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Effects of Student Choice on Engagement and
Understanding in a Junior High Science Class

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EFFECTS OF STUDENT CHOICE ON ENGAGEMENT AND UNDERSTANDING IN A JUNIOR HIGH SCIENCE CLASS

By

Laura Elizabeth Foreback

A THESIS

Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of

MASTER OF SCIENCE

Biological Science - Interdepartmental

2010

ABSTRACT

EFFECTS OF STUDENT CHOICE ON ENGAGEMENT AND UNDERSTANDING IN A JUNIOR HIGH SCIENCE CLASS

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The purpose of this study was to determine the effects of increasing individual student choice in assignments on student engagement and understanding of content. It was predicted that if students are empowered to choose learning activities based on individual readiness, learning style, and interests, they would be more engaged in the curriculum and consequently would develop deeper understanding of the material. During the 2009-2010 school year, I implemented differentiated instructional strategies that allowed for an increased degree of student choice in five sections of eighth grade science at DeWitt Junior High School. These strategies, including tiered lessons and student-led, project-based learning, were incorporated into the "Earth History and Geologic Time Scale" unit of instruction. The results of this study show that while offering students choices can be used as an effective motivational strategy, their academic performance was not increased compared to their performance during an instructional unit that did not offer choice.

ACKNOWLEDGEMENTS

I would like to extend special thanks to Dr. Merle Heidemann for her guidance and support, not only in the preparation of this thesis, but throughout my undergraduate and graduate studies. I would also like to thank the other graduate students in the Division of Science and Math Education program for their assistance, ideas, and advice.

Most of all, thank you to my wonderful family for your support and encouragement without which I would be lost.

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INTRODUCTION

Rationale and Statement of Problem

In a typical junior high classroom, students' abilities can vary widely. It is not uncommon for students well-below grade-level in terms of basic skills to be seated right next to students labeled as gifted. Yet, all students must meet certain standards and reach levels of proficiency despite their differences. In classrooms filled with 20, 30, even 40 students, what is a teacher to do? How can teachers make the content accessible to students with learning disabilities while still challenging the advanced student? All too often, we end up 'teaching to the middle', leaving some students behind and simultaneously holding some students back. This practice is inherently unfair to both groups. In today's educational climate, where school funding is tied to making adequate yearly progress, much attention has been paid to developing and implementing interventions for the lowest achieving students. These students need and deserve extra support, but so do the students who are achieving at a higher level.

Although it's what teachers often feel they must resort to, teaching to the middle not only disenfranchises students at both ends of the spectrum, it may not be the easiest alternative after all. In fact, it could be argued that 'the middle' is at best a small and moving target, if it really exists at all. That is, when we refer to 'the middle', we could be referring to a number of different things. 'The middle' could mean, 'the majority of students' or 'where we believe the students ought to be' or 'the students of average intelligence'. The problem is, our students are unique individuals and as much as we try to group them into clusters of similarity, we cannot change the fundamental truth that kids are different from one another. An added layer of complexity to this problem is that students, particularly adolescents, are growing and changing at a rapid pace, making it even more difficult for teachers to categorize them. Effective instruction must take into account students' individuality.

This is not to say, however, that all instruction should be individualized. There is an important social aspect to learning that demands that students work and explore ideas together. Students must frequently be grouped for a variety of reasons, not the least of which is to facilitate cooperative learning, an essential part of education. The point is that teachers need to recognize and respond to the differences among students and be flexible in their grouping practices. While the basic skills of the students will certainly not change drastically from one day to the next (although it should be expected that students' basic skills will improve over the course of the school year), their background knowledge and personal experience with different topics of study are very likely to be different from unit to unit. A student who has trouble reading and had little knowledge of electricity, for instance, may have been observing the stars for years and be well-versed in astronomy concepts. Further, that same student who has difficulty reading may have exceptional auditory processing skills.

Thus, what we term 'the middle', however we define it, varies from topic to topic. Teachers are expected to reach all students, yet as the list of demands on teachers' time grows longer, that becomes more and more difficult. We should not be trying to teach to the middle and then going back and re-teaching the students who didn't understand the first time around while desperately trying to come up with something to challenge the advanced students (and somehow occupying the students who did understand the first time through). Rather, we should plan for our students' differences from the beginning. Students' interests, experiences, and learning styles are as varied as the content we teach in schools. If teachers are to reach the lowest achieving students, the gifted, and the students 'in the middle', they must first know each student as an individual learner and then differentiate instruction to meet the needs of their students.

I hypothesize that if students are given the opportunity to choose learning activities according to individual readiness, learning style, and personal interests, they will be more engaged in the curriculum and will subsequently develop deeper understanding of the material. In order to study the effect that student choice has on engagement and understanding, I implemented several differentiated instructional strategies including tiered lessons and student-led projects into the Earth History and Geologic Time Scale unit of eighth grade science at DeWitt Junior High School.

The eighth grade science course at DeWitt Junior High School has been evolving over the last several years. Previously, this course had been taught as an integrated science class but as the state's Grade Level Content Expectations are written for grades K – 7, eighth grade science now falls under the umbrella of high school content. Currently, eighth grade science is taught as an interdisciplinary science class that covers topics from primarily the physical sciences and earth sciences. The life science units previously taught were completely phased out of the class this year. Next year, eighth grade science will be exclusively earth science and will cover just over half of the High School Content Expectations for Earth Science.

The Earth History and Geologic Time Scale unit was taught for the first time in our curriculum during the fall of the 2009-2010 school year. It followed the Electricity unit taught early in the school year to allow this cohort of students to be instructed on content that they had missed in earlier grades before the state standardized test was administered in October of 2009. It preceded the Rocks and Minerals, Advanced Rock Cycle, Plate Tectonics, and Earthquakes and Volcanoes units. These five units comprised this year's Earth Science portion of the class. Along with the Electricity unit, a Waves unit and a Forces and Motion unit made up the physical science portion of the course.

Also embedded in the eighth grade science curriculum is instruction designed to prepare students for the Science Fair. The Science Fair occurs in the spring and all eighth grade students complete an independent research project where they identify a testable question, develop and conduct an experiment to investigate the question, and report on their findings. Throughout the school year, several "mini-units" are included to support students in these independent projects.

Summary of the Science Concepts

The Earth History and Geologic Time Scale unit covered three of the four High School Content Expectations (HSCEs) in the "Earth History and Geologic Time" section of the "Earth in Space and Time" strand of the Earth Science HSCEs. The omitted content expectation (E5.3B - Describe the process of radioactive decay and explain how radioactive elements are used to date the rocks that contain them) was left out of the eighth grade unit because it is taught as part of the high school's earth science class. This objective will become a part of the eighth grade unit in the future but was not part of the instruction for this study. The three content expectations that were covered are listed in Table 2.

Table 1: HSCEs covered in the Earth Science and Geologic Time Scale Unit

E5.3A	Explain how the solar system formed from a nebula of dust and gas in a spiral arm of the Milky Way Galaxy about 4.6 Ga (billion years ago).
E5.3C	Relate major events in the history of the Earth to the geologic time scale, including formation of the Earth, formation of an oxygen atmosphere, rise of life, Cretaceous-Tertiary (K-T) and Permian extinctions, and Pleistocene ice age.
E5.3D	Describe how index fossils can be used to determine time sequence.

The solar system formed from a huge cloud of gas and dust 4.6 billion years ago. This cloud of gas and dust, the solar nebula, was originally somewhat spherical in nature and slowly rotating, but some disturbance, perhaps a shock wave from a nearby supernova, caused it to begin to collapse. As the solar nebula collapsed, the force of gravity increased and the nebula began to rotate faster. Gravitational potential energy was converted into heat energy and the nebula became hotter. As the nebula began to spin faster, it flattened out into a disk shape. The temperature and pressure at the center of the disk became great enough that nuclear fusion reactions began to occur and our Sun was born. In the disk, gas and dust particles collided and began to form clumps of matter through a process called accretion. As the particles grew larger, they began to attract more matter by gravity and become planetesimals. Once these planetesimals grew large enough to clear out their own orbit, they are known as protoplanets. The kinds of compounds that formed from the collisions depended upon the temperature. Closer to the sun, where temperatures were hotter, metals and silicates could form resulting in the formation of the terrestrial planets. Farther from the sun, the temperatures were colder and methane compounds formed icy planetesimals that captured hydrogen and helium gasses to form the gas giants. The asteroid belt formed between Mars and Jupiter Eventually, the solar wind, charged particles streaming out from the sun, blew the rest of the gas and dust away leaving just the planets rotating around the sun. There are several pieces of evidence that scientists use to support this nebular theory. First, the planets are all revolving around the sun in the same direction, the same direction in which the sun is rotating, and in the same plane. Second, the planets (except Venus), and most of their moons, are all spinning in the same direction. Third, the orbits of the planets are roughly circular. Fourth, the terrestrial planets are closest to the sun and the Jovian planets (the Gas Giants) are farthest from the sun. Fifth, asteroids and comets exist in certain parts of the solar system. And finally, we observe this process happening in interstellar clouds of gas and dust in other areas of the solar system.

Geologic Time is measured from the formation of the earth to present day. It is divided into eras which are further subdivided into Periods, Epochs, and Ages. Precambrian

Time is measured from the formation of the Earth, estimated at about 4.5 billion years ago to the beginning of the Phanerozoic, about 543 million years ago. The Precambrian is subdivided into the Hadean (4.5 Ga – 3.8 Ga), the Archean (3.8 Ga – 2.5 Ga) and the Proterozoic (2.5 Ga – 543 Ma). During the Hadean, Earth's crust was solidifying as the planet cooled. The oldest Earth rocks are about 3.8 billion years old, compared to meteorites and moon rocks which data back as far as 4.5 billion years ago. During the Archean, the atmosphere was comprised of methane, ammonia, and other gases that would be toxic to life today. Photosynthetic blue-green algae and bacteria that were able to live in these harsh conditions appear and begin to release oxygen into the atmosphere. During the Proterozoic, life becomes more abundant and the first eukaryotic cells appear. Oxygen begins to build up in the atmosphere.

The Phanerozoic begins with the Paleozoic Era about 543 Ma and continues to the present. The Paleozoic Era extends from 543 Ma to 248 Ma taking up nearly half of the Phanerozoic. It is divided into the Cambrian (543 – 490 Ma), the Ordovician (490 – 443 Ma), the Silurian (443 Ma – 417 Ma), the Devonian (417 – 354 Ma), the Carboniferous (354 – 290 Ma), and the Permian (290 – 248 Ma). During the Cambrian, the first major diversification of animal life occurred. This is commonly known as the Cambrian explosion. The Ordovician is best known for the presence of diverse marine animals. Plants probably invaded the land at this time. The first jawed fishes and vascular plants appeared during the Silurian which brought significant climate stabilization and high sea levels due to the melting of the polar ice caps. The Devonian is known as the "Age of Fishes" because fish became abundant and diverse. The Carboniferous is divided in the

United States in the Mississippian (Lower Carboniferous) and the Pennsylvanian (Upper Carboniferous). Huge swamps and forests dominated the land resulting in the present day deposits of coal from which the Carboniferous derives its name. The first reptiles and winged insects appear at this time. The Paleozoic ends with the Permian Period, also known as the "Age of Amphibians". Amphibians and Reptiles dominate animal life and gymnosperms dominate plant life. Pangaea existed during the Permian and the atmosphere was oxygenated to approximately present-day conditions. The Permian ended with the largest mass extinction in Earth's history. Over 50% of all animal species go extinct, as do 95% of marine species and many plants and trees. It is thought that this mass extinction was caused by volcanism or glaciation.

The Mesozoic Era of the "Age of Reptiles" extended from 248 to 65 Ma. It is divided into three major Periods; the Triassic (248 – 208 Ma), the Jurassic (208 – 146 Ma), and the Cretaceous (146 Ma – 65 Ma). The first dinosaurs and mammals appear during the Triassic. A small extinction at the end of the Triassic allowed dinosaurs to expand and diversify during the Jurassic. The first birds and flowering plants appear during the Jurassic which is named for the rock formations in the Jura Mountains where these fossils were originally studied. The Cretaceous Period is sometimes known as the "Age of the Dinosaurs" and the break-up of Pangaea continued so that by the end of the Cretaceous, the continents were close to their present-day positions. At the end of the Cretaceous, another mass extinction event, known as the K-T extinction occurred. It is thought that this extinction, which killed off the dinosaurs, was caused by massive climate change resulting from the impact of an asteroid near the Yucatan Peninsula.

The Cenozoic Era (65 Ma to present) is divided into the Tertiary Period (65 – 1.8 Ma) and the Quaternary Period (1.8 Ma – present) and is known as the "Age of Mammals". After the extinction of the dinosaurs, mammals became abundant. Rodents and modern birds also appear. New mammals include horses, early primates, dogs, bears, and whales. At the end of the Tertiary Period, around 1.8 Ma, the first hominids *Australopithecus* appear. The Quaternary Period is known as the "Age of Man". Human evolution eventually results in modern-day *Homo sapiens*. A large extinction, probably due to the end of the last ice age, occurred about 10,000 years ago killing off species like the mammoth and saber-tooted tiger.

Index fossils are fossils that are used to define geologic time periods. Good index fossils have two primary characteristics: they existed over a wide-spread geographic area and they existed for a short time in geologic history. Brachiopods, trilobites, and ammonites are commonly used index fossils. Geologists can use index fossils to in the relative dating of rock layers because index fossils occur at during a narrow time in Earth's history. Therefore, if the same fossil is found in two different rock formations, it can be assumed that these layers of rock were formed at the same time. Using this comparison of rock layers, geologists can infer what geological processes have occurred over time.

Theoretical Framework

What is **differentiated instruction**? In his book *Fair Isn't Always Equal* (2006), Rick Wormeli defines differentiated instruction as

> "doing what's fair for students. It's a collection of best practices strategically employed to maximize students' learning at every turn, including giving them the tools to handle anything that is undifferentiated. It requires us to do different things for different students some, or a lot, of the time in order for them to learn when the general classroom approach does not meet students' needs. It is not individualized instruction, though that may happen from time to time as warranted. It's what works to advance the students. It's highly effective teaching" (ibid).

The science classroom is a natural place for differentiated instruction to occur. Effective science instruction is rooted in processes of inquiry, discovery, and problem-solving; all of which foster individual thinking and creativity. "At its best, science instruction nurtures the creative spirit in all students as they develop and deepen their understandings of the subject" (Hamm, 2008).

The role of the teacher in a differentiated classroom is to provide opportunities for all students to construct their own knowledge. This begins with careful planning. "Differentiated instruction is an approach to strategic planning of classroom instruction that meets the needs of all students. Differentiated instruction enables students to build a meaningful and accurate knowledge base, develop skills needed to become scientifically and technologically literate, and practice dispositions that are valued in the society.

Differentiated instruction requires carefully designed lessons that align with important goals and standards and include a variety of methods and strategies to meet the needs of students" (Gregory, 2008). In order to accomplish this, the teacher must be cognizant of curriculum goals, assessment possibilities, and students' varied learning needs all at the same time.

Planning for differentiation begins with assessment. "To differentiate science lessons and experiences, teachers formally and informally assess their students' capabilities with respect to multiple intelligences and preferred learning styles" (Hamm, 2008). Because differentiated instruction is a philosophy that gives careful consideration to individual students' learning styles and needs and provides different paths to the same learning goals, it is essential that teachers both know their students as learners and be well-versed in various instructional strategies for their content area. As noted by Wormeli above, teachers need not plan 30 different lessons for 30 different students in a differentiated classroom. If differentiated instruction were simply individualized instruction, it would be unmanageable in a typical school environment. Rather, the teacher's goal in differentiated instruction is to meet the needs of small groups, or clusters of students. Once a teacher knows his learners, he can then begin to plan for modifications that will make the content accessible to all groups. To ensure that all students are appropriately challenged and are gaining the essential skills and enduring understandings in the curriculum, teachers can modify (1) the content that is being learned, (2) the process (the way in which the content is learned), and (3) the product (the way the learning is assessed).

