Teaching Fifth Graders Science
through the Lens of Medieval Scientific Discoveries and Developments

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BACKGROUND

Looking back, I believe history has always been important to me. I grew up in Mexico. Ours was a large house with a vast library, and every one around me talked about events in the past as though they had actually experienced them. I was fascinated. Equipped with a degree in Anthropology and experienced in the field of archaeology and ethnography, I realized that many of our young people lack the necessary investigative tools to understand science and social studies. To remedy this, I decided to teach elementary school and was certified as a science teacher.

Lantrip Elementary, the school where I teach, is in a primarily Hispanic section of Houston. It comes under the umbrella of Title I. The majority of the students were born in this country, but their parents migrated here from Mexico or diverse Central American countries. A few of them have upper level education, but, for the most part, they are almost illiterate. Certainly their knowledge of the historic background of mainstream United States is nonexistent, impeding to a certain extent their integration into the culture of this country.

UNIT BACKGROUND

I have always wanted to expand my knowledge of European history, especially the Medieval period. That is why I signed up for this seminar when I learned of it. I was curious to know about the social structure, to know more accurately the population's degree of civilization, and the people who influenced the development of their society and made possible its continuation. In other words, the conditions prior to the onslaught of the Black Death, so that I could more clearly detect the effects that it had on the population, the social structure, and how the people had rebuilt their lives. I had not suspected that climatic and ecological changes had played a crucial role in the development, advancement, and slowing down of that cultural thrust. Yet, realizing it has made the pieces fit into the enormous puzzle that is the European Medieval Period. It explains decisions, perceptions and ultimately impact upon present day western thinking. My intentions are to connect those experiences to the present or recent past, especially for those students whose parents migrated from war-torn countries with devastated ecosystems and rampant disease. As I share some of this knowledge with my students, they will share that information with their parents and grandparents. The parents often make the connection to their own experiences and tell their children about them, thus creating a commonality between the cultures.

INTRODUCTION

The era called the Middle Ages is one of the most impressive periods in the development of occidental culture. In it many technological advances that we take for granted were made. It is hard to know if they were made as the result of peoples' needs or out of simple curiosity. What we do know is that among the mentally active people there was a desire to know about nature and the laws that govern it. They were open minded and interested in what other peoples were doing and knew and eagerly adopted any information that would make their lives more comfortable. They learned of and developed philosophical and theological ideas that helped lay the foundations for scientific experimentation and discovery. These, in turn, were greatly aided by arithmetic and geometric imported knowledge that they applied to engineering, construction, mining, transportation, and banking: all evinced in the architectural and documentary remains of European cities.

The technological and intellectual improvements, however, did not happen simply out of curiosity and open mindedness. They were the result of a marked improvement in climatic conditions that began in the ninth century. The milder, more dependable weather allowed for increased, more profitable agriculture and pastoral pursuits that in turn permitted enough surplus production to encourage exchange of goods. Simultaneously, a cessation in raids, pillaging, and burning from Vikings and other marauding groups occurred. The resulting relative peace probably produced a healthier and better nourished population that had more time to study, meditate, create, investigate, and even specialize (Dales 35; Gimpel 29- 58).

PHILOSOPHERS, SCIENTISTS AND LINGUISTS

According to various writers on the Middle Ages, the twelfth and thirteenth centuries were the most impressive and can justifiably be referred to as the First Renaissance. Notable for its concern with philosophy and science, it was a period when men learned anew how to reason and dispute intellectually. Dales suggests that a few luminaries kept the light of learning alive during the years between the downfall of Rome and the beginning of the Middle Ages. He mentions in particular two Roman philosophers -- Calcidius (4^{th} century) and Boethius (5^{th} century) -- who independently translated the works of Greek authors such as Plato and Euclid.

Among the first great western Medieval thinkers was the 10^{th} century Gerbert of Aurillac, who, influenced by the Islamic intellectual movement taking place in the fringes of Christendom, revived the use of the ancient calculating instrument called the abacus and developed Boethius' treatises on arithmetic and music. Using the abacus and Euclid's geometric instructions, Gerbert wrote his own treatises on astronomy. His thought processes were perhaps too confusing and complicated for many of his contemporaries because, failing to understand his work, they accused him of being in league with Satan in spite of his being the current pope, Sylvester II (died 1004).

