
8. Ask students if they think they understood the text better because of your verbalized thoughts than just by passively reading without active thoughts. Their answer will be "Yes," if you have done an effective Think-Aloud.
9. Have students practice their own Think-Alouds in pairs.
10. Repeat Think-Alouds often with both narrative and expository texts.

Greenleaf, C., Moje, E., Pearson, D., (2010). Literacy and Science: Each in the Service of the Other. *Science* 23, 459-463



Pro-Con

Issue/Topic: \_\_\_\_\_

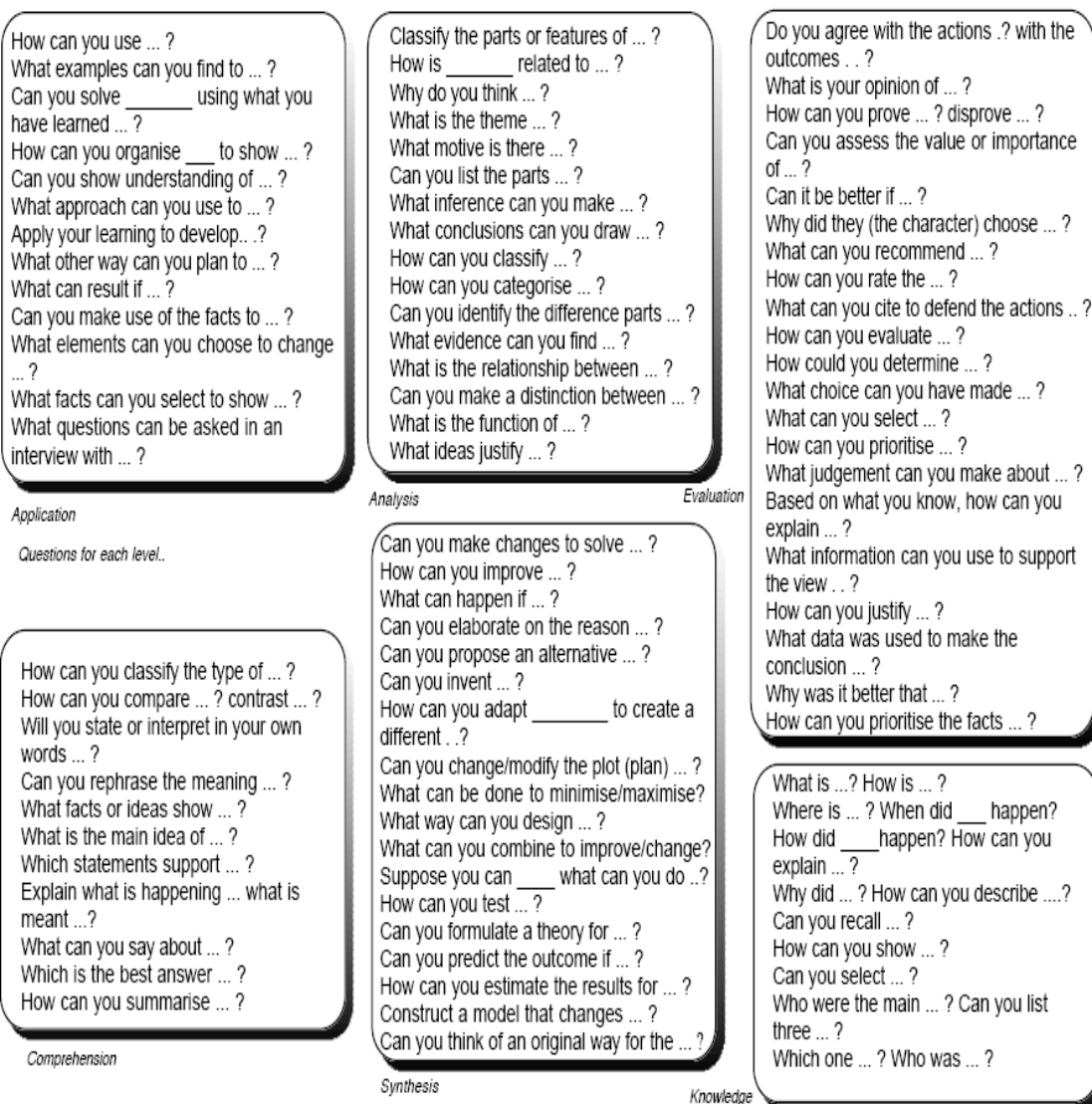
| Pro | Con |
|-----|-----|
|     |     |