Differentiating Content

Content is most often determined by the school, the district, and/or the state. Teachers can differentiate content by determining student readiness through pre-assessment and then planning activities that are appropriate for each student's readiness. It is important to note in the philosophy of differentiated instruction readiness is not the same as ability level. Readiness refers to the student's current understanding of the content. In elementary classrooms, for example, students are often grouped according to ability level for reading instruction. Proponents of differentiated instruction frequently use the classic example of the Blue Birds, the Red Birds, and the Buzzards. Differentiating content does not mean 'watering down' the content for the Buzzards. A teacher may find that a student with Buzzard reading skills knows a lot about rocks because his dad is a geologist. This student deserves to have the content modified for him so that he does not spend valuable class time engaged in activities that are designed to teach students things that he already knows. It is important to note that grouping in a differentiated classroom should be flexible. That is, students should work with a variety of other students. Grouping may be based on readiness in some situations, while in others it may be based on students' interests or learning styles. The size of the groups should also be flexible.

Differentiating content is one of the most direct ways to challenge the highest achieving students. Educational psychologist Benjamin Bloom developed a model familiar to teachers which he called his *Taxonomy of Educational Objectives.* The levels in Bloom's taxonomy, in increasing complexity, are knowledge, comprehension, application, analysis, evaluations, and synthesis. When considered in terms of Bloom's taxonomy, activities can be categorized by their level of challenge and complexity. All students must be provided with opportunities to work at all of the levels of Bloom's Taxonomy, but identifying the appropriate level of an activity may allow teachers to select appropriate challenges for students who do not need as much time at the basic knowledge levels. Gifted students do not need more of the same work. By thinking about activities in terms of Bloom's thinking skills, teachers can provide true challenges that are rigorous and relevant for the academically talented students (Heacox, 2002).

Differentiating process

Differentiating the way in which the content is learned is often linked to students' interests and learning profiles. The most commonly used framework for describing students' learning styles is Gardner's Multiple Intelligence theory. "Gardner's theory of multiple intelligences claims that every student has strength in thinking and learning" (Heacox 2002). By offering a variety of activities that play to certain intelligences, teachers can ensure that students have both opportunities to work in areas where they feel comfortable and confident as well as areas where they are not as sure. Thus, their natural strengths are further developed while their weaknesses are strengthened. Gardner has identified and described nine different kinds of intelligences (Table 2) (Heacox 2002, Gardner 2004).

While Multiple Intelligence theory is frequently used by educators in making curriculum decisions and lesson planning, there is some debate as to its reliability and place in the classroom. Waterhouse (2010) argues that there is insufficient data to warrant the use of multiple intelligence theory in education and that it is inconsistent with current understandings of cognitive neuroscience. Others argue that even if Gardner's theories are too broad for planning curriculum or not supported by empirical evidence, valid and reliable testing could be useful for matching instruction and learning in the classroom (McMahon 2004). Although the inventory used in this study is undoubted limited in terms of reliability, it does provide some insight into individual students' preferences and personalities. Because a teacher's knowledge of students as individual learners is central to differentiated instruction, any tool that helps teachers learn more about their students can be helpful. Another desired outcome of differentiated instruction is that students come to know themselves better and develop strategies for managing their own learning. Inventories such as these may help students become more self-aware as they reflect upon their strengths and weaknesses.

Table 2: Gardner's Multiple Intelligences

Verbal/Linguistic Intelligence	Learners enjoy and understand oral and written language. They prefer to communicate through writing and speaking. They learn best through listening, reading, speaking, and writing.
Logical/Mathematical Intelligence	Learners have the ability to see patterns and think conceptually. They like to solve problems and manipulate numbers. They learn best through using numbers and analysis.
Musical/Rhythmic Intelligence	Learners respond to pitch, melody, and rhythm. They can identify musical patterns and may enjoy playing instruments or singing. They learn best when learning is connected to their sense of rhythm.
Bodily/Kinesthetic Intelligence	Learners express their ideas through movement. They have excellent motor skills and prefer to 'do' things. They learn best through hands-on activities.
Visual/Spatial Intelligence	Learners make mental pictures and use images to help them learn and remember. They see the spatial world in their minds. They learn best when they can use tools like graphic organizers and diagrams.
Naturalist Intelligence	Learners are sensitive to the natural world and can adapt to and use their surroundings effectively. They may be called 'street smart'. They learn best when they have the opportunity to figure things out, to observe, and to investigate.
Intrapersonal Intelligence	Learners are reflective and know themselves. They understand their own feelings and value their independence. They learn best when they are given the opportunity to reflect and work alone.
Interpersonal Intelligence	Learners are empathetic and intuitive. They are natural leaders and enjoy being around and interacting with people. They learn best when they can talk with and work others.
Existential Intelligence	Learners are able to ponder questions about life, death, and 'ultimate issues'. They learn best when they have the opportunity to reflect and connect their learning to larger issues.

There is no single, definitive test to determine one's propensity for a certain intelligence; however, many authors have developed surveys and inventories, usually based on what kind of activities the subject enjoys, that can indicate which intelligences are likely to be strengths. Students can exhibit characteristics from several different intelligences and it can be very useful to spend time in class helping students to understand how they process information best. They can use this information to help them choose partners or group members, to choose more effective study methods, and to identify skills on which they may need to work. Of importance to this study, students' knowledge of their learning preferences can help them make informed decisions when they are given choices about activities in class (Heacox 2002).

Differentiating product

"Motivation to learn often stems from the connection between authentic assessment and teaching." (Hamm 2008). The third way that teachers can differentiate instruction is by modifying the product by which students show their learning. Assessment is on-going and diagnostic in the differentiated classroom. Differentiated instruction employs pre-assessment, formative assessment, and summative assessment. Pre-assessment allows the teacher to know her students in order to plan activities and use flexible grouping where appropriate. Formative assessments are used by teachers to guide instruction and respond to students' progress and needs. Formative assessments also serve as learning tools for students. It is important to note that timely and actionable feedback is critical to student learning. Summative assessments are used to determine if a student has achieved the learning objectives. Summative assessments should be varied in the differentiated classroom to accommodate students' strengths and interests. Assessment tools could include paper-and-pencil tests, projects, teacher observations, portfolios and so on. Hamm (2008) comments on the particular usefulness of portfolios as summative assessment tools in *Differentiated Instructions for K-8 Math and Science: Ideas, Activities, and Lesson Plans.* "We have found that having students collect, select, and reflect on a sample of their work (portfolios) allows them to more effectively participate in their own learning and the learning of peers. Differentiated instruction and related assessment activities build on the fact that even when small groups of students have shared goals and materials, they build on their different backgrounds and cognitive strengths." (ibid)

Tiered Instruction

One common strategy employed in differentiated instruction is tiering lessons. In a tiered lesson, all of the students are working on the same content, but they are working in groups determined by the teacher based on pre-assessment of students' knowledge. These groups can be based on readiness, learning style, method of assessment, etc.

It is important to note the difference between tiered lessons and ability grouping. Ability grouping is a practice based on the idea that lower-ability students need more discipline, a slower pace, less interaction, basic skills, and easier content material while higher-ability students need a rapid pace, independence, and more difficult content material (Danzi, Ruel, & Smith 2008). Tiered lessons also use student readiness for grouping; however, the grouping is short-term. Students are only assigned to a group for that particular lesson based on preassessments, teacher observations, etc. Also, in tiered lessons, all students are expected to learn the same material and assignments are designed to require the same amount of work from the students. Ability grouping on the other hand often results in different content for different groups or simply more of the same work for advanced students.

In summary, differentiated instruction is a philosophy that acknowledges and plans for students' differences. It is a method of instruction that employs many strategies and best practices in order to meet the needs of all students. Students benefit from differentiated instruction not only by learning the content in meaningful ways, but also by discovering more about themselves as learners.

“Students for whom teachers have differentiated instruction learn well; they’re competent. They understand themselves as learners, and because of that, they are better equipped to advocate for themselves. They see classmates as being at different points on the same journey, and differences from their own point on the journey are not seen as weak – just different. They are not threatened by difference; it’s seen as strength. These students consider themselves beginners at some things, experts in others, and this variance is natural” (Wormeli, 2006).

Student Choice and Motivation

How does **choice** impact student motivation and learning? One of the hallmarks of adolescent behavior is the desire to establish identity. Teens separate themselves from their parents and begin to identify more strongly with peers. According to Erikson's fifth developmental stage (identity versus identity confusion), adolescents are faced with new, more adult-like roles that they must explore to determine who they are and where they are going in life (Santrock, 1998). One commonly held belief in our society is that making choice is a meaningful and effective way for people, and perhaps especially adolescents, to define themselves as individuals (Patall, 2008).

Choice is often used in classrooms as a motivator. There is a large body of educational research that suggests that students can benefit when they are provided the opportunity to make academic choices (eg. von Mizener & Williams 2009). Research shows that students spend more time engaged in on-task behaviors, show increased completion of assignments, and more favorable attitudes toward their academic work when they make choices (ibid). Teachers frequently capitalize on the positive effects of choice on student behavior. Flowerday and Schraw (2000) conducted a phenomenological study of teachers' beliefs about instructional choice and found that "providing choice is a popular method by which teachers attempt to enhance student motivation. In their meta-analysis of literature regarding the effects of choice on intrinsic motivation, Patall et. al (2008) report that teachers believe that providing teacher-determined options to students increased student interest, engagement, and learning by increasing personal responsibility and motivation to learn". Despite the seemingly obvious positive aspects of providing students academic choices, the effect of student choice on *academic performance* is less clear. While students report being more engaged and teachers observe more on-task behavior during instructional activities, are students actually learning more when they are given academic choices? Von Mizener and Williams suggest in their review of twenty-nine studies regarding the effects of student choices on academic performance that "the academic choices of general education students typically do not produce better performance than systematic teacher orchestration of the instructional process." This suggests that while choice may be an effective tool for engaging students, teachers' expertise is an essential part of planning for instruction. While students may be more engaged in activities when they have the ability to make choices about their learning, they do not have the knowledge and experience to understand which choices would maximize their learning.

In a study conducted by George (1977), high school students were randomly assigned to two different Algebra I classes where they were presented with three instructional objectives with four learning activities for each objective. One group was instructed by the teacher to complete all four activities for each learning objective while the other group was permitted to choose one or more of the activities for each objective. Both groups were also provided with a self-test to help them determine how well they had mastered the material. Students were allowed to work at their own pace though it was suggested to both groups by the teacher that 10 class periods should be sufficient time to complete their work. George found that the students who selected their own learning activities took significantly more time before they took the posttest, but their scores were not significantly different from the students who were instructed to complete all four activities for each objective (von Mizener & Williams 2009).

There is some debate over the potential benefits and detrimental aspects of choice. Self-determination theory holds that people tend to interact with their environment in ways that promote learning (Patall 2008). In their meta-analysis of studies concerning choice and intrinsic motivation, Patall et. al cite the work of E. L. Deci (1980). "Self-determination is the process of utilizing one's will. This involves accepting one's boundaries and limitations, recognizing the forces operating on one, utilizing the capacity to choose, and enlisting the support of various forces to satisfy one's needs." The psychological needs for autonomy, competence, and relatedness are central to the theory of self-determination. Self-determination theory supports the idea that in a classroom, students who are given choices will demonstrate a higher degree of intrinsic motivation and consequently show increased learning. They found that the provision of choice was linked to an increased sense of personal control, as well as to enhanced motivation, liking, and interest for a task (Patall 2008).

Conversely, other studies have found that choice may have no impact on performance at all. In fact, under specific circumstances, choice may have a negative effect on student performance. Flowerday & Schraw (2003) found that students who were given a choice between completing a crossword puzzle or an essay showed no effect on the level of engagement or performance of the students. Some psychologists have explained these findings with a theory known as ego-depletion. Ego-depletion is a state of fatigue that results from the effort required to engage in self-regulatory behavior such as making a choice. The argument is that if a choice is difficult or requires effort on the part of the individual, it will deplete a finite amount of capacity for self-regulation, leaving the individual less able to initiate activities, make choices, or further self-regulate. Patall et al. (2008) point out that there are significant methodological differences between studies that support self-determination theory and ego-depletion theory. Studies done concerning ego-depletion have measured performance as the subsequent persistence on a task that is unrelated to the choice-making activity. Self-determination studies have typically used the same activity to measure intrinsic motivation.

In light of conflicting theories and mixed research findings, it is reasonable to suppose that the relationship between choice and motivation is complicated and there may be specific circumstances where motivation is enhanced, unaffected by, or decreased by choice. For example, the *type of choice* seems to be particularly important when determining its impact on motivation. If a choice is deemed unimportant by the individual, then that individual may not feel motivated by having the choice. Research by Stefanou, Perencevich, DiCintio, and Turner (2004) supports this idea and suggests that there are in fact three three different ways that autonomy (and thus motivation) can be supported in a classroom setting. They divide these methods in increasing degree of impact on student performance as follows: organizational autonomy support, procedural autonomy support, and cognitive autonomy support. Organizational autonomy support includes asking students to participate in decisions about seating arrangement and classroom rules. Procedural autonomy support gives students the opportunity to make choices about what materials will be used in class and how competency will be measured. Finally, cognitive autonomy support, the level of choice that has the greatest effect on motivation involves students generating their own solutions to problems (Patall, 2008).

In addition to the type of choices, the number of choices, how the control groups were treated in various studies, the age of the participants, and the context in which the choices were presented all influenced the impact that choice had on intrinsic motivation (Patall, 2008). There seems to be a sort of balance point between self-determination theory and ego-depletion theory regard to the effect that the number of choices has on motivation. It has been found that too many choices is over-whelming (in line with ego-depletion theory) and has a detrimental effect on motivation, while too few choices may lead an individual to feel as if the choice is inconsequential, or that there is no choice at all (in line with self-determination theory). In the context of a classroom, the number of choices offered must be great enough to be interesting and meaningful for students, yet not so large that they feel overwhelmed or paralyzed by the number of options. Students asked to write a persuasive essay and then given 50 topics from which they must choose one may feel intimidated or confused by the number of options.

Patall et al, also found in their meta-analysis that how the studies were conducted, specifically how the control groups were treated (whether they were denied a choice, informed of options that they were not allowed to choose, etc.) largely influenced the magnitude of the effect of choice on motivation. For instance, groups that were aware of choices that they were not allowed to choose showed a particular decrease in motivation.

Of particular interest to this study are the findings about choice and motivation with respect to age of the participants as well as the context, or the setting, in which the choice was given. It seems that choice is more important for children than for adults, perhaps because children encounter fewer opportunities to make choices (and thereby increase their autonomy) and so when they are presented with choices, they are particularly motivated by them. For the purposes of the meta-analysis by Patall et al., 'children' refers to students in grades K-12. This would seem to indicate that junior high students may be particularly motivated by having a choice.

Student choice seems to be more effective at increasing academic performance when the students had some background knowledge about the targeted content area (von Misener & Williams 2009). Flowerday et al. (2004) found that there was little effect on students' engagement when they were given a 'blind choice' of reading tasks. The students were asked to choose between two different options without knowing what the options actually were. They suggest that the choices that students make are influenced by other factors including background knowledge and individual interest. In a study of student engagement during inquiry activities, students identified choice as an important motivator in the activity (Palmer 2009). The author suggests that it was not the choice alone that the students found motivating, but the fact that they were able to make meaningful choices about how to use materials that were presented to them to find out things that they didn't know. This suggests that the actual motivating factor was really a combination of choice, background knowledge about the materials that were made avail

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available to the students, and a cognitive desire to discover something new on their own (Palmer 2009).