A third, and perhaps the greatest, Greek philosopher to influence western thinking was Aristotle. His writings on such diverse subjects as physics, poetics, politics, ethics rhetoric, biology, and the soul among others reached the West through Latin translations in the 11^{th}, 12^{th}, and 13^{th} centuries and had a prevailing influence on Medieval and later thought. His emphasis on observation and analysis of the physical world underlies modern science, and the system of logic that we have used ever since in the west was developed by him. At first the progression toward the development of science was not as noticeable as other aspects of culture such as commerce, mining and industry, but after a slow start it did develop momentum, influencing the construction of buildings, machinery and instrumentation.

Undeniably the process of translating Greek and Arabic works into Latin, barely begun in Spain in the tenth century (Dales 36) and in Sicily in the eleventh, made that progress possible. The trend toward scientific thinking, however, was not immediate. It seems to have evolved from a type of introspection manifested in the writings of the great theologian, St. Anselm (1033 - 1109), who considered it important to question what one believes in order to understand it. In other words, Anselm applied reason toward the refinement of faith. A few years later, Peter Abelard (1079 -1142) addressed lay readers, encouraging them toward that same introspection adding that only through intellectual inquiry could truth be investigated. He suggested that in order to sharpen the tool of inquiry it was important first to doubt, as doubt would lead to questions and, by questioning, the truth would be reached.

The concept of analyses and questioning was not universally accepted. In fact, Abelard's teachings set him definitely at odds with St. Bernard of Clairvaux, who was of the opinion that one could find more in forests than in books, and that nature could reveal more than any teacher. It seems that Bernard, the founder of the Cistercian Abbey of Clairvaux in 1115, was in some ways a mystical naturalist who accepted the vicissitudes of life as God's will and thus inevitable. To him, reason was always subordinate to faith, and any ideas about increasing believers understanding of what was believed was suspect of heresy. He may have felt that his faith was threatened by the massive invasion of books from the classical world that were being translated from Greek and Arabic on the edges of Christendom: Sicily and Spain. Bernard may have considered their use a departure from a more mystical form of religion and so opposed Abelard's theories and became instrumental in his condemnation in 1140 A.D.

In Iberia (Spain), the Moors had succeeded in establishing themselves and fellow Moslems since 711 A.D. Once comfortably ensconced, they imported from the Middle East all manner of items and ideas that would make this new home as close to the Islamic ideal as possible. Among the imported items were books, scrolls, and treatises on different aspects of learning from far and wide. They established Houses of Wisdom in many of the cities where they dominated. Toledo in Spain and Salerno in Italy were home to the most famous Houses of Wisdom. There, teams of learned men -- Jews, Muslims, and Christians -- came together to produce Latin translations from Greek works as well as works written by Arabic scholars, particularly in the fields of medicine, astronomy, arithmetic, algebra, and trigonometry. Adelard of Bath, possibly an Englishman, is one of the crucial figures of the transitional period of the twelfth century, when the Latin classics and the late antique handbooks and translations were still the dominant sources of scientific information and attitudes, but when the new translations from Greek and Arabic were just becoming known to European scientists.

Adelard exemplifies the growing curiosity and intellectual adventuresomeness of European scholars in general during the twelfth century. His attitudes and values were new and different, but they were the causes rather than the results of the translating activity. Avid for greater knowledge and understanding, Adelard learned Arabic and is thought to have traveled extensively throughout many Arab countries learning from and visiting different learned men. During his absence from Europe, he acquired a large number of books and treatises written in Arabic as well as translations from Greek.

Before his travels, he had learned, as all European scholars did, the *quadrivium*: arithmetic, music, geometry and astronomy; and the *trivium*: grammar, rhetoric, and dialectic, which were taught in the Houses of Wisdom as well as in the Learning Centers of Europe. He was influenced to pursue knowledge by the works of great Arabic philosophers from Toledo such as ibn Rushid, Averroës, and Avicenna. From scholars in Paris, such as Abelard, who taught Aristotelian dialectic, he learned to consider observation and analysis the basis of science and reason. But, as taught, the Aristotelian intellectual movement relied on purely secular reason and did not seem to address the natural world, as did the Platonic Augustinian theories causing a disconcerted sense of frustration among some religious scholars.