| Action Words for Bloom's Taxonomy |               |             |               |              |             |
|-----------------------------------|---------------|-------------|---------------|--------------|-------------|
| Knowledge                         | Understand    | Apply       | Analyze       | Evaluate     | Create      |
| define                            | Explain       | Solve       | analyze       | reframe      | design      |
| identify                          | Describe      | Apply       | compare       | criticize    | compose     |
| describe                          | Interpret     | Illustrate  | classify      | evaluate     | create      |
| label                             | Paraphrase    | Modify      | contrast      | order        | plan        |
| List                              | Summarize     | Use         | distinguish   | appraise     | combine     |
| name                              | Classify      | Calculate   | infer         | judge        | formulate   |
| state                             | Compare       | Change      | separate      | support      | invent      |
| match                             | Differentiate | Choose      | explain       | compare      | hypothesize |
| recognize                         | Discuss       | Demonstrate | select        | decide       | substitute  |
| select                            | Distinguish   | Discover    | categorize    | discriminate | write       |
| examine                           | Extend        | Experiment  | connect       | recommend    | compile     |
| locate                            | Predict       | Relate      | differentiate | summarize    | construct   |
| memorize                          | Associate     | Show        | discriminate  | assess       | develop     |
| quote                             | Contrast      | Sketch      | divide        | choose       | generalize  |
| recall                            | Convert       | Complete    | order         | convince     | integrate   |
| reproduce                         | Demonstrate   | Construct   | point out     | defend       | modify      |
| tabulate                          | Estimate      | Dramatize   | prioritize    | estimate     | organize    |
| tell                              | Express       | Interpret   | subdivide     | find errors  | prepare     |
| copy                              | Identify      | Manipulate  | survey        | grade        | produce     |
| discover                          | Indicate      | Paint       | advertise     | measure      | rearrange   |
| duplicate                         | Infer         | Prepare     | appraise      | predict      | rewrite     |
| enumerate                         | Relate        | Produce     | break down    | rank         | role-play   |
| listen                            | Restate       | Report      | calculate     | score        | adapt       |
| observe                           | Select        | Teach       | conclude      | select       | anticipate  |
| omit                              | Translate     | Act         | correlate     | test         | arrange     |
| read                              | Ask           | Administer  | criticize     | argue        | assemble    |
| recite                            | Cite          | Articulate  | deduce        | conclude     | choose      |
| record                            | Discover      | Chart       | devise        | consider     | collaborate |
| repeat                            | Generalize    | Collect     | diagram       | critique     | collect     |
| retell                            | give examples | Compute     | dissect       | debate       | devise      |
| visualize                         | Group         | Determine   | estimate      | distinguish  | express     |
|                                   | Illustrate    | Develop     | evaluate      | editorialize | facilitate  |
|                                   | Judge         | Employ      | experiment    | justify      | imagine     |
|                                   | Observe       | Establish   | focus         | persuade     | infer       |
|                                   | Order         | Examine     | illustrate    | rate         | intervene   |
|                                   | Report        | Explain     | organize      | weigh        | justify     |
|                                   | Represent     | Interview   | outline       |              | make        |
|                                   | Research      | Judge       | plan          |              | manage      |
|                                   | Review        | List        | question      |              | negotiate   |
|                                   | Rewrite       | Operate     | test          |              | originate   |
|                                   | Show          | Practice    |               |              | propose     |
|                                   | Trace         | Predict     |               |              | reorganize  |
|                                   | Transform     | Record      |               |              | report      |

Noble, T. (2004). Integrating the revised bloom's taxonomy with multiple intelligences: A planning tool for curriculum differentiation, Teachers College Record (Vol. 106, pp. 193): Blackwell Publishing Limited.

# Cornell Notes

[illegible]



Based on Task Oriented Question Construction Wheel & Bloom's Taxonomy. ©2001 St. Edward's University Center for Teaching Excellence.  
[www.stedwards.edu/cte/bwheel.htm](http://www.stedwards.edu/cte/bwheel.htm)

Construct a model to show how it will work  
 Edit films/photographs/recordings to demonstrate a particular point  
 Make a puzzle game using ideas from event  
 Create a presentation that shows how it applies to another situation  
 Play a piece of music showing your understanding of it

*Application*

*Possible activities for each level..*

Design a questionnaire to gather further information  
 Write a commercial to sell a new product  
 Conduct an investigation to produce information supporting a point of view  
 Make a flow chart to show critical stages  
 Illustrate data/information with a graph  
 Make a Tree Map  
 Write a Biography  
 Review art/music in terms of form, texture, colour, rhythm  
 Write an index and glossary  
 Create a model  
 Brace Map  
 Double Bubble Map  
 Reorganise your brainstorm/mindmap and add ideas to it  
 T Chart  
 Venn diagram

*Analysis*

Prepare a list of criteria to judge a show.. include priorities and ratings  
 Conduct a debate about an issue of special interest  
 Evaluate the composition (art/music) that you performed or others performed  
 Hold a discussion about viewpoints  
 Write a letter outlining changes that will be needed to be made on...  
 Put on your blue hat and look at the process of how you got to where you are on the topic.. what have you learned.. what would you change?  
 PMI (Plus, Minus, Interesting)  
 C & S (Consequences & Sequels)  
 O.P.V. (Other peoples viewpoint)  
 Black Hat... all Six Hats

*Evaluation*

Draw/paint pictures to explain what an event was about  
 Illustrate the main idea  
 Sequence the events in a cartoon or flowchart  
 Write and perform a play based on event/facts  
 Retell in your own words  
 Write a summary report  
 Edit the film/recording/presentation to illustrate important parts  
 Bubble Map

*Comprehension*

Invent a machine for a specific task  
 Create a new product  
 Write about your feelings in relation to..  
 Do a visual presentation (video, TV show, play, puppet show etc) on a 'new' version or angle connected to the topic  
 Compose a rhythm/song or put new words to a known melody  
 Write your prediction about how views on this topic would change in time or place  
 Set goals from your learning  
 Green Hat, Red Hat to create new

*Synthesis*

Make a list of the main events  
 Make a timeline of events  
 Make a facts chart  
 Write a list of what you can remember  
 Make a chart showing...  
 Recite a poem  
 Film, record or photograph the event or person  
 Write the facts  
 Draw what you know  
 Make a mind map of what you know