Beyond the choice among different assignments, student determination of how much time to spend on an assignment and the order in which assignments are completed may affect student performance (von Misener & Williams 2009). Undergraduates who were given a choice regarding the amount of time spent working through a series of self-paced tasks spent significantly less time on the packet and scored lower on a written assessment than the group that whose pace was determined by the researcher; however, the choice group showed more effective engagement (Flowerday and Schraw 2003).

How does choice impact student motivation and learning? It would seem that the effects of student choice on learning are still somewhat unclear, but research tends to suggest that students' academic performance is not positively influenced by making choices. The relationship between choice and motivation seems to be more complex and dependent upon many factors. Not only are the types and number of choices important variables to consider, but as previously discussed within the framework of differentiated instruction, students are fundamentally different from one another so it follows that they would respond differently to motivational strategies including choice.

Demographic Information

DeWitt, Michigan is located about ten miles north of the capital city of Lansing. It has retained some of its 'small town feel' although its total population was 4,702 according to the 2000 U.S. Census Data. It primarily made up of middle to upper income level households. The median income for a family living in the city of DeWitt in 2000 was $78,365 and about 3.6% of families in the city were below the poverty line. DeWitt Public Schools serves approximately 3,000 students in grades kindergarten through twelve. The entire school district is only about eight square miles, making it a relatively densely populated area compared to neighboring districts like St. John's and Grand Ledge Public Schools. It is also bordered by smaller, more rural Bath Public Schools and larger, urban Lansing Public Schools. Because of its high population to surface area ratio, DeWitt is a unique district in that it does not employ the traditional neighborhood school model. Rather, students are grouped by grade throughout the district resulting in students being together with the members of their graduating class throughout their academic career. Most of the schools are located on one large, central campus, although two of the buildings are located downtown (about 2 miles from the main campus). Schavey Road Elementary School is located on the main campus and houses the first and second graders. Third and fourth graders go to Scott School, downtown. Herbison Woods Middle School (fifth and sixth grades), the Junior High (seventh and eighth grades), and the High School (ninth through twelfth grades) are all located on the main campus.

In the 2009-2010 school year, there were 479 students enrolled in DeWitt Junior High. The seventh grade was a more typically sized class at 211 students. The eighth grade class was one of the larger classes (or "bubble" classes) and had 268 students. Just like other school districts, these bubble classes periodically move through the district resulting in staffing changes from year to year. These large classes cause frequent building changes for teachers at DeWitt because of the grade structuring described above. Approximately 11.5% of students in the building are eligible for free or reduced lunch. The 8^{th} grade class had a slightly higher percentage of students eligible for free and reduced lunch at 13.1% while the 7^{th} grade class was only 9.5%. The student population by ethnicity is as follows: 90.4% of students were white, not Hispanic, 4.38% of students were Black, not Hispanic, 4.38% of students were Hispanic, 0.41% of students were Asian, and 0.41% of students were American Indian or Alaskan Native.

DeWitt Junior High has one building principal, 2 counselors, and 30 teachers, three of which are special education teachers. One media specialist splits her time between the Junior High and Herbison Woods. The junior high operates on an alternate-day block schedule where students have a total of eight eighty-minute classes, four on "A" days and four on "B" days. Students have their core classes and their elective or exploratory classes every other day. Exploratory classes are one semester (18 weeks) long and core classes run the full school year. In addition, students have a "seminar" class that meets for 30 minutes every day that is dedicated to extra-curricular activities. Two days a week are known as "travel days" and students can seek out additional help from their teacher.

IMPLEMENTATION

The Earth History and Geologic Time Scale unit was chosen for this study for three primary reasons. First, this content was new to the eighth grade curriculum this year and so activities need to be developed. Because differentiated instruction was strongly encouraged by the administration, it seemed advantageous to begin planning for the direction that the district is taking. Second, the number of content expectations in the unit was manageable. Implementing new instructional strategies in a smaller unit was a more manageable for the purposes of research. And third, the content, specifically geologic time, lends itself well to project-based instruction, differentiation strategy.

This study was conducted with a total of 112 students across five sections of eighth grade science. Only 28 students (25%) consented to participate in the study. Two students were excluded from the study. One student was excluded because before the unit began, this student was no longer able to attend school and was enrolled as a home-bound student, the other suffered a personal loss that greatly impacted her academic performance during the unit. The unit took approximately 11 eighty-minute class periods and was taught over a period of about five weeks.

Prior to the beginning of instruction, students completed a Multiple Intelligence Inventory (Appendix C) in order to assess which of Gardner's intelligences they most strongly exhibited. When students had opportunities to make choices during the unit, students were reminded to think about the results of their inventory and make decisions based on their learning styles. Differentiated instructional strategies allowed for student choice at three points during the unit as indicated in Table 3. The first and second choices were tiered activities while the third choice was simply a choice in the product produced by the student. Table 3 shows the basic outline of the instructional activities including both the choice activities and several activities that did not offer choices for students.

Table 3: Summary of Instructional Unit Timeline (All activities newly developed for unit.)

Day 1	Solar system formation pre-assessment questions Powers of 10 movie One in a Million Activity (Appendix E)
Day 2	Formative Assessment: How were the planets formed? ***Choice Activity #1:* Formation of the Solar System Reading Activity (Appendix F)** Begin Formation of the Solar System Lecture and PowerPoint
Day 3	Finish Formation of the Solar System Lecture and PowerPoint Review for Quiz
Day 4	Formation of the Solar System Quiz Geologic time scale pre-assessment questions Placement of events and organisms on the geologic time scale. Ordering events card sorting activity (Appendix G)
Day 5	**Choice Activity #2: Introduce Geologic Time Scale Activity (Appendix H)** Work time for Geologic Time Scale Activity
Day 6	Work time for Geologic Time Scale Activity
Day 7	Sharing of projects Geologic Time Scale Quiz Index fossil pre-assessment questions
Day 8	Formative Assessment: How are fossils formed? JELLO Geology Activity (Appendix I)
Day 9	It's All Relative Activity (Appendix J)
Day 10	**Choice Activity #3: Index Fossil Analogy Activity (Appendix K)**
Day 11	Earth History and Geologic Time Scale Unit Test Student Survey (Appendix B)

Descriptions of Non-Choice Activities

In order to help students establish a sense of scale, a traditionally difficult concept for students, the unit began with the popular Powers of 10 video and the One in a Million activity (Appendix E). After viewing the movie, students were shown several containers with sprinkles used for decorating baked goods. The first contained 9 white sprinkles and one purple sprinkle. The second contained 99 white sprinkles and one purple. The third, 999 white and 1 purple and so on up to a container with 100,000 sprinkles. The students worked through a series of questions and calculations designed to help them make sense of very large numbers in preparation for discussion of the formation of the solar system and the geologic time scale. The next activity, Choice Activity #1: Formation of the Solar System Reading Activity, is discussed in detail in the following section. The Formation of the Solar System Lecture and PowerPoint described Nebular Theory and evidence that supports it. It was lengthy for eighth graders and thus was broken up into two different class periods. Students were provided with a note-taking guide to assist them during the lecture. Following the lecture, students took a ten question quiz covering the material.

To begin the Geologic Time Scale portion of the unit, a large timeline was placed on the wall to assess the students' prior knowledge about geologic time. The scale for the timeline was 1 cm = 10 million years and the major divisions were labeled. Each student was given a labeled picture of an organism, fossil or event with a piece of tape on the back. For instance, organisms included *Tyrannosaurus rex* and *Australopithecus* *aferensis* and events included the K-T and Permian Extinctions. Students were asked to place their pictures on the timeline. After the whole-class 'placement of organisms and events on the geologic time' activity, all students completed the 'ordering events card sorting activity' (Appendix G). Students used adding machine tape to make their own timeline using the same scale as the large whole class example. Students then cut out the small cards and placed them on the timeline in the correct location. Students could then compare the large whole-class predictions with the time line that they made themselves. After the card sorting activity, students began Choice Activity #2: The Geologic Time Scale Activity Project (Appendix H). After students completed and displayed their time scale projects, a short quiz (12 questions) was used to assess their progress.

The index fossil portion of the unit began with another pre-assessment activity. Each lab group was given 2-3 fossil examples to examine. They were asked to explain what a fossil is and how fossils are formed. Students then began the JELLO Geology Activity (Appendix I). This activity was designed to help students understand relative dating by examining layers of 'rock' simulated by layers of JELLO. Using information about the ages of known 'fossils', simulated by candies, students determined the age of an unknown fossil by examining their layers of JELLO. After the JELLO Geology Activity, students completed the It's All Relative Activity (Appendix J) also designed to help students understand relative dating of rock layers. Pieces of yarn were strung from the ceiling to the floor to represent geologic columns. Cards with pictures of index fossils were placed along each column. Students then connected matching fossils with the neighboring columns to represent rock layers that have undergone geologic changes.

Working through a series of questions helped students to see how geologists use index fossils to determine the age of rock formations and how geologic features were formed. To complete the index fossil portion of the unit, the third choice activity, Choice Activity #3: Index Fossil Analogy Project, was completed.

Description of Choice Activities

Choice Activity #1: The Formation of the Solar System Reading Activity allowed students to choose among five different articles to read and analyze. Because the articles were of varying difficulty, the activity was differentiated by readiness. The articles also represented a variety of writing styles, including an "outline-type" document for students that have trouble organizing information. Thus, the activity was also differentiated somewhat for student interest and learning-style. Each of the articles was introduced to the students with special emphasis on the reading level and the type of audience. For instance, the article *Building Planets at PSI* was described to the students as being at an 8th or 9th grade reading level with a particular emphasis on technology. Students essentially had two choices to make for this activity. The first choice was simply which article they were interested in reading. Students were encouraged to think about their Multiple Intelligence Inventory and what might interest them the most. The second choice that students had to make was more collaborative in nature. They had to decide which activity they wanted to complete with their group.

Choice Activity #2: Geologic Time Scale Project was another tiered activity. Option 1 was designed for students who struggled with the Card Sorting Activity the day before. For Option 1, students used the same cards that they used in the previous activity and a scale determined by the teacher to construct a scale model of the geologic time scale. Students received a new set of cards to cut out and a piece of adding machine tape 5 meters in length. This option had a more structured set of directions and was designed to support students who might otherwise have difficulty with the calculations involved in making a scale model. Option 2 asked students to generate their own scale model of the geologic time scale and listed several events that should be placed on their time scale. This option required sufficient understanding of scaling and proportional reasoning, making it more challenging, but not necessarily more work, than Option 1. Option 3 was more abstract in nature and allowed for a higher degree of creativity. For Option 3, students were to design a book that represented the geologic time scale. The same list of events included in Option 2 was provided to the students who chose Option 3. All three options asked students to make a scale model of geologic time, but different levels of support were built into the directions for each of the options to accommodate students' needs. All three options were summarized in a whole-class setting and students were given time to review the three options before making a decision about which one to choose.

Choice Activity #3: Index Fossil Analogy Activity required a smaller, less-significant decision about what kind of product they would make to explain their index fossil analogy. The analogies needed to explain the two characteristics of good index fossils: (1) good index fossils existed for a relatively short period of time; and (2) they were widespread geographically. Students were given some examples of analogies and several suggestions of products that they could make including posters, models, written reports, etc.

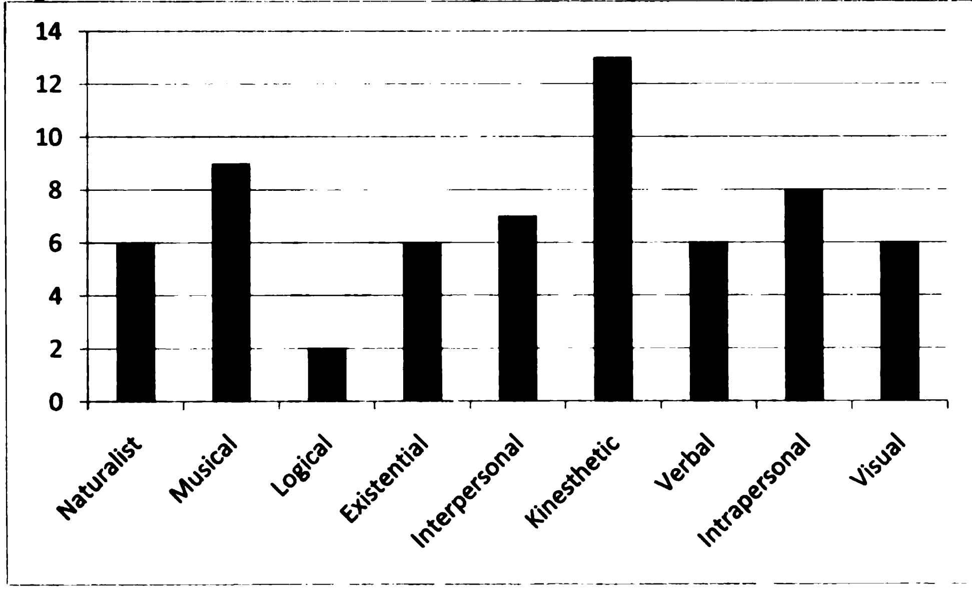
After the unit was completed, students were given an attitudinal survey (Appendix B) to assess their feelings about choice and engagement. They were asked to rate their level of agreement with several statements using a Likert Scale as well as two open-ended questions about their opinions regarding the effectiveness of choice in instruction.

RESULTS AND EVALUATION

The sample size for this study was 26 students, 13 male and 13 female. Of the 27 students giving consent, four students (14.8%) qualify for special education services and one student was exited from the special education program at the end of last school year and so is considered 'at-risk' this year and eligible for additional support. In addition, one of the students was identified as 'at-risk' and received additional academic support services. These six students were grouped together as "special education and at-risk students" for subsequent data analysis.

Before the onset of the unit, students were given a Multiple Intelligences Learning Style Inventory (see Appendix B). Of the 27 students who participated in the study, only 20 of them returned their inventory. The inventory asked students to list the three areas of intelligence in which they scored the highest. The total number of students listing each of the areas in their "top three" is shown in Figure 1 below. Note, some students listed additional areas as a result of 'ties' between the top categories. For example, one student listed his top three as follows: Intrapersonal, Musical, Logical/Kinesthetic. In these situations, each one of the categories listed by the student was included in the tally for Figure 1.

Figure 1: Number of students listing each multiple intelligence in their "top three".



After the completion of the unit, students were encouraged to recall their learning style inventories when making choices about which learning activities to complete for each of the content expectations. Their feelings about having instructional choices were gathered using the Student Survey (Appendix B) and are reflected in Table 4. Two students did not complete the survey. One student of the students received special education services and the other was identified as at-risk. Students' individual responses can be found in Appendix L.