Adelard of Bath must have been trying to come to grips with this sense of confusion when he wrote *Natural Questions*, because he often remarks that he is not trying to take away any credit from God as he explains the observed phenomena to his nephew. Later, a bit more at ease with his conscience, he wrote *Eodem et Diverso* (Concerning the Same and the Different), in which he discusses the positive and negative attributes of life with *philosophia* - love of wisdom versus that with only *philoscosmia* - love of worldly pursuits, concluding that he believes the first guarantees a more fulfilling and rewarding life than the second. Hence he devoted much of his life in pursuit of knowledge and seems to have married both the Aristotelian dialectic and the Platonic philosophy; and so we see that in *Natural Questions* he attempts to explain, in quite understandable terms, such concepts as adaptation (Dales 43), gravitational force (Dales 48), and matter, with its spacial constrictions. Adelard's curiosity led him to translate the works of many of the Greek and Muslim scholars. Of all his works, it was Euclid's *Elements* that had the most profound effect on the development of scientific thinking because it made Europeans conscious of methods by which a theorem could be proven deductively (Cockrane 63).

Two very influential philosophers of the thirteenth century in Continental Europe were Albertus Magnus and Thomas Aquinas. Albertus (1206? - 1280) was a German scholastic philosopher and scientist who helped establish Aristotelianism and the study of natural sciences in Christian thought. He did this by Christianizing philosophy and systematizing theology, accepting only what was true and rejecting what he felt was false in the writings of Aristotle (Jacques Maritain Center). For Albertus, there was only one integral truth to be found through the knowledge of theology, ethics, logic, and metaphysics. In their pursuit he became a remarkable chemist, geographer, geologist, mechanic, botanist, and anatomist.

In one of his treatises Albertus disagreed with the 8th century English scholar Bede about the uninhabitability of the hemisphere below the equator. He argued that not only did he think there was land between the equator and the South Pole but, thought that in all probability, it was actually inhabited, except directly at the poles where he imagined the cold to be excessive. He continued to write that he suspected that animals in the poles would probably have very thick skins and be white. Conjectures such as these led many of his contemporaries to suspect him of being in league with a supernatural source. Nor was "his production of a winter garden or hothouse, where on the feast of the Epiphany, 1249, he exhibited to William of Holland, king of the Romans, plants and trees in full blossom" to clear him of the suspicion of sorcery (Jacques Maritain Center).

St. Thomas Aquinas (1225 -1274), an Italian, was Albertus' student. In soundness of judgment he surpassed his master and became a theologian and philosopher of the first magnitude influencing the direction of the Roman Catholic Church thereafter. In his treatises he attempted successfully to reconcile Christian faith with Aristotelian reason assuring his readers that knowledge derives principally through rational ordering of what our senses reveal to us about the natural order.

In England, specifically at Oxford, a combination of both currents of thought: Neoplatonism and Aristotelianism seems to have been preferred. There it was considered essential to incorporate that way of thinking into the *quadrivium* and is probably the cause for the impressive progress in experimental science at Oxford. Robert Grosseteste (1175-1253), Oxford University's first Chancellor, believed that natural philosophy needed to be based on mathematics and experimentation. His observations and applications led him to write *Compendium Spherae* in which he discussed the spherical shape of all celestial bodies including the planets. From that same application Grosseteste realized that the calculations for the annual religious events were progressively off by a tiny fraction each year and suggested a reform to the Julian calendar. His theory came about through his observations of solar light diffusion and its ability to propagate itself instantaneously in straight lines without losing substance. From these he concluded that light had generated the universe. Such observations led Grosseteste to experiment and develop an interest in optics, considering them to be the key to understanding the physical world. He suggested the use of lenses for the purpose of magnification that pointed the way for later scientists to make microscopes and telescopes. The first known eyeglasses were made in the 1280s, but it is not really known whether or not Grosseteste's treatises influenced their making.

At any rate his fellow Franciscan and student was Roger Bacon, followed in the field of optics and experimental science, insisting that only through observation could an understanding of things be reached. Following Grosseteste's teachings he knew something about the microscope, and possessed an instrument very much like our telescope. This tube, he claimed, would make the most distant object appear near, and that it would make stars appear at will. As a natural scientist, he studied astronomy, chemistry and physics, but he was also a mathematician, logician and implicitly a theologian. In his *Opus Majus* he proposed a program for educational reform describing some of Grosseteste's experiments, the usage of lenses, and the reform to the Julian calendar.