*Knowledge*

Based on Task Oriented Question Construction Wheel & Bloom's Taxonomy. 2001 St. Edward's University Center for Teaching Excellence.  
[www.stedwards.edu/cte/bwheel.htm](http://www.stedwards.edu/cte/bwheel.htm)

**Stem Statements**

|   |  |
|---|--|
| I was successful in                       | I'm not sure...                            |
| I got stuck.....                          | What puzzled me the most was.....          |
| I figured out.....                        | I was really surprised when .....          |
| I got confused when ... so I .....        | I will understand this better if I .....   |
| I didn't expect.....                      | I stopped... because....                   |
| I thin I need to redo.....                | I think tomorrow I would like to try ..... |
| I need to rethink.....                    | The hardest part of this was.....          |
| I first thought.... but now I realize.... | I really feel good about the way.....      |
| Right now I am thinking about.....        | I figured it out because.....              |
| I wish I could.....                       |  |

## **Reflective Journals**

### **Lesson Plan**

**Objective:** Students use metacognitive strategies to reflect on their conceptual understanding of evolution content.

**Big ideas or concepts:** Students will explore the guiding questions: What have I understood thus far? What do I need to understand? How can I further my learning? How do I learn best?

**Resources or materials:**

Double-entry notebook guidelines

Stem Statements

Concepts of Learning

Reflective Journal Questions

Assessment Rubrics

**Preparation:**

1. Do the prior activities in class so students can have a good grasp of reflecting on their own learning and setting learning goals.
2. Prepare correlated assessment for content covering in the class.
3. Make rubrics and grading expectations clear before assessments.
4. Prepare appropriate curriculum choices to relearn or further students' learning in the lesson's content.

**Procedure:**

1. Review what students understand about metacognition.
2. Explain or review and practice metacognitive activities: think alouds, stem statements, think-aloud techniques, double-entry journals, self-administered checklists, and portfolio registries.
3. Have students use a formative assessment such as a concept map, quick write or quiz.
4. Assess students' content understanding using a rubric or answer key.
5. Have students reflect on their assessments in their reflective journals using optional reflection questions, bloom's action words and stem statements as tools to verbalize their reflections.
6. Discuss with students curriculum choices for relearning or furthering learning after reflection.

Have students select a curriculum and reflect upon this choice or/and use the reflection questions as a guide.

**Reflective Journal Questions**

|   |
|---|
| What were the results of your assessment?   |
| What were your strengths on the assessment? Where can you make some improvements?     |
| Where in the concept of the learning scale did you feel you reached as a learner?     |
| What areas of biology will you focus on for the next assessment?                      |
| How will you relearn or further your learning in these areas for the next assessment? |
| Why did you choose this type of method? How do you learn best?                        |



# Individual Learning Plan Template

Student Name: \_\_\_\_\_ Date: \_\_\_\_\_

Long Term Goals: \_\_\_\_\_

\_\_\_\_\_

Student's Areas of Strength: \_\_\_\_\_

\_\_\_\_\_

Student's Areas of Need: \_\_\_\_\_

\_\_\_\_\_

Short Term Objectives/Benchmarks: \_\_\_\_\_

\_\_\_\_\_

| Skills Practice | Periodic<br>Review Date | Assessment<br>Measurement | Progress |
|-----------------|-------------------------|---------------------------|----------|
|                 |                         |                           |          |
|                 |                         |                           |          |
|                 |                         |                           |          |
|                 |                         |                           |          |
|                 |                         |                           |          |
|                 |                         |                           |          |
|                 |                         |                           |          |
|                 |                         |                           |          |
|                 |                         |                           |          |
|                 |                         |                           |          |
|                 |                         |                           |          |
|                 |                         |                           |          |

Quarterly Summary: \_\_\_\_\_

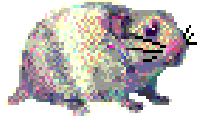
\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

## Case Studies

You are a field biologist assigned to study a little known mammal on the Island of Washoo. Your job is to analyze some known data and turn in your report to the Agency of New Species Control. Below is some information that was gathered about warbles. On a separate sheet of paper complete the following assignment. Your report must be as complete as possible to receive your full grant. (Refer to rubric).



*Warbles are small mammals that live in the desert and feed on seeds. One important variation found in warbles is the time of day they forage for food—some warbles are nocturnal (active at night) and some warbles are diurnal (active during the day). The primary predators of warbles are owls, which hunt only at night.*

1. Do you think nocturnal warbles and diurnal warbles have equal chances of being eaten by owls? Explain your reasoning.
2. Do you think that nocturnal warbles and diurnal warbles produce an equal number of offspring? Explain your reasoning.
3. Which type of warble is more fit? Explain your answer.
4. Over a long period of time, changes can occur in warbles as a result of evolution. Based on the answers you have given in this case study, what sorts of change do you think could occur in warbles due to evolution?