Table 4: Student Survey Results – Average Rating (n=24, 5: Strongly Agree; 1: Strongly Disagree)

	Average Rating
1. I was more engaged in science class during the times that I had choices about the assignments I completed compared to the times when the teacher game everyone the same assignment.	4.0
2. I put more effort into the assignments that I chose to do compared to the assignments that the teacher assigned to everyone.	3.8
3. I learned more when I did assignments that I chose compared to assignments that the teacher chose for the whole class to do.	3.3
4. I learn the same amount when I have choices about the assignments that I complete compared to times when the teachers gives everyone the same assignment.	3.3
5. When I was able to choose which assignments I did, my choice was based on my individual learning style or interests.	4.5
6. I feel overwhelmed when I have choices about assignments and wish the teacher would tell me which assignment to do.	2.1
7. Having choices about assignments is confusing and makes it more difficult to learn.	1.7
8. I wish that I had choices about which assignments to do more often in science class.	3.8

Some interesting trends appear when the survey data are grouped by student (Figures 2, 3, and 4). In Figure 2, survey questions #1 and #2 were grouped together to show the students' perception of the effect of choices on their motivation and effort in class. It shows that most students believed that they were more engaged and put more effort into the assignments where they had a choice. Two students, numbers 21 and 24, disagreed with the statement. These two students were quite different from one another in terms of academic achievement and personality. Student 21 was a special education student who was typically quiet in class. His feelings about his engagement were neutral, but he rated his effort lower compared to assignments chosen by the teacher. Student 24 was a very outgoing, highly motivated student whose academic achievement is generally somewhat higher than average. This student gave both her engagement and effort low rankings.

Figure 2: Survey Data by Student – Engagement and Effort (Questions 1 and 2)

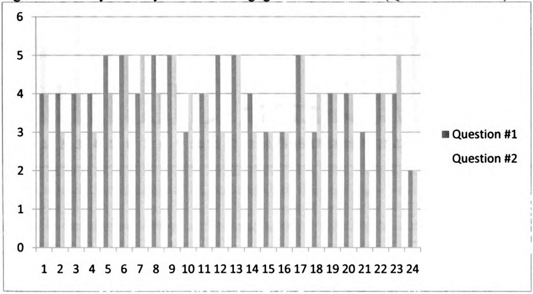
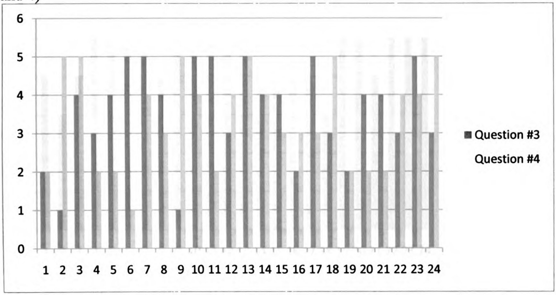


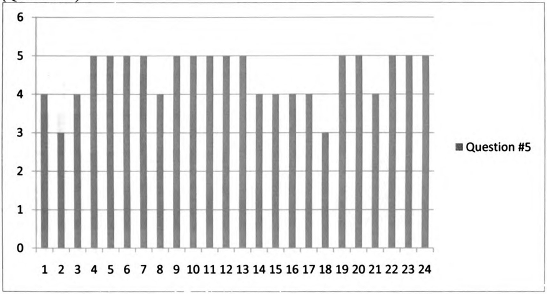
Figure 3 shows students' perceptions about their learning (survey questions #3 and #4). The statement for survey question #3 was "I learned more when I did assignments that I chose compared to assignments that the teacher chose for the whole class to do." The statement for survey question #4 was "I learn the same amount when I have choices about the assignments that I complete compared to times when the teachers gives everyone the same assignment." It is interesting that several students rated these two statements the same. Student #13, for example, strongly agreed with both of these statements.

Figure 3: Survey Data by Student – Students' Perceptions of Their Learning (Questions 3 and 4)



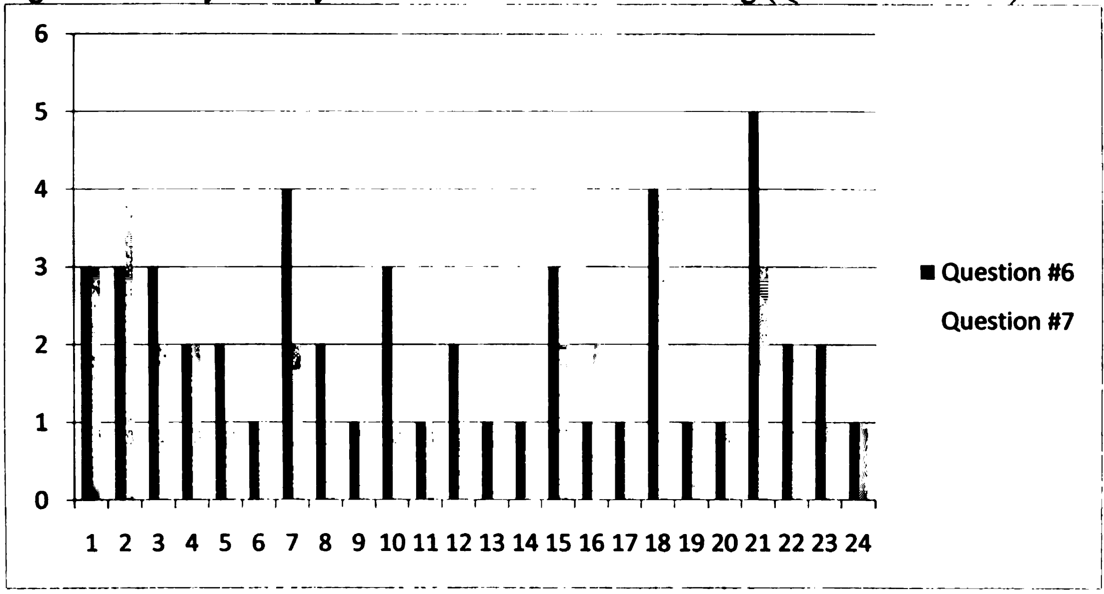
Throughout the unit, as assignments with choices were introduced to students, the different options were presented in the context of the different multiple intelligences. In Choice Activity #2: Geologic Time Scale Activity, building scale models of the geologic time scale using the length of the hallway or the parking lot, for example, was identified as an activity that might be of interest to students who scored high in the kinesthetic area. Figure 4 shows that students largely believe that they made their choices based on their own learning styles.

Figure 4: Survey Data by Student – Student's Choices Based on Learning Style (Question 5)



One consideration that teachers must make as they are planning units that involve student choice is that there seems to be a balancing point between providing students enough information to make informed decisions and the cognitive overload that can occur if too much information about each option is presented. The results from questions 6 and 7 on the student survey are shown in Figure 5.

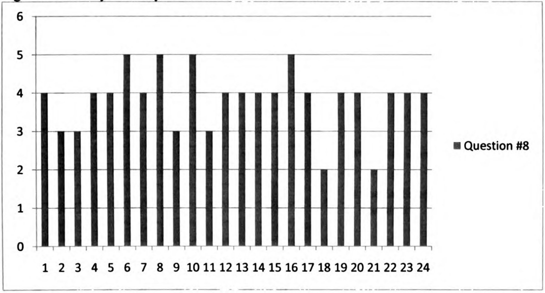
Figure 5: Survey Data by Student – Choices are confusing (Questions 6 and 7)



While it appears that most students disagreed with the statements that having choices is overwhelming and having choices is confusing, there were clearly some students who were confused by having choices. A closer look at the students who agreed with these statements shows an interesting pattern. Student number 10 and student 21 were both students that qualified for special education services as learning disabled. Student number 2 was exited from special education at the end of last year and student number 7 was a student that could be described as a struggling learner. Student numbers 15 and student 18, however, are both very high achieving students of well-above average intelligence. Student 18 provided a clue about the thinking of high-achieving students in her response to Question 9 (an open-ended question asking what are the best and worst things about having choices in class). Her response was as follows; "Choices are good for some people. It gets them engaged and they feel they control their learning. For me, it just gives me one more thing to do: choose. It doesn't overwhelm me, it just takes time." Her response seems to indicate that she is not overwhelmed or confused with the choices themselves, but perhaps a little annoyed with the fact that it is 'just one more thing to do'. Student 15 didn't express these feelings in his response to Question 9; however both student 15 and student 18 seemed to focus on the issue of teacher control in their answers to Question 10 (another open-ended question asking if giving students choices in class matters). Student 15 answered "I think it does, because then kids can't say the teachers control everything" while student 18 answered "No, I think students expect teachers to assign something to them. A choice is sometimes a nice surprise but I don't think people try that much harder". The responses of the high-achieving students are interesting when compared to the other students who more strongly agreed with the statements that they were confused or overwhelmed by the choices. Student number 2, for instance answered (on Question 9) that the best and worst part of having choices were "that I was more free, but it is sometimes too free" or student number 9 who answered "The best part was that if you didn't like one project you could do one that fits you better. The worst part was that you picked a choice and sometimes you didn't know how to do it".

It is also interesting to note that while most students indicated that would like to have more choices in science class (Figure 6), students 18 and 21, one of the special education students that responded that choices were confusing and one of the high achieving students, were the two students who most strongly disagreed with this statement.

Figure 6: Survey Data by Student – Students Want More Choice in Science Class



In general, the survey data do not seem to indicate that there is a gender difference between how strongly males and females agree or disagree with the statements (Figure 7). There do appear to be some differences between regular education and special education students although these comparisons must be made with extreme caution because only four students are included in the special education and at-risk student group.

Figure 7: Survey Data – Gender Differences (Female: n = 13, Male: n = 12)

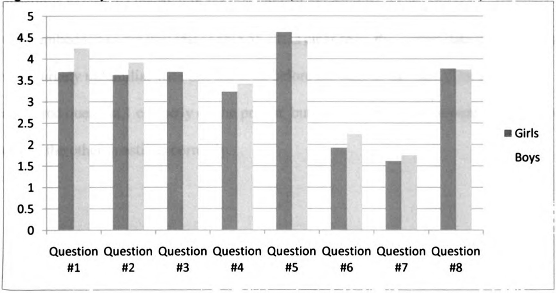
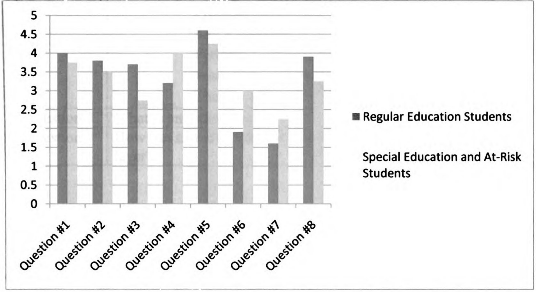


Figure 8: Survey Data – Regular Education Students versus Special Education and At-Risk Students (Regular Education Students: n = 21, Special Education and At-Risk Students, n = 4)



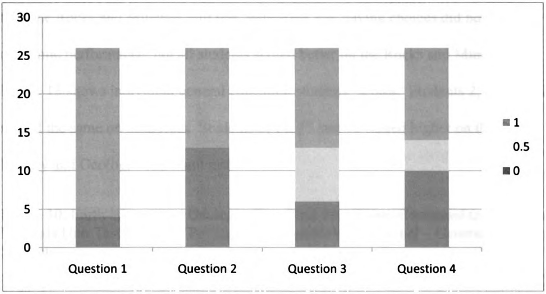
While the survey data were used to indicate students' perceptions of their levels of motivation and engagement throughout the unit, their academic performance was measured using pre and posttest data as well as comparing their performance on the Earth History and Geologic Time Scale unit test to other indicators of academic performance throughout the year. To obtain pre and posttest data, students were given short pretest questions before the instruction for that content expectation began and the same questions were embedded in the unit test (Table 5). It is clear from the pretest data that students were largely unfamiliar with this material before the start of the unit. Ten students answered question 1 correctly on the pretest, but none of the students were able to answer any of the other questions correctly.

Table 5: Geologic Time Scale Pre and Posttest Questions.

Question 1	How old is the Earth?
Question 2	Place the following events in order from earliest to most recent. _____ Pleistocene Ice Age _____ K-T Extinction _____ Permian Extinction _____ Formation of an oxygen atmosphere _____ The rise of life
Question 3	What is an index fossil?
Question 4	How can an index fossil be used to determine the age of a rock layer?

Figure 9 shows the number of students receiving credit on the posttest for the four questions in Table 5. For questions 1 and 2, no partial credit was given; students either scored 0 or 1. Both questions 3 and 4 were open-ended and partial credit was awarded; students could score 0, 0.5, or 1. For question 3, seven students received partial credit, most frequently because one characteristic of index fossils was indentified, but the definition was not complete. Thirteen students answered correctly and six received no credit. For question 4, four students received partial credit. Twelve students answered correctly and ten answered incorrectly.

Figure 9: Individual Responses to Posttest Questions (n = 26)



Additionally, students' academic performance was measured by comparing the Earth History and Geologic Time Scale unit test with the Rocks and Minerals unit test. The Rocks and Minerals unit test was selected for comparison because it was a unit of similar length approximately five weeks of study), the test was of similar length (both had 30 possible points) and students were not given any instructional choices during this unit. The content of the two units was different and therefore this comparison should be made with caution. The average score for the Earth History and Geologic Time unit test was 71%. The average score for the Rocks and Minerals unit test was 80%. Because this was the first time the Earth History and Geologic Time Scale unit was taught, there is no way to compare this year's scores with previous classes data so the best comparison that can be made is to a similar unit.

While the average score on the Earth History and Geologic Time Unit was much lower than the Rocks and Minerals unit test, indicating that having choices did not improve academic performance, not all students scored better on the Rocks and Minerals unit test. Figure 13 shows individual general education students' scores. Students 2, 3, 13, and 20 scored the same on both tests. Students 8, 14, 15 and 16 scored higher on the Earth History and Geologic Time unit test.

Figure 10: Earth History and Geologic Time Unit Test Scores Compared to Rocks and Minerals Unit Test Scores of Participating Students by Individual – General Education Students

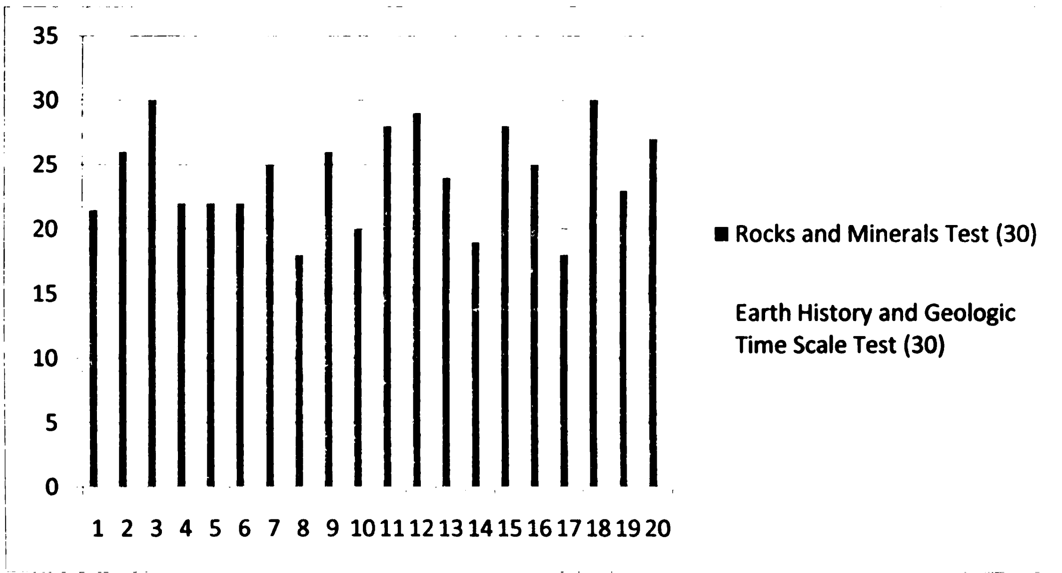
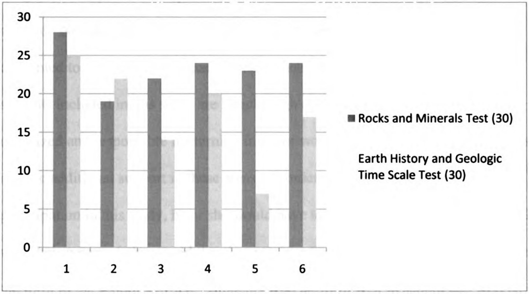


Figure 11 shows the special education and at-risk students' individual scores for the two unit tests. Only student 2 scored higher on the Earth History and Geologic Time unit test.