The latter went unheeded until 1582, when Pope Gregory X realized that the existing calendar was ten days off and was making the calculation for Easter totally wrong. He agreed to absorb those ten days on October 5th, which became October 15th 1582. He further decreed that in the new calendar -- Gregorian -- leap years should only be those divisible by 400. This is the calendar we presently use to calculate time.

From many of Bacon's treatises it is evident that he knew the powers of steam and gunpowder and foresaw suspension bridges, diving-bells and flying machines. He would have put these to the test with enthusiasm but for the vigilance of his superiors who apparently thought he was dabbling in sorcery.

IMPROVEMENTS AND INVENTIONS

Water Mills

While philosophers and scientists were writing treatises, experimenting and discovering, other people were developing machinery for agricultural, industrial and military use and constructing secular and religious buildings that have lasted to our days. Improvements were made in ways to harness the water of the sea or fast flowing rivers to provide hydraulic energy for mills. Where rivers had slow flowing waters, dams were made to collect the water on one side. On the other side the community dredged the riverbed enough to place the waterwheel into it, to be powered by the water released from the dam. In coastal wetlands high tides were taken advantage of to power the mills. This meant that they only worked during the night hours. In some places where the riverbed did not have the necessary slope to power the mill and a steeper slope could be found the water was diverted. Water powered energy was so dependable that many machines were invented that would help reduce labor. One such machine was in iron forges where the water pressed the bellows enough to raise the heat high enough to melt iron. Another machine that had a lot of promise was the water driven clock. Its only problem was that in the latitudes where winters are severe the water froze, rendering the clocks useless for many months of the year.

Windmills

Where water was unavailable or undependable wind was harnessed. The same principle used in the Middle East was applied in Europe with one great adaptation. Instead of the asps turning horizontally they were made to turn vertically and gyrate around the tower in accordance with the prevailing wind. This largely Medieval innovation is still being used in many parts of the world (Gimpel 21).

Heavy Plow

Tools like spades and hoes used in agriculture were improved with an iron blade added to the cutting edge. By far the most far-reaching change in Medieval agriculture was the adoption of the heavy wheeled plow. It was a "formidable agricultural weapon, equipped with a colter cutting vertically into the sod, a flat plowshare cutting the grass horizontally at the roots, and a moldboard designed to turn the slice of turf. Its two wheels enabled the plowman to move from field to field and helped him regulate the depth of the furrows" (Gimpel 41). In the eleventh century this formidable machine was used to clear the forests and to cultivate vast new areas that had been avoided earlier.

Architectural Engineering

Construction of castles and churches is undoubtedly the area where we find the greatest amount of tangible proof of the advances made by Medieval people. Edifices were being made to reach the sky, and their architects vied with one another to build the highest one in Christendom. To this effect a few innovations had to be made to guarantee the stability of the construction. Foremost among them was the flying buttress, which strengthened the high walls and distributed the weight throughout the arch. That distribution of weight also permitted the inclusion of windows thereby solving the technical problems created by the desire to give maximum light to the churches while raising the vaults higher and higher. Another invention in the cathedrals was the complex system of passageways that were built into their fabric and sometimes reached no less than five levels. Gimpel feels that there were various reasons for making the passageways inside and outside the walls. They facilitated the maintenance of the roofs and the stained glass windows. Furthermore they could provide access to fire or escape from it.

Agricultural Engineering

One of the most interesting institutions of the Middle Ages was the economic empire based on a highly centralized administration created by the Cistercian monks, who set up model farms and opened up for agriculture hundreds of thousands of woodlands and wastelands by forest clearing, terracing, draining, and irrigation. Although not all were educated in the arts and sciences taught in Paris, Oxford, and Toledo, the Cistercian monks and engineer-architects made excellent use of the arithmetic and geometric information to innovate machinery and resolve structural problems. It was they who, through applied observation, calculation and experimentation, brought about conditions that improved spatial distribution in buildings, transportation, agriculture, economics, health, and the general standard of living for many.

There is archaeological evidence that flax was cultivated for linen cloth in the European wetlands of Sweden, Poland, and Switzerland as early as the Iron Age, and although linen was still a desirable cloth during the Middle Ages, wool had, by far, the greater commercial value at home and abroad. The textile industries of Flanders and Florence used tens of millions of woolen fleeces each year that England supplied, thanks to the efforts of the English farmers and monks of the Cistercian order who raised sheep, carefully breeding them to guarantee continued excellence (Gimpel 46).