*Some warbles are born without the ability to reproduce. This is due to a genetic disorder caused by the recessive “no Baby” alleles. **Why is it that this disorder continues to persist even though the warbles that have the disorder cannot pass on the allele to their offspring?** Your analysis needs to include the word heterozygous.*

*The “no Baby” allele did not always exist in the gene pool. **Explain how this allele first entered the gene pool.***

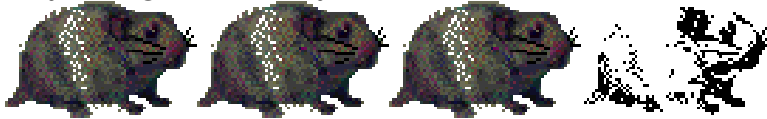
*Most warbles are either light or dark. There are a lot more dark warbles than light ones. If a volcanic eruption covers the ground of white ash, **why is it good that there is more than one color of warbles?** Describe how the change over time will occur in the warble population.*



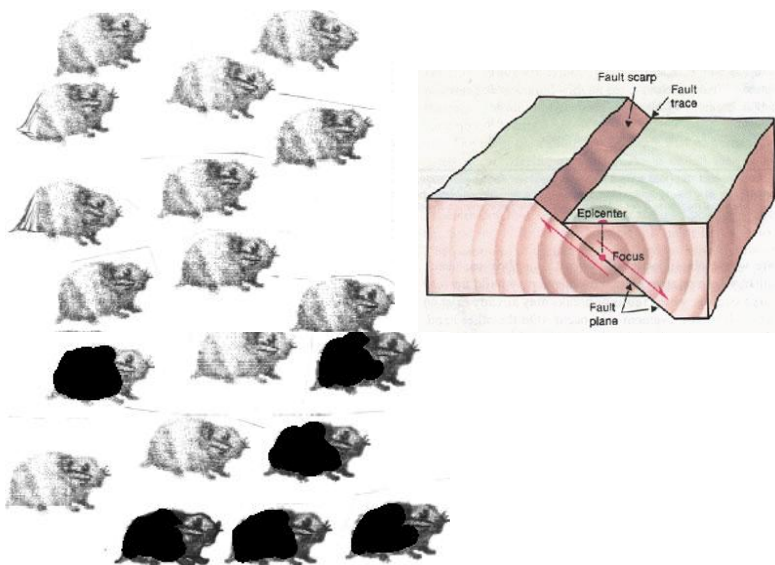
*What if a natural disaster caused all warbles to go extinct? Why would the natural disaster probably not kill all living things?*



*What if a natural disaster killed all but these four warbles? What affect may this have on the future generations of warbles?*

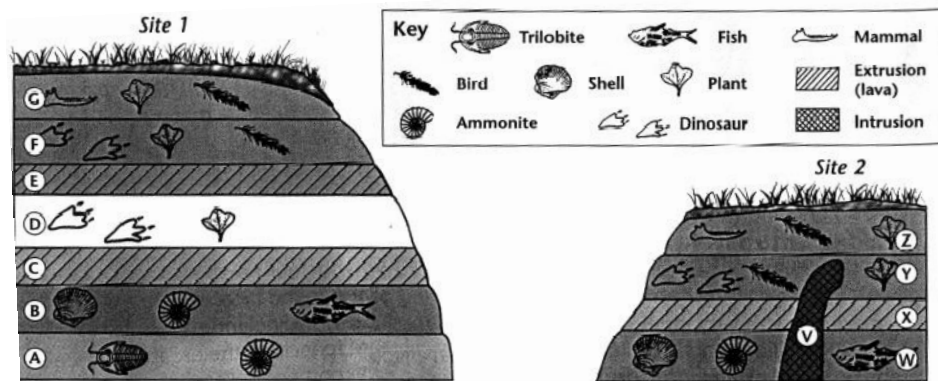


*What if an earthquake split the warbles into two groups? How might geographic isolation lead to speciation?*

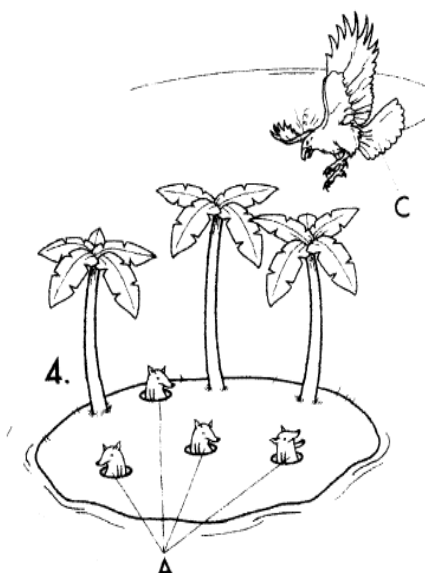
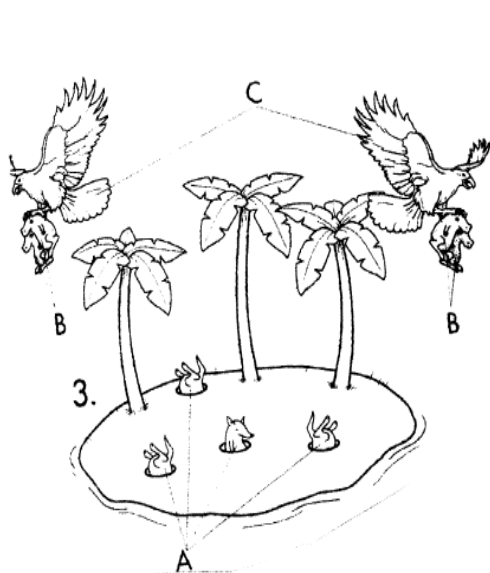
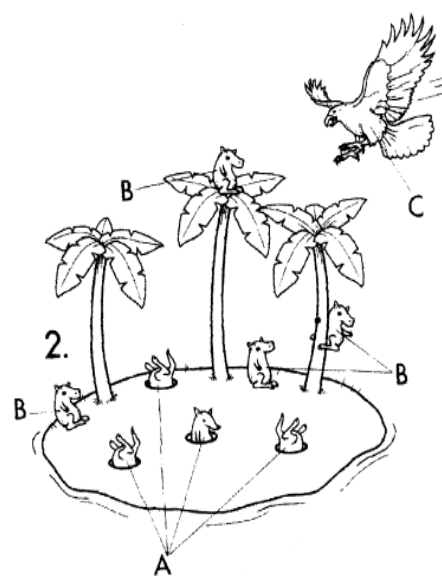
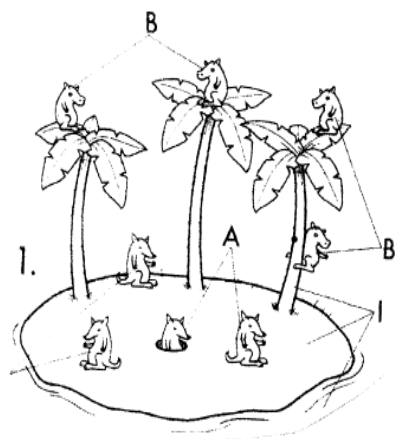