Figure 11: Earth History and Geologic Time Unit Test Scores Compared to Rocks and Minerals Unit Test Scores of Participating Students by Individual – Special Education and At-Risk Students



It is interesting to note in both Figures 10 and 11 that some students' scores were only slightly different while others were quite different, for example, students 1 and 5 in Figure 11.

DISCUSSION AND CONCLUSIONS

Conclusions about the data presented must be made with caution as they are likely to be skewed. Not only does this study have a small sample size, but the students who consented to be a part of the study do not constitute a representative sample. The students included in this study are largely high achieving students who tend to be organized and responsible for turning in paper work and special education students who receive additional support in these areas. In order for a student to be eligible for participation in this study, he or she would have to bring the consent form home, share it with their parents (who would then have to take time to review it and sign), then return the form to the school's office. Students who perform well in school and who have a high degree of support at home are more likely to accomplish these tasks resulting in a group that is not typical of the entire student body. This is an intrinsic problem in educational research.

Clearly, students' academic performance as measured by comparing their unit test scores for the Earth History and Geologic Time Scale unit (during which they had choices about assignments) and their Rocks and Minerals unit test scores (during which they had no choices about assignments) was not improved by the offering of choices. This is a limited comparison at best and the differences could be attributed to other factors as well. Students had very little prior knowledge about the content in the Earth History and Geologic Time Scale unit as evidenced by their pre and posttest data and the Rocks and Minerals unit contained some material that students were exposed to in earlier grades.

Also, the complexity of the material and the conceptual understandings for the Earth History and Geologic Time Scale unit could be considered more difficult. For example, many students struggle with the concept of scale making discussions involving very large numbers and very small numbers difficult. The One in a Million activity at the very beginning of this unit was designed to help students gain a deeper understanding of this concept so that they would be better prepared to deal with the age of the solar system and geologic time. This knowledge is essential for the construction of their own geologic time scales in the second choice activity. The Rocks and Minerals test could be considered easier conceptually because large amounts of content were not based on concepts with which students typically struggle.

While this study does not indicate that academic performance is enhanced by student choice, rather students performed worse when they were given choices, the effect on students' motivation and engagement is less clear. Individual students reacted differently to being offered choice, not an unexpected result considering that students are so different from one another. While some students embraced choice and rated their enjoyment and engagement higher than when the teacher assigned the learning activities, others indicated that they were confused and somewhat overwhelmed by having choices. The following sections discuss the differences in the students as measured by their multiple intelligence inventories, their reactions to being given choices, and practical implications for teachers seeking to use choice as a motivator in the classroom.

It is interesting to note that of the twenty students who completed and turned in their multiple intelligence inventories, no two students had the same profile. These results just serve to underscore the importance of differentiating instruction and knowing the learner. From the teacher's perspective, it is important for planning purposes to note that certain modalities or learning styles may occur more frequently than others in the same class. Kinesthetic and musical intelligences were both highly represented in this particular group of students, indicating that many hands-on activities should be included during instructional units. It was also interesting to see which individual students checked many boxes in each category and which checked only a few. There are, of course, the inherent problems associated with students assessing themselves when using these kinds of inventories, but it seemed that some students were more enthusiastic about checking the boxes to indicate that they enjoyed activities while others were more reserved. It would be interesting to investigate how students arrived at their own individual 'threshold' when deciding to check a box or not. This inventory simply indicates which activities students enjoy more than others. It does not directly yield information about their natural abilities. Also, some students took a significant amount of time to complete the survey while others worked very quickly. If students were allowed to take the survey home and complete it at their leisure, the results may have been quite different. This inventory was also given just once, before the start of the unit, making it a snapshot in time. It would be interesting to see how students' multiple intelligence profiles change through time. It is unclear how reliable such inventories are and how much weight they should be given in terms of planning for lessons. In combination with other, perhaps more informative, assessment tools such as teacher observations, teacher-student interactions, and parent-teacher conferences, multiple intelligence surveys offer some indication of students' preferences and learning styles.

Once teachers have assessed students' learning styles and readiness levels with pre-assessments, teacher observations, etc., they can begin the process of differentiating instruction. In this sense, this study does not truly represent differentiated instruction because the development of the tiered activities was done before the beginning of the school year. While the needs of the majority of the students can be anticipated ahead of time, truly responsive instruction would require changes to the activities be made once the teacher has had a chance to know the students better. These activities were planning in advance and only minor modifications were made during their implementation. This is just one of the difficulties that face teachers using differentiated instruction. Another logistical problem that must be addressed when doing project-based work in a differentiated classroom is time. In this situation, seminar time (the 30 minute class that students attend every day in the alternate day block schedule) became very important for both the students and me. Students needed additional time to work with partners and group members and for junior high students, who are not highly mobile after school, this time during the school day was very valuable. Groups frequently met to make arrangements and complete work during this time. Providing students with many choices meant that students had more individual questions and needed more one-on-one time. I also needed to conference with students who wanted to make their own proposals about activities and be available for students with performance aspects to their projects. For instance, one pair of students made a scale model of the geologic time scale in a hallway that looked like a path and was located some distance from the classroom. They had prepared short monologue-type explanations at each "stop" on the path. They made an appointment with me to walk down their path during seminar so that I could evaluate their work.

While differentiating instruction requires additional planning, organization, and a certain flexibility on the part of the teacher, most of the difficulties encountered can be overcome with some creative thinking. Keeping track of which students were working on what projects quickly became an organizational challenge, for instance. To help keep track of what students were doing (and which students were falling behind in their work), a large white board can be used to make a table with the assignment options at the top and spaces for students to write what they planned to do during work days and what they accomplished. Each student also had a file folder (stored in hanging files in milk crates) where they could keep their work that was easily accessible by the teacher. Using the differentiation strategies to provide student choice was ultimately a manageable and useful practice. Students tended to spend more time on-task and were excited about their projects when they were working on the tiered activities like the geologic time scale project and the analogy activity.

It was not the differentiatied instructional strategies that came to the forefront in this particular study, however. It was the choices that students made and why they made them. For this study, students were allowed to choose any option they wished. They were encouraged to consider their readiness level and their preferred learning styles each time they were given a choice, but they made the ultimate decision. This degree of freedom is not always the case. In the differentiated classroom, while choice is often used, students are regularly assigned to specific groups or given specific activities to complete based on what the teacher has determined to be the best for that student (Hamm 2008). It was very clear in this study that when students were given total freedom in their choices, they frequently chose options that the teacher would not have chosen for them. Most of the time, students chose based on what they felt would be the easiest option or the option that they could complete the most quickly. In fact, even when students were expressly told that an activity had been differentiated by learning style, they seemed much more interested in what they perceived to be the difference in difficulty between the options.

This problem was particularly evident in the reading activity. When the reading activity was introduced to students, approximate grade-levels were used to describe the difficulty level of the reading as well as some description of the interest-area. For instance, one article was described as "around a 10^{th} or 11^{th} grade reading level with a particular emphasis on new technologies that help us understand how the planets were formed". Many students chose the selection that was at the lowest reading level, making the second part of the activity (forming heterogeneous groups) very difficult. Very little sharing took place within the groups because so many students chose the same article to read. When asked, one student who chose an article significantly below his reading level responded, "Why would I do more than I have to?". This sentiment was expressed several times by a variety of students and was somewhat discouraging. Several responses on the survey also indicated that students were opting for the easiest choices. One student answered that the best thing about having choices was "choosing an assignment that we could easily do." For this particular activity, the choice was simply which article to read. Everyone had to read something. It may be that when students perceive that a task has been assigned, in this case, reading an article, the motivating benefits of choice are undermined. Students seemed most concerned with completing the task as fast as they could and it was that desire that drove their choices. When the choices were broader, as they were in the geologic time scale activity, they seemed less concerned with getting done quickly and more concerned with what would be the most enjoyable. The analogy activity was another situation where all students were given the same task, develop an analogy that explains the characteristics of index fossils, but students didn't seem as quick to chose the 'easiest' option in this case. It could be that the nature of the activity was 'fun' enough that students didn't feel they were being made to work hard. Reading an article may have been viewed by the students as 'boring' and so their desire to get the chore over with quickly was more motivating than choosing something of interest or of appropriate reading level. It would be interesting to observe students' choices if the reading level had been removed from the choice equation. If students were only given a brief description of the articles so that they could make a decision based on their interests, they may have chosen quite differently. It would seem that there are several competing motivators when students are faced with making a learning choice. Teachers want to maximize student learning and so when students have complete control, it is possible for them to make choices that are too easy for them, resulting in less than optimal learning for some students. While choice can be an effective motivator, some practical implication for teachers should be considered including what kinds of choices students should be given and how those choices should be structured.

What kind of choices should students be given?

In their meta-analysis, Patall et al. (2008) indicate that several studies have shown that when participants were given a choice between different versions of the same task, such as the choice to write an essay about a plant or an animal, the effect on motivation was significantly less than when participants had a choice about more meaningful aspects of a task, such as pacing or ultimate goal (ibid). In the classroom, the ultimate goal must be the same for all students: to learn the content. Even when accommodations are made for individual students, the primary objective is for all students to learn the material. The only exception to that rule is those students who require a modified curriculum because of a significant disability. This presents classroom teachers with a challenge as curriculum is determined by local, state, and federal guidelines and decisions about what to learn cannot be placed entirely in the hands of students or even their teachers. There are some meaningful choices students can make about their learning however. Differentiated instruction allows for student choice with regard to method of learning and in some cases, the pacing of learning. If a teacher is only able to allow students choices between different versions of the same task (which would typically not increase motivation), the effects of that choice on motivation can be increased by pairing it with a more meaningful decision, such as time apportionment. In this study, the reading activity is an example where students were only given a choice between different versions of the same task. The effect of this choice turned out to not advance the learning of those students who made choices that were too easy for them and did not challenge them. If this activity had been paired with another choice, perhaps it would have been more effective. If students were told that they needed to choose an article, read it, and complete review questions from the text book during the hour and they could spend as much time on each of the activities as they wished during the class period, maybe the desire to complete the reading as fast as possible wouldn't have been so strong. In order to overcome this desire, it seems that the other tasks to be completed would have to be similar in nature. If students were told to read an article and complete a hands-on lab and were allowed to apportion their time, it seems likely that the students would spend considerably more time on the lab.

Zuckerman et al. (1978) found that allowing participants to make choices about how to apportion their time, as well as choose among several versions of a task, enhanced intrinsic motivation. The confines of a typical school schedule may make this kind of choice difficult, even impossible, in some situations, but often it would be quite easy to achieve in the differentiated classroom. The use of anchor activities for instance is a particularly effective and widely-used method of instruction. Anchor activities are long-term, independent projects that students can work on while the teacher is working with other students. For example, if one group of students requires re-teaching, the rest of the class can work on their anchor activities during this time.
During the time when students are not directly working with the teacher, they have a large degree of control over how they spend their time all the while working on activities that may simply be different versions of each other.

Other differentiation strategies that offer students choices include learning menus, choice boards, and cubing. When these strategies are appropriately constructed and implemented in the classroom, students all work toward the some learning targets, but exercise choice in how they spend their time doing so (eg. Kondor 2007, Chapman 2005). This raises an interesting question in light of the competing theories of self-determination and ego-depletion. According to self-determination theory (and in accordance with the findings of Zuckerman cited above), it is the more meaningful choices that have the greatest impact on motivation. However, in the ego-depletion model, such 'meaningful' choices would require more self-regulatory resources and would therefore be detrimental to motivation.

Number of Choices

Some students wrote about being confused in their surveys. Some student responses that illustrate this confusion are as follows: "The best thing about having choices was that we had time to do things individually and to get individual help. The worst thing was that there was less instruction so sometimes the things I chose to do were harder than when I didn't make a choice" and "The best thing about having choices is I can pick something I want to do. The worst thing about having choices is that sometimes things aren't as clear if you don't do them with the whole class." While the number of choices (three for the Geologic Time Scale Project) may not have been particularly large, the amount of explanation and direction included with each of the choices was substantial. That is, each choice had its own set of instructions and by the time students had read and considered each of the options, they were confused. It may be that with all of the instructions, students had difficulty separating out the choices from one another. I tried to avoid confusion by clearly stating the expectations for each option on its own information sheet (Appendix H), but I noticed on a few separate occasions that students seemed to including aspects of one option into their completion of another. For instance, one student who was working on Option 3: The Geologic Time Scale Book first made a linear scale on her lab table and expressed confusion about how to combine the two ideas. After speaking with this student, I discovered that she was remembering the instructions incorrectly. When she re-read each sheet, she realized what she had done and was able to move forward with her project; however, she needed my prompting to go back to the original instructions. This is an important point for teachers. We want to write clear, detailed expectations for each project. We also want students to read the expectations carefully and decide which option they would like to choose. The problem is, if there is too much information to process, the lines between the options can become blurred. This tipping point will undoubtedly be different for different students. What one student needs to make an informed decision may be too much information for another. The challenge for the classroom teacher lies in knowing each student well enough to predict how much information is necessary and when information overload is imminent. Furthermore, according to ego-depletion theory, the more important a decision is, the more costly it will be in terms of self-regulatory resources. If students are faced with high-stakes challenges multiple times each day throughout the school year, it seems likely that the balance between empowerment and motivation and confusion and defeat will become more tenuous and students will become exhausted.

Is there a difference between special education and regular education students in this study?

Von Mizener and Williams (2009) found that "the success rate for choice over no choice was dramatically different for the two student categories: 80% of special-needs students and 12% of general education students responded favorably to choice. While the sample size is extremely small, it appears that the special education students in this particular study found the choices to be confusing and were more overwhelmed when they had to make choices. Their test scores clearly do not show a positive effect on their learning (Figure 11). It is difficult to draw any conclusions from these results, but this is an interesting area for further research.

One interesting result of the meta- analysis of Patall et al. (2008) is that instructionally irrelevant choices, such as which color pen to use on a written assignment, had the greatest impact on intrinsic motivation. The authors suggest several ideas that may explain this finding. First, this relationship may be due to the balance between motivation and ego-depletion. That is, it is the simpler choices that maximize the cost-benefit nature of choice-making. Second, they suggest that it may be that what researchers have called 'instructionally irrelevant' may in fact be ways that individual participants can show their personal identities fulfilling their need to express individuality. This desire is evident in some of the students' responses on the survey. One student wrote, "I think the best thing about having choices is I feel like my paper will reflect more on me and what I like." This effect was observed in Choice Activity #3. This activity seems to generate the most excitement from the students. Perhaps this is because it was a shorter-term assignment with a smaller product. It was less of a commitment for students and therefore, less of a risk. It seems that offering a higher degree of choice on this type of activity seems to increase engagement and fulfill some students' need to express individual identity through their work.

The results of this study seem to indicate that while academic performance may not be increased, giving students choices can be used as effective motivational strategy provided that the choices are not too difficult for the students to make. Choices should be 'important' enough to be seen as authentic by the student, but should not require so much effort, or be of such consequence, as to undermine the benefits of choice to motivation. Also, the number or explanation of the choices should not be overwhelming. When the choices are structured in such a way, both the teacher and the students enjoy the benefits of students' taking control of some aspects of their learning; teachers can provide opportunities for students to express themselves and take on the added responsibility of making choices in a manageable and sustainable way and students are motivated and more engaged in their learning.