Improved agriculture, transportation, industries, construction, commerce, and mining all required different degrees of numerical knowledge, and all of them were facilitated by the adoption of the Arabic numeral system that in its turn had been learned from earlier Hindi scholars. That and the reintroduction of the ancient abacus revolutionized the known mathematical possibilities. Arithmetic began to be applied in every conceivable area of human social operation and endeavor. The results crossed over into other fields of study such as astronomy, physics, chemistry, and medicine and back again.

Hindu and Arab scholars had long used geometry and mathematics to study the planetary system and its relationship with time. Therefore, it was no surprise when Western thinkers like Grosseteste began to use mathematics to investigate the phenomenon of light and its ability to propagate itself in straight lines and to deduce from it that optics are crucial toward the understanding of the physical world. His studies and observations made it clear that lenses would greatly enhance the possibility of detecting what the naked eye could not. As mentioned above, there is little doubt that his treatises were instrumental in leading later scientists to make lenses of different shapes and sizes to facilitate observations.

But the production of new machinery and the fascination with construction increased the need for the exploitation of wood, iron, and stone. Stone was quarried in ever increasing quantities and its transportation to the site of erection demanded better roads or, preferably, canals by which to ship it. The quarries left enormous great holes and tunnels throughout the land that had already been left bare of trees. Worse than that, minerals develop in different types of ores many of which are or contain toxic substances. When mining, these gases and toxic substances are released into the atmosphere or into the surrounding land causing it to become infertile for many years. Metals usually need to be separated from the ore through chemical procedures: silver needs to be submerged in large amounts of brine while gold is normally separated from its ore by being dipped into hydro fluoric acid. In both cases the substances that the metals are dipped in need to be disposed of somewhere. No matter where that place is, the ground will be rendered useless for an extremely long time.

All means of transportation--ships, carts, highways and bridges--required the use of wood. So did most of the interior features in the churches and castles. For everyday life in rich and poor homes alike, kitchens burned wood in the preparation of food for an ever increasing, relatively healthy population. So it was that wood was used to keep homes and public places warm for fireplaces--also a Medieval invention--had become very popular. Added to this daily dependence upon wood was the need to provide wood for the foundries of Europe that used enormous amounts to melt iron, copper, lead, and other metals. Trees were being cut down everywhere faster than they could grow. By the late 13th century the forest ecosystems of Europe had been transformed into wastelands. The authorities in different places made laws to control logging with little to no effect. In parts of Italy every citizen was obligated to plant ten trees a year, but in England the people refused to be deprived of lumber. Eventually wood had to be imported from Scandinavia at exorbitant prices that, of course, contributed to negative economic fluctuations throughout Europe.

ENVIRONMENTAL AND CLIMATIC CHANGE

A subject of great importance today is mirrored in events that occurred in the late Middle Ages and contributed to the end of that particularly spectacular period of progress: environmental and climatic change. There is evidence that for two or three hundred years prior to the fourteenth century major portions of the globe enjoyed a significantly comfortable warm period during which groups of people were able to increase their agricultural yields, improve their life styles and population numbers, congregate in urban areas and construct public buildings. The period is referred to as the "Little Climate Optimum," a time in which we see that the Anazasi Pueblo Indians settled and built their impressive edifices in the American Southwest, the Mixtecs in Southern Mexico thrived, and construction of cathedrals and castles in Europe was unprecedented and unparalleled. It is noteworthy that the construction in all three places halted in the 14th century when the climate turned colder and the populations plunged.

Just when the period called the Little Ice Age began is the subject of much debate. Some experts, perhaps the majority, place its inception as early as the 1200s while others believe it began around 1450 or even later. The disagreements arise because the phenomenon was not simply a giant cold snap. The cooling trend began at different times in different parts of the world and was often interrupted by periods of relative warmth. All agree however, that it lasted for centuries, and that the world began emerging from its grip between 1850 and 1900.

Climatic shifts or swings always leave their marks on human cultures and natural ecosystems. "With each climate swing, whether global or local, ecological communities shift north or south or are disrupted, leading to the creation of new groupings of species. Likewise, human cultures are uprooted and driven to more favorable locales, or people adapt by changing their technologies and behaviors" (Cutler). According to archaeological data it seems that in Western Europe and in

Southern Mexico the people changed their technologies and behaviors while in North America the populations appear to have been uprooted and driven to more favorable locales.