Analyze the following fossil record by answering the questions in complete sentences:

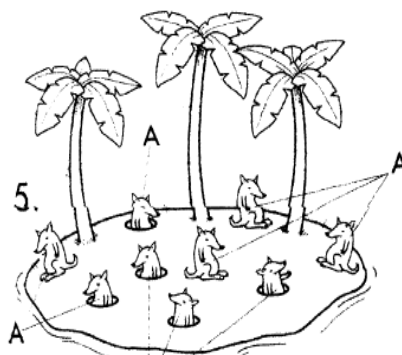
1. List the kinds of fossils that are found in each rock layer of Site 1 (Layer A-G) and Site 2 (Layer V-Z).
2. Discuss whether or not these fossil layers show evidence of biodiversity. Be as descriptive as possible.
3. Discuss whether there is any evidence of mass extinctions. If so, be specific about which layer and which site and why you think this is true.
4. Do you see new species arising in layers? If so, in which layers and what site?
5. For site 1 and 2 which layer is the oldest and youngest and how do you know?



On the next page there are five scenes. For each scene you need to write what is happening. Make sure you relate this whole story to Natural Selection. Make sure you note the variation between the two animals and describe their phenotypes. This must be colored and all sentences must be complete.



- Natural Selection**
- Isolated Island.....I
  - First Animal .....A
  - Second Animal .....B
  - Predator .....C



## My “Hood”

(*Natural Selection*)

Handwritten rough draft:

Introduction Paragraph:

- In complete sentences describe where you live and the type of environment (be very descriptive)
  - What is your city called
  - When you step outside what do you see (ex buildings, people, transportation, etc)
  - Describe the things you mention with adjectives (ex bright, new, fast, wearing out, etc)
  - What is the weather like?
  - Describe the organisms in your hood
  - What types of people live around you (mention their physical features and their personalities or beliefs)

Paragraph #1:

- In complete sentences explain to me what it takes to survive in the environment you described in your intro paragraph.
  - Can anyone survive in your hood? Why or why not?
  - What traits must a person or living organism have in order to survive in your hood? (list physical features, beliefs, personalities, level of education, social economics, etc)
  - Who survives in your hood and who doesn't?

Paragraph #2:

- Select a person (imaginary or real) who lives in your hood and **HAS** adapted to your environment in order survive in it.
  - Why is this person able to survive?
  - List qualities/adaptations that help him survive (physical appearance, personality, etc)

Paragraph #3:

- Select a person (imaginary or real) who lives in your hood and **HAS NOT** adapted to your environment and will not survive in it.
  - Why is this person not able to survive?
  - List qualities/adaptations that prevent him from surviving (physical appearance, personality, etc)

Conclusion:

- Sum up your essay. Briefly describe your environment and the adaptations need to survive in it.

## **Section V**

Quick write rubric  
Inquiry lab rubric  
Culminating task rubric

Quick Write Rubric

| CATEGORY                          | 4  | 3   | 2  | 1   | NS/0   |
|-----------------------------------|--|---|--|---|--|
| Content:<br>FOCUS 1               | Topic/subject is clear, though it may/may not be explicitly stated.    | Topic/subject is generally clear though it may not be explicitly stated.                        | Topic/subject may be vague.  | Topic/subject is unclear or confusing.  | This code may be used for compositions that are entirely illegible or otherwise unscorable: blank responses, restatements of the prompt, responses that are off-topic or incoherent. |
| Content:<br>SUPPORT               | Support information is related to and supportive of the topic/subject. | Support information has minor weaknesses in relatedness to and/or support of the topic/subject. | Support information has major weaknesses in relatedness to and/or support of the topic/subject.            | An attempt has been made to add support information, but it was unrelated or confusing. | This code may be used for compositions that are entirely illegible or otherwise unscorable: blank responses, restatements of the prompt, responses that are off-topic or incoherent. |
| Content:<br>ELABORATION           | Elaboration consists of specific, developed details.                   | Elaboration consists of some specific details.  | Elaboration consists of general and/or undeveloped details, which may be presented in a list-like fashion. | Elaboration is sparse; almost no details.   | This code may be used for compositions that are entirely illegible or otherwise unscorable: blank responses, restatements of the prompt, responses that are off-topic or incoherent. |
| Content:<br>STYLE -<br>Vocabulary | Exhibits skillful use of vocabulary that is precise and purposeful.    | Exhibits reasonable use of vocabulary that is precise and purposeful.                           | Exhibits minimal use of vocabulary that is precise and purposeful.   | Lacks use of vocabulary that is precise and purposeful.                                 | This code may be used for compositions that are entirely illegible or otherwise unscorable: blank responses, restatements of the prompt, responses that are off-topic or incoherent. |