APPENDICES

APENDIX A: CONSENT LETTER AND FORM

September 8, 2009

Dear Parents/Guardians and Students:

During the 2009-2010 school year, I will be working to complete my Master's Thesis through the Division of Science and Mathematics Education (DSME) at Michigan State University. I will be conducting a research study that will examine the effects of differentiated instruction on student engagement and understanding. Differentiated instruction involves constructing different paths of learning based on each individual student's readiness, learning style, and interests so that *all* students are able to understand the content expectations. One of the hallmarks of differentiated instruction is allowing students a greater degree of choice in the activities in which they engage throughout a unit of study. Differentiated instructional strategies such student-led, project-based learning will be incorporated into the Earth History and Geologic Time Scale unit during this school year.

To evaluate the effectiveness of these strategies, I will be collecting normal instructional data in the form of standard assessment tools including pre and post tests, quizzes, surveys, projects, and teacher observations. With your permission, I would like to include data generated by your child in my thesis. Your child's privacy will be of utmost importance and will be protected to the maximum extent of the law. All data will remain confidential and secure. Participation in this study is voluntary. Your child will receive no penalty in regard to their grade or any other aspect of the class should you deny permission for the use of their data. You may request that your child's information not be included in the study at any time and your request will be honored. Should you decide to withdraw from the study <u>before</u> semester grades are posted, please do not contact me directly in order to maintain confidentiality. Instead, please contact Mrs. Webb (517-668-3250 or webbl@dewittschools.net) and request that your child not be included in the study. If you would like to withdraw from the study <u>after</u> semester grades have been posted, you may contact me directly.

There are no risks associated with participation in this study. Your child's participation may contribute to the understanding of how differentiated instructional strategies impact student learning in the science classroom. In addition, students may learn more about themselves as learners, enhancing their future academic careers.

If you will allow your child's data to be included in this study, please complete the attached form and return it to the Junior High Office by September 30, 2009. All consent forms will be sealed by a DeWitt Junior High School staff member other than myself and kept in a secure location (a locked drawer in the junior high office) until after grades are posted at the end of the semester. I will not know your decision until the semester is over. At that time, I will de-identify all data from those participants who have given consent for further analysis. At no time will your child's name be associated with the data nor will they be identified by name in any images that are used in the written thesis or the defense presentation. Data collected from any student who does not have permission to participate in the study, or whose parent withdraws permission during the data collection process, will be discarded. In addition to parental consent, student assent is also required for participation in this study. On the attached form, you will find a parent section and a student section. If you choose to participate in this study, please be sure to fill out both parts of the form.

If you have any concerns or questions about this study, such as scientific issues, how to do any part of it, or to report an injury, please contact the researchers, myself or Dr. Merle Hedimann. My contact information is listed below. Dr. Heidemann can be reached by mail at the Division of Science and

Mathematics Education, 118 North Kedzie Hall, Michigan State University, East Lansing, MI 48824, by phone (517-432-2152 ext.107) or by email (heidema2@msu.edu).

If you have any questions or concerns regarding your rights as a study participant, or are dissatisfied at any time with any aspect of this study, you may contact – anonymously, if you wish – The Office of Social Science Institutional Review Board at Michigan State University, 202 Olds Hall, Michigan State University, East Lansing, MI 48824, by phone (517-355-2180), by fax (517-432-4503), or by email (irb@msu.edu).

I am excited about the potential impact that differentiated instructional strategies may have on student learning and hope that studies like this one will improve classroom instruction for all students.

Sincerely,

Laura Foreback

517-668-3291

foreback@dewittschools.net

Consent to Participate in Mrs. Foreback's Research Project

During the 2009-2010 school year, I will be working to complete my Master's Thesis through the Division of Science and Mathematics Education (DSME) at Michigan State University. I will be conducting a research study that will examine the effects of differentiated instruction on student engagement and understanding. Please complete this form and return it to the **Junior High Office** by September 30, 2009. Please do not return this form to Mrs. Foreback. Thank you.

PARENT/GUARDIAN CONSENT:
I voluntarily agree to allow ________________________________(child's name) to participate in Mrs. Foreback's Research Project during the 2009-2010 school year. I acknowledge that my child's privacy will be protected throughout this study and neither their class work nor their image will be identified by name. I acknowledge that I may request to be excluded from this study at any time and that my child's grade will not be impacted by their participation in this study. Please check all that apply:

DATA: _____ I give Mrs. Foreback permission to use data generated from my child's work in this class for this study. Data may be in the form of pre and post tests, quizzes, surveys, and classroom observations. All data from my child will remain confidential and secure.

_____ I do not wish to have data generated by my child used in this study.

IMAGES: ______ I give Mrs. Foreback permission to use images of my child or their work for this study. My child will not be identified by name in any image.

______ I do not wish to have my child's image or the image of their work used in this study.

________________________________ ________________________________

Parent/Guardian Name (please print) Parent/Guardian Signature Date

________________________________ ________________

Relationship to Child Age of Child

STUDENT ASSENT:

I voluntarily agree to participate in Mrs. Foreback's study during the 2009-2010 school year.

________________________________ ________________________________

Student Name (please print) Student Signature Date

APPENDIX B: STUDENT SURVEY AND DATA

Name: ______________________

Student Survey

For the following questions, please read the statements carefully and circle the number that best describes your experience or opinion.

1 = strongly disagree; 2 = somewhat disagree; 3 = no opinion/not applicable; 4 = somewhat agree; 5 = strongly agree

1. I was more engaged in science class during the times that I had choices about the assignments I completed compared to the times when the teacher gave everyone the same assignment.	1	2	3	4	5
2. I put more effort into the assignments that I chose to do compared to the assignments that the teacher assigned to everyone.	1	2	3	4	5
3. I learned more when I did assignments that I chose compared to assignments that the teacher chose for the whole class to do.	1	2	3	4	5
4. I learn the same amount when I have choices about the assignments that I complete compared to times when the teacher gives everyone the same assignment.	1	2	3	4	5
5. When I was able to choose which assignments I did, my choice was based on my individual learning style or interests.	1	2	3	4	5
6. I feel overwhelmed when I have choices about assignments and wish the teacher would tell me which assignment to do.	1	2	3	4	5
7. Having choices about assignments is confusing and makes it more difficult to learn.	1	2	3	4	5
8. I wish that I had choices about which assignments to do more often in science class.	1	2	3	4	5

Please answer numbers 9 and 10 as honestly and completely as you can. You may use the back if you need more room.

9. What do you think the **best** thing about having choices was? What do you think the **worst** thing about having choices was? Explain your opinions carefully.

10. Do you think students having choices about assignments matters in school? Why or why not?

Table 6: Student Survey Data – Questions 1 - 8

Student Number	Question #1	Question #2	Question #3	Question #4	Question #5	Question #6	Question #7	Question #8
1	4	4	2	2	4	3	3	4
2	4	3	1	5	3	3	4	3
3	4	4	4	5	4	3	2	3
4	4	3	3	2	5	2	2	4
5	5	4	4	2	5	2	1	4
6	5	5	5	1	5	1	1	5
7	4	5	5	4	5	4	2	4
8	5	4	4	3	4	2	1	5
9	5	5	1	5	5	1	1	3
10	3	4	5	4	5	3	1	5
11	4	4	5	2	5	1	1	3
12	5	3	3	4	5	2	1	4
13	5	5	5	5	5	1	1	4
14	4	3	4	4	4	1	1	4
15	3	3	4	3	4	3	2	4
16	3	3	2	3	4	1	2	5
17	5	5	5	3	4	1	1	4
18	3	4	3	5	3	4	4	2
19	4	4	2	2	5	1	1	4
20	4	4	4	2	5	1	1	4
21	3	2	4	2	4	5	3	2
22	4	4	3	4	5	2	2	4
23	4	5	5	4	5	2	1	4
24	2	2	3	5	5	1	1	4

Table 7: Student Survey Data – Questions 9 and 10

Student Number	Question #9	Question #10
1	You get to choose.	(no answer)
2	That I was more free, but it is sometimes too free.	No, I do not think it matters.
3	The best thing was I could choose based on how much challenge I need.	I think its good because some people learn better like that.
4	The best thing about having choices was that we had time to do things individually and to get individual help. The worst thing was that their was less instruction so sometimes the things I chose to do were harder than when I didn't make a choice.	I think that it does matter because sometimes students learn differently than others and the choice can provide a more enjoyable learning experience.
5	Doing what you like doing better. Sometimes not understanding it.	Yes because then they get to do what they like to do to learn better.
6	The freedom, the worst part was it wasn't explained as well.	Yes, because it allows you to learn in your own way.
7	The best part was that if you didn't like one project you could do one that fits you better. The worst part was that you picked a choice and sometimes you didn't know how to do it.	(no answer)
8	I think the best thing about having a choice is a sense of freedom and we're getting old enough to make our own decisions The worst thing is that its hard to make decisions sometimes.	I think it matters because if students like what they're doing they will work harder.
9	The best thing is I can pick what I want to do. I don't think there is no bad thing.	I think it does matter because when I get a choice I am happier and more engaged (spelling corrected).
10	The best thing about having choices was I learned more and had fun doing it. The worst part was trying to find the choices.	Yes, because they know they will have a more of a say in what they do.
11	I think the best thing was we got to choose what we liked best. The worst thing was sometimes it was harder.	I think it does matter that students have choices so they can do what they like to do. It is also more fun.
12	The best thing is choosing which one best fits with the way you like to learn. The worst thing is getting confused between all of the different assignments.	I think it matters because if a student gets to choose the assignment, they can pick what they want instead of being forced to do the same thing.

Table 7 (continued)

13	**You do what your good like and you can do your best so you understand it. Someimtes its hard to think up an idea when I don't have much time.**	**Yes because that may determine if I like school determining if I do my best or not.**
14	The best part was being able to do what you thought was easier. The worst thing about having choices was not being able to compare with other students in class.	Yes. I think its important because they would most likely wan tot do it. They also could do a project like they enjoy like making a poster or having to write paragraphs. Whatever they liked to do the most or what was easier for them.
15	That I could have control over what I wanted to do. I think the worst part was trying to come up with what you should do, like on the research part of otion 1 on the geologic time scale thing.	I think it does, because then kids can't say the teachers control everything.
16	The best thing about having choices is I can pick something I want to do. The worst thing about having choices is that sometimes things aren't as clear if you don't do the with the whole class.	Yes. Because it makes them more independent
17	Best – choose based on your learning. Worst – not finishing.	Yes, it matters for better grades but most teachers don't care.
18	Choices are good for some people. It gets them engaged and they feel they control their learning. For me, it just gives me one more thing to do: choose. It doesn't overwhelm me, it just takes time.	No, I think students expect teachers to assign something to them. A choice is sometimes a nice surprise but I don't think people try that much harder.
19	The best thing about having choices is getting to do what you are most interested in. It makes it more enjoyable. Maybe some people aren't really sure what to choose sometimes and they get something they don't understand.	I believe it matters if we have choices because it makes pole do better on certain projects (since they understand it better or enjoy it more.)
20	I think the best thing about having choices is I feel like my paper will reflect more on me and what I like.	Yes, because we're old enough where we can handle it and a lot of teachers are still treating us like babies.
21	The best thing of having a choice is because you chose what to do.	Yes, because when I have a choice I think I'm more into it.

Table 7 (continued)

22	**The best thing about having choices is you get to do things you like. The worst thing is having too many options and not knowing what to choose.**	**Yes, I think giving kids freedom will make them feel less stressed.**
23	The best thing was choosing an assignment that we could easily do. The worst thing was having the pressure of making a choice.	Yes because it helps them learn about a certain subject.
24	You get to have more freedom which is fun but sometimes you learn less.	Yes, students will be more interested.

APPENDIX C: MULTIPLE INTELLIGENCE INVENTORY

Name: ______________________

MULTIPLE INTELLIGENCES INVENTORY SURVEY

Place a one (1) next to each item below that describes you well.

<table>
<tr><td>Section 1
_____ I enjoy categorizing things by common traits.
_____ Ecological issues are important to me.
_____ Hiking and camping are enjoyable to me.
_____ I enjoy working in a garden.
_____ I believe preserving our National Parks is important
_____ Putting things in hierarchies makes sense
_____ Animals are important in my life
_____ My home has a recycling system in place
_____ I enjoy studying biology, botany, or zoology
_____ I spend a great deal of time outdoors

_____ TOTAL for Section 1</td><td>Section 2
_____ I easily pick up on patterns
_____I focus in on noise and sounds
_____ Moving to a beat is easy for me
_____ I've always been interest in playing an instrument
_____ The cadence of poetry intrigues me
_____ I remember things by putting them in a rhyme
_____ Concentration is difficult while listening to a radio or television
_____ I enjoy many kinds of music
_____ Musicals are more interesting than plays
_____ Remember song lyrics is easy for me

_____ TOTAL for Section 2</td></tr>
<tr><td>Section 3
_____ I keep my things neat and orderly
_____ Step-by-step directions are a big help
_____ I get easily frustrated with disorganized people
_____ I can complete calculations quickly in my head
_____ Puzzles requiring reasoning are fun
_____ I can't begin an assignment until all my questions are answered
_____ Structure helps me be successful
_____ I fin d working on a computer spreadsheet or database rewarding
_____ Things have to make sense to me or I am dissatisfied

_____ TOTAL for Section 3</td><td>Section 4
_____ It is important to see my role in the "big picture" of things
_____ I enjoy discussion questions about life
_____ Religion is important to me
_____ I enjoy viewing art masterpieces
_____ Relaxation and meditation exercises are rewarding
_____ I like visiting breathtaking sites in nature
_____ I enjoy reading ancient and modern philosophers
_____ Learning new things is easier when I understand their value
_____ I wonder if there are other forms of intelligent life in the universe
_____ Studying history and ancient culture helps give me perspective.

_____ TOTAL for Section 4</td></tr>
</table>

Section 5	Section 6
_____ I learn best interacting with others _____ The more the merrier _____ Study groups are very production for me _____ I enjoy chat rooms _____ Participating in politics is important _____ Television and radio talk shows are enjoyable _____ I am a "team player" _____ I dislike working alone _____ Clubs and extracurricular activities are fun _____ I pay attention to social issues and causes _____ TOTAL for Section 5	_____ I enjoy making things with my hands _____ Sitting still for long periods of time is difficult for me _____ I enjoy outdoor games and sports _____ I value non-verbal communication such as sign language _____ A fit boy is import for a fit mind _____ Arts and crafts are enjoyable pas-times _____ Expression through dance is beauti-ful _____ I like working with tools _____ I live an active lifestyle _____ I learn by doing _____ TOTAL for Section 6
Section 7 _____ I enjoy reading all kinds of materials _____ Taking notes helps me remember and understand _____ I faithfully contact friends through letters and/or e-mail _____ It is easy for me to explain my ideas to others _____ I keep a journal _____ Word puzzles like crosswords and jumbles are fun _____ I write for pleasure _____ I enjoy playing with words like puns, anagrams, or spoonerisms _____ Foreign languages interest me _____ Debated and public speaking are ac-tivities I like to participate in _____ TOTAL for Section 7	**Section 8** _____ I am keenly aware of my moral be-liefs _____ I learn best when I have an emo-tional attachment to the subject _____ Fairness is important to me _____ My attitude effects how I learn _____ Social justice issues concern me _____ Working along can be just as pro-ductive as working in a group _____ I need to know why I should do something before I agree to it _____ When I believe in something I will give 100% effort to it. _____ I like to be involved in cause that help others _____ I am willing to protest or sign a peti-tion to right a wrong _____ TOTAL for Section 8

Section 9
_____ I can imagine ideas in my mind
_____ Rearranging a room is fun for me
_____ I enjoy creating art using varied media
_____ I remember well using graphic organizers
_____ Performance art can be very gratifying
_____ Spreadsheets are great for making charts, graphs, and tables
_____ Three dimensional puzzles bring me much enjoyment
_____ Music videos are very stimulating
_____ I can recall things in mental pictures
_____ I am good at reading maps and blueprints

_____ TOTAL for Section 9

Multiple Intelligence Inventory Tally

Total up your score for each section of the survey.

Section	Section Total	Multiply	Score
1		X 10	
2		X 10	
3		X 10	
4		X 10	
5		X 10	
6		X 10	
7		X 10	
8		X 10	
9		X 10	

Make a histogram. Shade in the boxes below to show your score for each category.

Your score in each category	100									
	90									
	80									
	70									
	60									
	50									
	40									
	30									
	20									
	10									
		1	2	3	4	5	6	7	8	9
	Categories represent your individual strength and areas of interest (see below).									

Section 1 – This reflects your Naturalist strength.
Section 2 – This reflects your Musical strength.
Section 3 – This reflects your Logical strength.
Section 4 – This reflects your Existential strength.
Section 5 – This reflects your Interpersonal strength.
Section 6 – This reflects your Kinesthetic strength.
Section 7 – This reflects your Verbal strength.
Section 8 – This reflects your Intrapersonal strength
Section 9 – This reflects your Visual strength.

MY TOP THREE STRENGTHS ARE: ____________________
____
____

APPENDIX D: INFORMATION ABOUT MULTIPLE INTELLIGENCES

Multiple Intelligence Inventory Survey

Key to Howard Gardner's Multiple Intelligences. Circle your top three strengths.

Section 1 – This reflects your Naturalist strength. - Likes to observe, care fore and interact with the natural world; plants and animals. - Is good at making and justifying differences and comfortable using a symbolic system - Learns best by: sorting, classifying, or distinguishing among the differences between things.	Section 2 – This suggests your Musical strength. - Likes to: sing, hum tunes, listen to music, play an instrument and respond to music. - Is good at picking up sounds, remembering melodies, noticing pitches/rhythms and keeping time. - Learns best by: rhythm, melody, and music.
Section 3 – This indications your logical strength. - Likes to: do experiemtns, figure things out, work with numbers, ask questions and explore patterns and relationships. - Is good at: math reasoning, logic and problem solving. - Learns best by: categorizing, classifying and working with abstract patterns/relationships.	Section 4 – This illustrates your Existential strength. - Likes to: consider the infinites an the infinitesimal; able to see the "big picture" - Is good at: considering or contemplating "ultimate" issues, but no stipulation on the "ultimate" truth. - Learns best by: asking and considering BIG questions. Often can come up with broad insights to a given problem.
Section 5 – This shows your Interpersonal strength - Likes to: have lots of friends, talk to people and join groups - Is good at: understanding people, leading others, organizing, communicating, manipulation and mediating conflicts. - Learns best by: sharing, comparing, relating, cooperating and interviewing.	Section 6 – This tells your Kinesthetic strength - Likes to: move around, touch and talk and use body language. - Is good at: physical activities (sports/dance/acting) and crafts. - Learns best by: touching, moving, interacting with spaces and processing knowledge through bodily sensations.

Section 7 – This indicates your Verbal strength - Likes to: read, write and tell stories. - Is good at: memorizing names, places, dates and trivia. - Learns best by: saying, hearing and seeing words.	Section 8 – This tells your Intrapersonal strength - Likes to: work along and pursue own interests. - Is good at: understanding self, focusing inward on feelings/dreams, following instincts, pursuing interests/goans and being original. - Learns best by: working along, individual projets, self-paced instruction and having own space.
Section 9 – This suggests your Visual strength - Likes to: draw, build design and create things, daydream, look at pictures/slides, watch movies and play with machines. - Is good at: imagining things, sensing changes, mazes/puzzles and reading maps and charts. - Learns best by: visualizing, dreaming, using the mind's eye and working with color/pictures.	

APPENDIX E: ONE IN A MILLION

Name: ______________________

One in a Million

There are approximately 480 students at DeWitt Junior High.
There are approximately 4,700 people living in DeWitt.
There are approximately 75,000 seats in Spartan Stadium.
The distance to the moon is 238,857 miles.
There are approximately 10 million people in Michigan.
There are approximately 6.7 billion people in the world.
There are an estimated 400 billion stars in the Milky Way Galaxy.
The national debt is over 11 trillion dollars.

But how big is a million? How big is a billion? In order to get a better idea about the size of these really big numbers, let

Observe the series of containers at the front of the room. Can you find the purple sprinkle in each container? The first Petri dish has 10 sprinkles in it. Nine of them are white and one is purple. The second Petri dish has 100 sprinkles in it. 99 of them are white and one is purple.

How many times more sprinkles are there in the second Petri dish? ____________

Knowing that the pattern continues, complete the table below:

Container	Number of Sprinkles
1^{st}	10
2^{nd}	100
3^{rd}	
4^{th}	
5^{th}	

Scientists and engineers often use the phrase "powers of ten". What do you think they mean? How does this phrase relate to what you know about decimals and exponents from math class?

The mass of 100 sprinkles is 0.383 grams. Add a column to the table above and make the heading "Mass (g)". Fill in the mass of the sprinkles in each container.

The volume of the sprinkles in the Mason Jar is approximately 400 mL. Add a fourth column to the table above and make the heading "Volume (mL)". Fill in the volume of the sprinkles in each container.

If our class wanted to make a container that had a million sprinkles in it (999,999 white sprinkles and 1 purple sprinkle), how big a container would we need? Show your calculations below. What kind of container would you suggest for our project?

Bottles of white sprinkles can be purchased online for $2.29. Each bottle contains approximately 100 grams of sprinkles. (Some have a little more, some have a little less.) How many bottles of sprinkles would we need for our project? How much would the sprinkles cost?

Some more practice

The last page of this packet is filled with asterisks. Answer the following questions using the 'asterisk page'. Show all of your calculations. Don't forget to use units.

How many asterisks are on the page?

How many pages would it take to get to a million asterisks?

If we posted the pages on the back wall, how much wall space would we need? (Assume that we line up the asterisks right next to each other – be careful about the margins on the pages.)

How many pages would it take to get to a billion asterisks?

How much wall space would a billion asterisks take up?

Challenge: At the end of class today, your science teacher starts counting.

Challenge: At the end of class today, your science teacher starts counting. "One, Two, Three, Four…". She is a pretty steady counter and can pronounce the names of big numbers really fast so you can assume that she can maintain a rate of one number per second. If she keeps counting all night and all day (no breaks, no sleeping, she's amazing!), will she be able to count to one million by the time the bell rings for your next science class? Justify your answer in the space below. Don't forget, we're on an A/B schedule, so it may be a few days before you see her again. Be sure to explain all of the possible scenarios.

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APPENDIX F: CHOICE ACTIVITY #1: FORMATION OF THE SOLAR SYSTEM READING ACTIVITY

Learning Choice #1: Formation of the Solar System Reading

For this activity, you will choose one of the articles provided in class and do a T4 with it. Then we will form groups of 2 to 4 people making sure that everyone in the group read different articles. Be prepared to share what you learned from your article with your group members using the *** protocol. Once everyone has shared the important information from their individual articles, your task as a group is to choose one of the following projects and complete it.

- ☐ Write a new article that puts all of the information that you learned together. Your article should include pictures and diagrams. Make sure you define your audience. Is your article for other junior high students? Adults reading a science magazine? Newspaper readers?

- ☐ Make a poster that explains how the solar system was formed. Your poster should be designed for junior high students who are learning about the solar system.

- ☐ Make a children's book for elementary students that describes how the solar system was formed. Your book should be illustrated.

- ☐ Act out a skit that shows explains how the solar system was formed. You <u>must</u> perform the skit for your teacher. You <u>may</u> perform the skit for the class if you would like.

- ☐ Draw a storyboard or a comic strip that explains how the solar system was formed.

- ☐ Create a concept map or flow chart that explains how the solar system was formed. Make the final draft of your concept map or flow chart large enough that it can be displayed.

APPENDIX G: ORDERING EVENTS CARD SORTING ACTIVITY

During the Quaternary Period, present day *Homo sapiens* began to inhabit the Earth. The Quaternary Period is divided into the Holocene Epoch and the Pleistocene Epoch.	208 million years ago, the largest dinosaurs appeared, such as Stegosaurus, Diplodocus, and Apatosaurus.	The Tertiary Period began warm and humid compared to today's climate. By the middle of the period, the climate began to cool and by the end, an Ice Age had begun.	During the Tertiary Period, mammals are abundant on land and in the sea. Flowering plants are dominant and the Alps and the Himalayas begin to rise.
Tyrannosaurus rex appeared during the last part of the Cretaceous Period, which ended around 65 million years ago.	During the Jurassic Period, dinosaurs are dominant and the first birds appear. Mountain building continues in western North America.	At the end of the Triassic Period, Pangaea began to break apart.	The Triassic Period was known as the "Age of Reptiles" because reptiles such as turtles, crocodiles, and dinosaurs became abundant.
The first mammals, which probably evolved from the mammal-like reptiles, began to develop late in the Triassic Period.	The supercontinent Pangaea formed during the Permian Period, which was around 250 million years ago.	Dinosaurs (and many other groups of organisms) become extinct after the Cretaceous Period. This event is known as the K-T extinction.	At the beginning of the Permian Period, the poles (and consequently, the southern region of Pangaea) were covered in thick Ice Sheets while the tropics were covered in swampy forests.
By the mid-Cretaceous, mammals had diverged into the two main groups that still exist today: the marsupials (like kangaroos and koalas) and placental mammals (like dogs, cats, and humans).	During the Pennsylvanian Period, the first reptiles developed. Also, large swamp forests known as 'coal swamps' were abundant.	During the Mississippian Period, which was 360 million years ago, amphibians were dominant. Glacial advances occur during this time.	Many marine invertebrates become extinct after the Permian Period. The building of the Appalachians ends and the glaciers retreat.
During the Devonian Period, lobe-finned fishes and the lungfish developed.	The Devonian Period, ending about 360 million years ago, was known as the "Age of Fishes". Fish with scales and bony skeletons developed during this time period.	The appearance of flowering plants during the Cretaceous Period was an important development for life on land.	During the Suilurian Period, the first land plants, the first insects, and the first fish with jaws began to develop.

Corals and other invertebrates were dominant during the Silurian. Warm, shallow seas cover much of North America.	During the Ordovician Period, the first fish (which were jawless) appear and the Appalachians begin to form.	During the Cambrian Period, sea invertebrates such as trilobites, brachiopods, sponges were abundant. Thick sediment was deposited in inland seas.	During the Precambrian Period, cyanobacteria were using photosynthesis to convert solar energy into the chemical energy of sugar and as a result, oxygen began to build up in the atmosphere.
Radiometric dating has determined that the oldest rocks on Earth are between 3.96 and 3.8 billion years old. The oldest meteorites are 4.5 to 4.7 billion years old. The oldest rock samples from the moon are 4.6 billion years old.	The oldest known fossil eukaryotes occur in a 2.1 Billion year old banded iron formation in northern Michigan.	The Varangian Glaciation occurred between 800 and 700 million years ago. The glaciers reached nearly to the equator and geologists liken the Earth at the time to a "giant snowball".	Reptiles that evolved from the early amphibians developed a new type of egg (the amniote egg) during the Carboniferous Period that did not have to be laid in water.

APPENDIX H: CHOICE ACTIVITY #2: GEOLOGIC TIME SCALE ACTIVITY

Learning Choice #1: Geologic Time Scale Card Sort Extension

For this activity, you will use the same cards that we used in class to make a scale model of the geologic time scale. You may choose to work alone or with a partner, but each person will make their own time scale. You will need a new set of cards (one per person) and a piece of adding machine tape that is 5 meters long (one piece per person).

Procedure:

1. Cut out the cards and arrange them in order. Number each card so that #1 is the oldest event and #28 is the most recent event.
2. Neatly draw a line down the center of your timeline like the example that we used in class.
3. Use a meter stick to make a small tick mark at 10 centimeter increments all the way down the line.
4. Label each tick mark starting with 4.6 Billion years ago at the far left end of your adding machine tape. Complete the following table to help you with the distances. Have your teacher check your work before you start labeling.

1 cm = 10 million years

So, 10 cm = ________ million years

100 cm = ________ million years

100 cm = 1 m, so 1 m = ________ million years

1 cm = 10 mm, so 1 mm = ________ million years

1 billion years = ________ million years

5. Find the point on the time line where each card belongs. You may glue or tape the card on <u>OR</u> you may simply write the number of the card on the adding machine tape. (Hint: Make sure you place all of the cards in the proper place before you start gluing or taping. You may find that you don't have enough room on the adding machine tape for all of the cards. You may find your own solution to this problem.) If you choose to write the number instead of gluing/taping the cards, please affix the cards to another piece of paper so that you can make a key to hang with your time scale.
6. Choose one thing on your geologic time scale that you think is particularly interesting. This may be an organism, a time period, a geologic event, etc. This is your extension topic. Research your topic and complete one of the choices below. If you have an idea for a project that is not on the list, see your teacher for approval. You may work with a partner for this task, but you must make a plan with your teacher to determine who will be responsible for which part of the project before you begin.

    a. Make a poster presentation about your extension topic.
    b. Prepare a lecture about your extension topic with visual aids.
    c. Make a webpage or PowerPoint presentation about your extension topic.
    d. Write a formal report about your extension topic.

e. Design a lesson for elementary students about your extension topic (be sure to include an activity that kids would like to do). Write a lesson plan. You may (but are not required to) teach the lesson to a group of children or peers.
f. Write a story about going back in time and write a fictional story about your extension topic. While the story may be fictional, be sure to include important facts about your topic.
g. Make a board game for your peers that would teach them about your extension topic.
h. Make a physical model or diorama of your extension topic and prepare a written or verbal or explanation to go with your display like you might see in a museum.
i. Choose your own project (make sure you meet with your teacher to discuss the details first!)

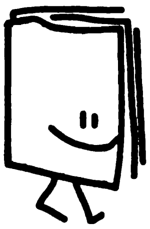
Learning Choice #2: Geologic Time Scale Project

For this activity, you will make a scale model of the geologic time scale. You have lots of options for making your scale, but **every project must contain the following elements:**

1. The project must be to scale and the scale must be clearly labeled or communicated in some way for the audience.
2. The four eons must be labeled (Hadean, Archean, Proterozoic, and Phanerozoic).
3. The eras and the periods of the Phanerozoic Eon must be labeled.
4. The following major events in geologic time must be labeled (note: this list is not in chronological order):
    a. Oldest known rocks
    b. Oldest known fossils
    c. Build up of oxygen in the atmosphere
    d. First appearance of animals
    e. First appearance of life
    f. First appearance of land plants
    g. First appearance of birds
    h. Pangaea
    i. The Pleistocene Ice Age
    j. Permian Extinction
    k. K-T Extinctions
    l. Cambrian Explosion
    m. Dinosaurs existed
    n. "Age of Amphibians"
    o. "Age of Reptiles"
    p. "Age of Mammals"
    q. "Age of Man"

The scale that we used for our in-class geologic time scale was 1 cm = 10 million years. If you would like to use that scale, you may. If you would rather make your time scale longer or shorter, you may. There are also non-linear representations that you might like to consider. Here are a few ideas to get you started:

- The face of a clock
- A calendar (year, month, week, day)
- A typical human's life time (or your life so far)
- The length of the classroom
- The length of a hallway at school
- The length of a football field or basketball court
- The length of the parking lot
- The length of the cross-country course or once around the track
- A birthday cake
- A thermometer
- A circle graph or pie chart



Learning Choice #3: Geologic Time Scale Book

This project is similar to the geologic time scale project (choice #2), however instead of creating a physical model of the geologic time scale, you will create a book about the history of Earth. Your book should have a cover and title and be illustrated. The required elements are very similar to choice #2 and are as follows:

5. The book must convey the length of each time period in some fashion. The method you use to show the length of time is up to you as the author. The four eons must be included (Hadean, Archean, Proterozoic, and Phanerozoic).
6. The eras and the periods of the Phanerozoic Eon must be included.
7. The following major events in geologic time must be included (note: this list is not in chronological order):
    a. Oldest known rocks
    b. Oldest known fossils
    c. Build up of oxygen in the atmosphere
    d. First appearance of animals
    e. First appearance of life
    f. First appearance of land plants
    g. First appearance of birds
    h. Pangaea
    i. The Pleistocene Ice Age
    j. Permian Extinction
    k. K-T Extinctions
    l. Cambrian Explosion
    m. Dinosaurs existed
    n. "Age of Amphibians"
    o. "Age of Reptiles"
    p. "Age of Mammals"
    q. "Age of Man"

When submitting your final product, please include a short description of the intended audience. Is it a children's book? Is it designed for your classmates? Is it a study guide for yourself?