# INQUIRY LABS LAB REPORT RUBRIC

Name: \_\_\_\_\_

Experiment: \_\_\_\_\_

Date: \_\_\_\_\_ Period: \_\_\_\_\_

|                    |  | NONE | SOME | HALF | MOST |
|--------------------|--|------|------|------|------|
| GENERAL<br>FORMAT  | 1. Lab is done in correct format                             | 0    | 1    | 2    | 3    |
|                    | 2. Entire lab is neat, readable, organized                   | 0    | 1    | 2    | 3    |
|                    | 3. Lab is written in a technical style (scientific language) | 0    | 1    | 2    | 3    |
| INTRODUCTION       | 4. Background information thoroughly explained               | 0    | 1    | 2    | 3    |
|                    | 5. Question clearly asked                                    | 0    | 1    | 2    | 3    |
|                    | 6. Purpose of the experiment clearly stated                  | 0    | 1    | 2    | 3    |
|                    | 7. Hypothesis strongly written                               | 0    | 1    | 2    | 3    |
| DESIGN             | 8. Materials list present and complete                       | 0    | 1    | 2    | 3    |
|                    | 9. Methods are in clear, brief steps                         | 0    | 1    | 2    | 3    |
|                    | 10. All the variables (IV, DV, control constants) listed     | 0    | 1    | 2    | 3    |
| DATA<br>COLLECTION | 11. Written observations complete and clear                  | 0    | 1    | 2    | 3    |
|                    | 12. Data tables/charts present                               | 0    | 1    | 2    | 3    |
|                    | 13. Data complete  | 0    | 1    | 2    | 3    |
|                    | 14. Data tables/charts have titles, labels and units         | 0    | 1    | 2    | 3    |
|                    | 15. Calculations clearly shown                               | 0    | 1    | 2    | 3    |
| DATA<br>ANALYSIS   | 16. Graphs present on graph paper (or done with computer)    | 0    | 1    | 2    | 3    |
|                    | 17. Appropriate type of graph                                | 0    | 1    | 2    | 3    |
|                    | 18. Graphs have title, axis name and units labeled           | 0    | 1    | 2    | 3    |
|                    | 19. Data properly graphed                                    | 0    | 1    | 2    | 3    |
|                    | 20. Description/evaluation of data                           | 0    | 1    | 2    | 3    |
|                    | 21. Possible sources of error                                | 0    | 1    | 2    | 3    |
| CONCLUSION         | 22. Reflection on question                                   | 0    | 1    | 2    | 3    |
|                    | 23. Reflection on hypothesis                                 | 0    | 1    | 2    | 3    |
|                    | 24. Use of data to support or refute hypothesis              | 0    | 1    | 2    | 3    |
|                    | 25. Explanation of results (what happened and why)           | 0    | 1    | 2    | 3    |
|                    | 26. Connection to classroom discussion (themes, targets)     | 0    | 1    | 2    | 3    |

Comments: \_\_\_\_\_

### ***Culminating Task Rubric***

|          |   |
|----------|---|
| <b>4</b> | Responses demonstrate a complete analysis of the role of variation in survival (both within and between species). An analysis of fitness, differences in reproduction rate, natural selection. Complete analysis of the effects of heterozygotic genotype's role in maintaining unwanted alleles. An understanding of the role of mutation in introducing variation. An analysis of the effects of genetic drift. Analysis of geographic isolation's role in speciation. Analysis of the fossil evidence with regard to biodiversity, speciation and mass extinction. Neat and accurate, thorough and well thought out. |
| <b>3</b> | Analysis incomplete on two or less key concepts. Not all vocabulary used accurately. Answers complete, neat and thorough.   |
| <b>2</b> | Demonstrates understanding of major concepts but lacking in evidence of application and analysis.   |
| <b>1</b> | Missing some sections completely. Less than neat.   |

## **Section VI**

Metacognitive Survey  
Self-efficacy Survey  
Evolution Beliefs Survey  
On-task/Off-task Behavior Recording Chart

## Metacognitive Survey

1. What is your name?

2. I understand my intellectual strengths and weaknesses.

|             | Almost never          | Seldom                | Sometimes             | Often                 | Almost Always         |
|-------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|
| Select one: | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |

3. I consciously focus my attention on important information.

|             | Almost never          | Seldom                | Sometimes             | Often                 | Almost Always         |
|-------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|
| Select one: | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |

4. I have a specific purpose for each strategy I use.

|             | Almost never          | Seldom                | Sometimes             | Often                 | Almost Always         |
|-------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|
| Select one: | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |

5. I use different learning strategies depending on the situation.

|             | Almost never          | Seldom                | Sometimes             | Often                 | Almost Always         |
|-------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|
| Select one: | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |

6. I have control over how well I learn.

|             | Almost never          | Seldom                | Sometimes             | Often                 | Almost Always         |
|-------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|
| Select one: | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |

7. I am aware of what strategies I use when I study.

|             | Almost never          | Seldom                | Sometimes             | Often                 | Almost Always         |
|-------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|
| Select one: | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |

8. I have a specific purpose for each strategy I use.

|             | Almost never          | Seldom                | Sometimes             | Often                 | Almost Always         |
|-------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|
| Select one: | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |

9. I find myself using helpful learning strategies automatically.

|             | Almost never          | Seldom                | Sometimes             | Often                 | Almost Always         |
|-------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|
| Select one: | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |

10. I find myself pausing regularly to check my comprehension.

|             | Almost never          | Seldom                | Sometimes             | Often                 | Almost Always         |
|-------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|
| Select one: | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |

11. I draw pictures or diagrams to help me understand while learning.

|             | Almost never          | Seldom                | Sometimes             | Often                 | Almost Always         |
|-------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|
| Select one: | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |

12. I try to translate new information into my own words.

|             | Almost never          | Seldom                | Sometimes             | Often                 | Almost Always         |
|-------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|
| Select one: | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |

|   |                       |                       |                       |                       |                       |
|---|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|
| 13. I change strategies when I fail to understand.  |                       |                       |                       |                       |                       |
|   | Almost never          | Seldom                | Sometimes             | Often                 | Almost Always         |
| Select one:   | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| 14. I read instructions carefully before I begin a task.  |                       |                       |                       |                       |                       |
|   | Almost never          | Seldom                | Sometimes             | Often                 | Almost Always         |
| Select one:   | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| 15. I ask myself questions about how well I am doing while I am learning something new.                           |                       |                       |                       |                       |                       |
|   | Almost never          | Seldom                | Sometimes             | Often                 | Almost Always         |
| Select one:   | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| 16. I stop and go back over new information that is not clear.  |                       |                       |                       |                       |                       |
|   | Almost never          | Seldom                | Sometimes             | Often                 | Almost Always         |
| Select one:   | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| 17. I stop and reread when I get confused.  |                       |                       |                       |                       |                       |
|   | Almost never          | Seldom                | Sometimes             | Often                 | Almost Always         |
| Select one:   | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| 18. I persevere even when I am frustrated by a task.  |                       |                       |                       |                       |                       |
|   | Almost never          | Seldom                | Sometimes             | Often                 | Almost Always         |
| Select one:   | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| 19. I give up too easily when faced with a difficult task.  |                       |                       |                       |                       |                       |
|   | Almost never          | Seldom                | Sometimes             | Often                 | Almost Always         |
| Select one:   | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| 20. There are new things I have learned about myself as a learner after having choices about relearning in class. |                       |                       |                       |                       |                       |
|   | Almost never          | Seldom                | Sometimes             | Often                 | Almost Always         |
| Select one:   | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |

Schraw, G. & Dennison, R. S. (1994). Assessing Metacognitive Awareness. *Contemporary Educational Psychology*, 19, 460–475.

### Self-Efficacy Survey

1. What is your name?

2. I can always solve problems if I try hard enough in science class.

|                    | Not at all true       | Hardly true           | Moderately true       | Exactly true          |
|--------------------|-----------------------|-----------------------|-----------------------|-----------------------|
| Please select one: | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |

3. I am confident I can learn the basic concepts taught in this science class

|                    | Not at all true       | Hardly true           | Moderately true       | Exactly true          |
|--------------------|-----------------------|-----------------------|-----------------------|-----------------------|
| Please select one: | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |

4. If someone tries to stop me, I can find a way to get what I want in science class.

|                    | Not at all true       | Hardly true           | Moderately true       | Exactly true          |
|--------------------|-----------------------|-----------------------|-----------------------|-----------------------|
| Please select one: | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |

5. It is easy for me to stick to my plans and accomplish my goals in science class.

|                    | Not at all true       | Hardly true           | Moderately true       | Exactly true          |
|--------------------|-----------------------|-----------------------|-----------------------|-----------------------|
| Please select one: | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |

6. I am sure I know what to do if something unexpected happens to me in science class.

|                    | Not at all true       | Hardly true           | Moderately true       | Exactly true          |
|--------------------|-----------------------|-----------------------|-----------------------|-----------------------|
| Please select one: | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |

7. Because I am smart I can figure things out when something unexpected happens in science class.

|                    | Not at all true       | Hardly true           | Moderately true       | Exactly true          |
|--------------------|-----------------------|-----------------------|-----------------------|-----------------------|
| Please select one: | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |

8. I can solve most problems if I really try in science class.

|                    | Not at all true       | Hardly true           | Moderately true       | Exactly true          |
|--------------------|-----------------------|-----------------------|-----------------------|-----------------------|
| Please select one: | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |

9. I can get what I want from people if I make them feel sorry for me in science class.

|                    | Not at all true       | Hardly true           | Moderately true       | Exactly true          |
|--------------------|-----------------------|-----------------------|-----------------------|-----------------------|
| Please select one: | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |

10. I can stay calm when I have a problem in science class.

|                    | Not at all true       | Hardly true           | Moderately true       | Exactly true          |
|--------------------|-----------------------|-----------------------|-----------------------|-----------------------|
| Please select one: | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |

11. When I have a problem, I can usually find more than one way to solve it in science class.

|                    | Not at all true       | Hardly true           | Moderately true       | Exactly true          |
|--------------------|-----------------------|-----------------------|-----------------------|-----------------------|
| Please select one: | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |

12. If I am in trouble, I can usually think of a way out in science class.

|                    |                       |                       |                       |                       |
|--------------------|-----------------------|-----------------------|-----------------------|-----------------------|
|                    | Not at all true       | Hardly true           | Moderately true       | Exactly true          |
| Please select one: | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |

13. I can usually handle whatever comes my way in science class.

|                    |                       |                       |                       |                       |
|--------------------|-----------------------|-----------------------|-----------------------|-----------------------|
|                    | Not at all true       | Hardly true           | Moderately true       | Exactly true          |
| Please select one: | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |

14. I spend time planning things I want to do in science class.

|                    |                       |                       |                       |                       |
|--------------------|-----------------------|-----------------------|-----------------------|-----------------------|
|                    | Not at all true       | Hardly true           | Moderately true       | Exactly true          |
| Please select one: | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |

15. If I want something from someone I should have a positive attitude in science class.

|                    |                       |                       |                       |                       |
|--------------------|-----------------------|-----------------------|-----------------------|-----------------------|
|                    | Not at all true       | Hardly true           | Moderately true       | Exactly true          |
| Please select one: | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |

16. I feel in charge of making things happen in science class.

|                    |                       |                       |                       |                       |
|--------------------|-----------------------|-----------------------|-----------------------|-----------------------|
|                    | Not at all true       | Hardly true           | Moderately true       | Exactly true          |
| Please select one: | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |

17. I can control my own life.

|                    |                       |                       |                       |                       |
|--------------------|-----------------------|-----------------------|-----------------------|-----------------------|
|                    | Not at all true       | Hardly true           | Moderately true       | Exactly true          |
| Please select one: | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |

18. I can control my performance in science class.

|                    |                       |                       |                       |                       |
|--------------------|-----------------------|-----------------------|-----------------------|-----------------------|
|                    | Not at all true       | Hardly true           | Moderately true       | Exactly true          |
| Please select one: | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |

19. I do most things because I think they the right things to do.

|                    |                       |                       |                       |                       |
|--------------------|-----------------------|-----------------------|-----------------------|-----------------------|
|                    | Not at all true       | Hardly true           | Moderately true       | Exactly true          |
| Please select one: | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |

20. I do things that I think I should do in science class.

|                    |                       |                       |                       |                       |
|--------------------|-----------------------|-----------------------|-----------------------|-----------------------|
|                    | Not at all true       | Hardly true           | Moderately true       | Exactly true          |
| Please select one: | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |

21. Most things happen to me because I am lucky.

|                    |                       |                       |                       |                       |
|--------------------|-----------------------|-----------------------|-----------------------|-----------------------|
|                    | Not at all true       | Hardly true           | Moderately true       | Exactly true          |
| Please select one: | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |

22. I am able to choose what I do.

|                    |                       |                       |                       |                       |
|--------------------|-----------------------|-----------------------|-----------------------|-----------------------|
|                    | Not at all true       | Hardly true           | Moderately true       | Exactly true          |
| Please select one: | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |

23. I work mostly on things that I can control.

|                    |                       |                       |                       |                       |
|--------------------|-----------------------|-----------------------|-----------------------|-----------------------|
|                    | Not at all true       | Hardly true           | Moderately true       | Exactly true          |
| Please select one: | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |

## EVOLUTION SURVEY

READ THIS: VERY IMPORTANT! Please indicate whether each following statement is true or false, in terms of how you think biologists use and understand the term "evolution" today. YOU do NOT necessarily have to AGREE with the statement for it to be "true" as you think biologists see it. Your answers will be confidential, and will not affect your grade. The purpose of this is to determine the level of understanding on this topic in this class, so that misconceptions can be discussed. In every case below, "evolution" means "biological evolution".

Write TRUE, (to biologists). Or FALSE, (to biologists)

1. Evolution is a scientific fact.
2. Evolution is something you should either *believe in*, or not *believe in*.
3. Evolution is a process that involved the origin of life.
4. Evolution is primarily concerned with the origin of humans.
5. According to evolution, people came from monkeys a long time ago.
6. Evolution was first proposed and explained by Charles Darwin.
7. Evolution is the same as "Natural Selection".
8. Evolution is something that happened only in the past; it is not happening now.
9. Evolution is something that happens to individual organisms.
10. Evolution is a totally random process, or a series of "accidents".
11. Science can properly infer what has happened in the past, based on evidence.
12. The formation of complex structures, like the eye, can be readily explained by evolution.
13. . There is actually considerable observable evidence against evolution.
14. Evolution simply means "change".
15. "Evolution is only a theory".
16. There is actually very little evidence for evolution.
17. One indication that evolution has not occurred is the total absence of "transitional organisms" (those with traits intermediate between two different groups).
18. Fossils provide many problems which evolution cannot explain.
19. Most biological and medical and agricultural research assumes evolution is real.
20. Evolution theory has been tested many times, and has always been supported by the evidence.
21. Dinosaurs lived during the time of early humans.
22. Evolution involves individuals changing in order to adapt to their environment.





## References

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