APPENDIX I: JELLO GEOLOGY ACTIVITY

JELLO Geology/Pudding Paleontology- Teacher Notes

This activity is designed to give students a tactile experience with relative dating in order to help them interpret diagrams of rock layers. Each student (or pair of students) will need a pudding cup (see preparations below).

Materials:

- Chocolate pudding (about half a cup per student, prepared)
- Vanilla pudding (about a quarter cup per student, prepared)
- Four kinds of gummi candies or fruit snacks. In this example, I used gummi worms, gummi bears, shark fruit snacks, and dinosaur fruit snacks. Other candies that work well include gummi lifesavers, jelly beans, Swedish fish. Note: If you chose larger candies, you will need larger cups and more pudding per student.
- Small paper or plastic cups
- Plastic spoons
- Metric rulers
- Colored pencils
- Text books or other reference materials to look up definitions on "Page 2".

Preparation:

Prepare the pudding according to the package instructions (or purchase large cans of pudding from a bulk foods store!). Decide which candies will represent which fossils. (You can fill in the names of your candies in the table below.)

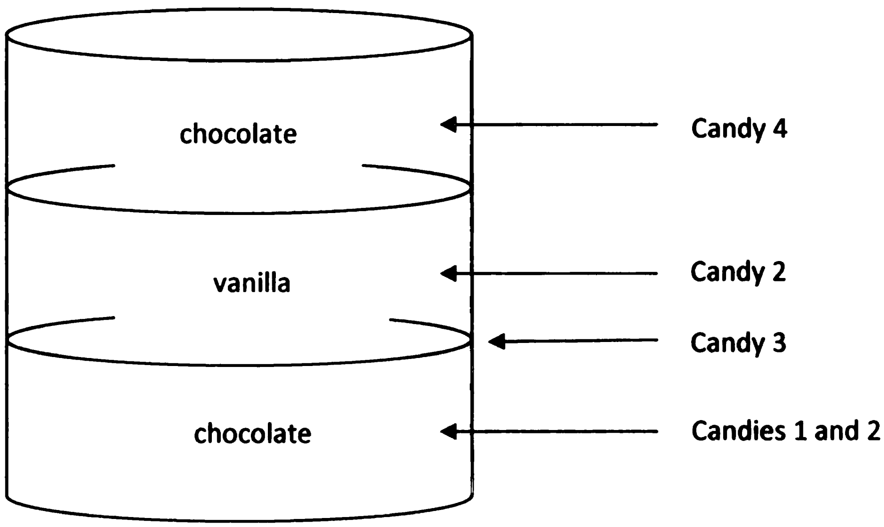
Candy 1		appeared about 1,500,000 years ago and went extinct 600,000 years ago
Candy 2		first appeared about 1,000,000 years ago and went extinct 4,000,000 years ago.
Candy 3		"new" fossil
Candy 4		appeared about 400,000 years ago and went extinct in the last 100,000 years.

Put a small amount (~1/8 of a cup) of chocolate pudding in the bottom of the cup. Place 2-3 pieces of candies 1 and 2 on top of the pudding. Cover the candies by putting another 1/8 of a cup of chocolate pudding on top and smoothing the layer.

On top of the chocolate pudding, place 2-3 pieces of candy 3. Cover candy three with ~ 1/8 cup of vanilla pudding. Place a few examples of candy 2 on top and cover with another 1/8 cup of vanilla pudding.

Finally, layer 1/8 cup of chocolate pudding on top of the vanilla. Place a few pieces of candy 4 on top. Cover and smooth with another 1/8 cup of chocolate pudding.

The pudding cups won't keep for more than a day or two so it is best to make the cups the night before the activity.



The table below shows when each 'species' lived. The top row gives time in millions of years.

	1.5	1.4	1.3	1.2	1.1	1.0	0.9	0.8	0.7	0.6	0.5	0.4	0.3	0.2	0.1
Candy 1															
Candy 2															
Candy 3															

The Lesson:

Introduce the activity by just giving the students the first page to start. *Do not pass out Page 2 until they have completed the section that asks them what other information they need.* Frame the problem for the students. A new fossil has been found and they have been asked to determine the age of this fossil using relative dating principles. It is helpful to show them the fossil that they are looking for. Remind them to be very careful as the 'dig' so that they don't destroy samples as they go. They should make careful observations and measurements. Encourage them to draw and label their sample in the space on the first page. Students should be able to say that candies 1 and 2 are older than the "new" fossil and candy 4 is younger. They should also indicate that in order to determine the age of the "new" fossil, they need to know the ages of the fossils in the surrounding layers.

Once students have given satisfactory responses to the questions on the first page, they may get "Page 2" from the teacher. Students should work through the questions on Page 2 with their partners or in lab groups. They should determine that the "new" fossil is approximately 600,000 years old because it appears right between the layer that contains candies 1 and 2 and the layer that contains just candy 2. You can make up silly 'scientific' names for your candies if you would like. Be sure to show students examples of each fossil that is not in pudding. This is especially important if you use fruit snacks that come in different shapes. Leave a box out so that students can see a diagram of all the possible shapes. You can call this a "field guide".

Alternate Preparation:

Preparing the pudding cups is time-consuming and expensive. A less expensive (though still time consuming) method is to use JELLO instead of pudding. The JELLO preparation will keep for a couple days, but some candies (such as jelly beans) tend to get slimy after the first day. If you would like to use this method instead, choose three flavors of JELLO (pick colors that will be easily distinguished when next to each other). There is an alternate student worksheet attached.

Prepare the JELLO according to the "Jigglers" recipe. (Prepare one flavor at a time!) Pour the first layer into a 9x13 pan and put in the refrigerator for 5 to 10 minutes. When the first layer is partially set, drop candies 1 and 2 into the JELLO. Make sure they are at least covered by the layer so that it doesn't look like they are part of the second layer. The time it takes to 'partially set' will vary, but it isn't very long so check often. Think about how you will cut the JELLO into blocks for the students. Make sure that there will be some examples of every fossil in every piece. You should be able to get 24 adequately sized squares out of one 9x13 pan.

When the first layer is completely set, place candy 3 on top. Prepare the second layer of JELLO and carefully pour over the first layer. When the second layer is partially set, put candy 2 in so that it is covered by second layer. When the second layer is completely set, prepare the third layer and carefully pour it over the second layer. Place candy 4 into the third layer when it is partially set.

When you cut the pan into individual squares, use a very sharp knife as the gummi candies can be difficult to cut through. For instance, if you knife can't easily cut through Swedish fish or gummi worms, they tend to pull out of their original location making it very difficult to tell where they were in the JELLO.

Give students plastic knives to "excavate". The serrated blades cut through the Jigglers recipe well and students can 'dig' around the candies to observe them. Plastic spoons don't work as well.

Name: ______________________

JELLO Geology

You are a brilliant paleontologist and you and your team have just been commissioned for a new dig. A new fossil has been identified in Theresalwaysroom, Montana and you have been asked to determine its age. A sample of this new fossil has been sent to your lab for you to study before you head out to Montana. Remember to be very careful as you excavate the area of study so that you can use information from the surrounding layers to help you date the new fossil.

As you dig, record all of your observations in the space below. Include a detailed diagram with labels and measurements.

Which fossils are older than the new fossil?

Which fossils are younger than the new fossil?

What information do you need in order to determine the age of the new fossil?

Name: ____________________________

JELLO Geology – Page 2

Because you are a brilliant paleontologist, you know the following information about the fossils found in the Pudding Falls area:

> ***Ursa gummi*** **first appeared about 1,000,000 years ago and went extinct 400,000 years ago.**
>
> ***Annelida gummi*** **first appeared about 1,500,000 years ago and went extinct 600,000 years ago.**
>
> **Various forms of colorful gummiosaurs appeared about 400,000 years ago and went extinct in the last 100,000 years.**

1. **Based on the information above, how old is the new fossil?** ***Explain your reasoning thoroughly.*** **Be sure to discuss how the gummi bears, gummi worms, and gummi dinosaurs helped you reach your conclusion. It may be helpful to draw a time line and indicate when each species lived.**

2. Define the following terms using your text book or other resources.

   a. **Law of superposition** –

   b. **Law of original horizontality** –

   c. **Uniformitarianism** –

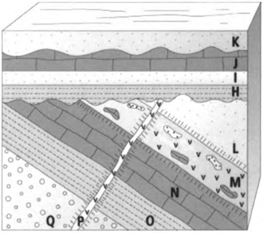
   How are these three principles used to "read" rock formations?

3. What is an **index fossil**? Which candies represent index fossils in the pudding exercise?

4. Consider the diagram to the right.
   a. Which layer is the youngest?

   b. Which layer is the oldest?

   c. Which layer formed just after a folding event?



d. Assume that *Annelida gummi* is an excellent index fossil. If *Annelida gummi* was found in layer N, what conclusions can you make about the fossils in layer M?

e. Layer P is an igneous intrusion. The principle of cross-cutting relationships states that when a fault, a crack, or a dike (like layer P), cuts across layers of rock, the rock that is being cut across must be older than the thing cutting across it. Think about a cement square in a sidewalk. If there is a crack in the cement, you know that the crack happened *after* the sidewalk was poured. Likewise, if there is grass growing in the crack, then it must have started growing *after* the crack formed. Considering the principle of cross-cutting relationships, list the layers in order on the line below.

Oldest Youngest

APPENDIX J: IT'S ALL RELATIVE ACTIVITY

Name: ___________________________

It's All Relative

This activity is adapted from "It's All Relative" NY State/DLESE Collection (www.dlese.org)

Correlation is the process of showing that rocks or geologic events occurring at different physical locations are of the age. **Index fossils** are one of the best means that we have of correlating rocks. Index fossil are those that appeared in the rock record abruptly, covered a large geographic area, lasted for a short duration of time, and died out abruptly.

The idea of using fossils for such purposes originated about 1800, when William Smith, and English engineer and geologist, made a number of basic observations about fossils and rock formations. While building canals to move coal from the country to the cities, Smith observed certain patterns in the order of the sedimentary rocks throughout the countryside. It got to the point where he could see an outcrop of a particular rock type and predict the underlying strata. Smith was also able to correlate sedimentary rock strata over large distances when he started to identify specific fossils that appeared only in certain rock layers. He noticed that in a given formation, different layers contained different fossils, but that the fossils in a particular layer of a rock formation were the same throughout the formation. On further investigations, Smith noticed that certain fossils were found in rock layers of the same age, even at widely separated locations. So, the presence of such fossils could be used to correlate the ages of rocks at different locations. Of particular importance to Smith were the ammonoids (see figure above). After decades of study, William Smith developed the very first geologic map. With the use of rock types and index fossils, he was able to correlate rocks from one end of England to the other.

The presence of fossils also reveals something of the past environment. For example, the presence of fossils of marine organisms shows that during a certain period in the past the area was covered by an ocean. If the fossils are index fossils, you can say with some certainty just when, in the past, the ocean covered the area.

In this activity, you will correlate index fossils from the state of New York found in six different geologic columns. Each group will need the following:

- Pack of fossil cards
- Yarn
- Scissors
- Paper clips

Procedure:

1. **Using the *Geologic History of New York State* (from the *Earth Science Reference Tables* – 2001 edition), identify the epoch and age (in millions of years) of each of the fossil specimens in your group. Record this information in the Table 1.**
2. **Arrange the fossils according to age (oldest on the bottom) and attach your fossil cards to your vertical string by putting the pieces of Velcro together over, pinching the string in between them. Assume that each fossil in your collection represents a stratum that is approximately 0.5 meters in thickness. This means that starting from the ceiling, you should place the fossil cards 0.5 meters apart (use a meter stick!).**
3. **Using the string your group was given and the bent paper clips, correlate the fossils in your stratigraphic section to the one directly to your right. Group 6, help other groups as necessary as there is not a group to your right. The string should be pulled taught so that it does not sag, but not so tight that it deforms the stratigraphic section. The string should attach the tops of the fossil cards.**
4. **Record (sketch) the fossils found at all locations in Table 2 and answer the questions that follow. You may find it helpful to sketch the correlations between the columns as well.**

Table 1: Group # _______'s Fossil Cards

youngest

Fossil Name	Period/Epoch	Age (millions of years)
1.		
2.		
3.		
4.		
5.		

oldest

Questions:

1. What is the oldest fossil? How old is it?

2. What is the youngest fossil? During which period and epoch did it live?

3. Which fossil is most widespread geographically?

4. Which fossil existed for the longest time?

5. Which fossil(s) would be the best index fossil(s)? Why?

6. Which fossil(s) would be the least useful index fossil(s)? Why?

7. Consider the strata between columns 4 and 5. What could have happened to cause this fossil distribution?

8. What conclusions can you draw about Euryterid based on our data?

9. What conclusions can you draw about Nautiloid based on our data?

Volcanic Ash Extension:

After the teacher demonstrates a volcanic ash deposit, answer the following questions. The yarn represents a thin layer of ash deposited after a large volcanic eruption in the area.

1. **Describe how the volcanic ash layer looks compared to the rest of the correlated strata.**

2. **Volcanic ash is considered to be an excellent maker of time in stratigraphic columns. Why do you think this is? (Hint: What is it about volcanic ash that makes it such a good marker? What is volcanic ash made of? Think about time and space.)**

APPENDIX K: CHOICE ACTIVITY #3: INDEX FOSSIL ANALOGY ACTIVITY

Name: ______________________

Analogy Activity

Index fossils are organisms that existed for a relatively short time in history.

Index fossils cover a wide geographical range.

"Good" index fossils appear and disappear abruptly from the fossil record.

(There is no such thing as a "perfect" index fossil.)

Your task is to create an original analogy that explains the characteristics of index fossils. For example, index fossils are like disco music. Disco was very popular for a short period of time. You can immediately identify disco as a product of the 1970s. Likewise, cellular phones that were carried around in bags were around for a very short time in the early 1990s.

For this activity:

1. think of your own index fossil analogy
2. choose one of the options below:

Option 1:

- make a mini-poster that explains why your analogy describes the characteristics of an index fossil well
- present your poster to the class or hang it in the classroom

Option 2:

- Write a short paper (~2 paragraphs) that explains your analogy
- Read your paper to a classmate or your lab group

Option 3:

- Make a model that explains your analogy
- Prepare a short presentation or written explanation to accompany your model

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