To claim that the climatic swing from warm to cold was the cause of the demise of the high Medieval period would be a glaring infraction in reading the evidence of events there for there are other factors that contributed to it. Among the factors is the gross and wanton depletion of forest resources carried out for over a hundred years of cathedral and castle building, increased reliance on heat energy for smelting of metals, cooking, and temperature control for their homes. Another forced ecological change was the clearing of wooded lands in preparation for agriculture and pasturage. Pollution of the waterways from different industrial and commercial wastes caused another lasting change in the ecological sphere. For all forms of life except bacteria and viruses it spelled diseases and possibly death. The problems became the source of many a discussion and effort to regulate the felling of trees and pollution of waters. Then as now many people considered the alarm to be needless and refused to heed any regulatory measures to detain the deterioration of the ecosystem.

While people were busy searching for solutions to these problems, others arose that kept them from making their regulations stick. First and most importantly was the series of extremely wet years that ruined one crop after another leading to widespread famine and death throughout Europe. The Hundred Years War began; it exacerbated misery and brought about much disruption of commerce, science, and construction. A third problem was the development of over-zealous religious movements that interpreted as heresy and sorcery any activities not clearly understood by the people in charge. The result of that movement was a reduction in intellectual experimental investigative pursuits.

Into this sad scene crept a silent surreptitious enemy the like of which had not been seen in the memory of any Europeans: a plague of unprecedented virulence called the Black Death. From Asia it had traveled to the Near East by way of caravans. From there it traveled by commercial ships to Europe where it arrived at Mediterranean Sea ports in 1347. It took the plague four years to disperse throughout the land but by the end of 1351 the Black Death had run its course. Although it is impossible to figure the plague mortality accurately there are some data that give an idea of its virulence. Agents for Pope Clement VI calculated the number of dead in Christian Europe at 23, 840,000 at the end of 1351. Compared to Europe's pre-plague population of about 75,000,000 this makes it a loss of about one third of the population (Gottfried 77).

It is very difficult to imagine a more terrifying and devastating series of events. Nor is it possible to understand how those who survived could have kept their equanimity and ability to go through the motions of social intercourse without feeling panic. Altogether the events of the fourteenth century brought about a tremendous series of social disruption and general breakdown of law and order. Because the plague did not honor social class, and mortality among the nobility approximated that of the general population, the social disruption was more damaging. That is due to the importance that proper patterns of inheritance had and land was no longer as valuable as it had been, but laborers were worth much more than before. As more tenants died, lords had to hire wage laborers to farm their lands and markets for foodstuffs collapsed as population decreased. Peasants benefited from high wages and by 1400 the old bonds of villeinage had loosened or crumbled, but not without a bitter struggle reflected in the popular rebellions which at first had political overtones and then, exacerbated by the depopulation of the Black Death, became increasingly socioeconomic in nature.

IMPORTANCE OF MEDIEVAL SCIENTIFIC AND TECHNOLOGICAL ADVANCES

For many Europeans the Medieval period evokes ideas of noble and heroic knights in armor, damsels in distress, jousting, romance, and evil sorcerers. The period has been, and continues to be, glorified in legends with romantic and mystical undertones. Without taking away the moral and ethical lessons presented in the legends or destroying a romantic view that sustains the imagination, it is necessary for students to realize that the period was real, and that it was the scenario of enduring human activity. The cultural historical evolution that occurred was the result of human perceptions and interactions in response to ecological, geomorphological, and climatic conditions in Europe over a period of more or less five hundred years. Added to these conditions were the cross cultural activities brought about by southward migrations of people from the Scandinavian regions, northward migrations by Islamic people from northern Africa, and the commercial interactions from the Orient via the Silk Road or the Mediterranean.

Equally important for students is their understanding that sooner or later excessive use of resources can lead to the deterioration of a population's social and economic structure. At the onset of the Medieval period there were large forested expanses in northern Europe which, by the 14th century, had been greatly reduced as a result of excessive logging to meet the demands of construction, energy for smelting, warmth and cooking. No longer was lumber available to kindle the fires for melting iron, lead, or tin. Neither were the logs large enough to sustain buildings of the same dimensions as before. Cooking and warmth had to be obtained from coal which, though efficient, brought with it pollution of the air and exacerbated pulmonary problems.

By teaching students to observe the natural world around them, to question facts in order to arrive at the truth, and to consider potential consequences before making decisions, I will have accomplished a very important goal for their future learning, and the well being of their society. These are skills crucial to science but also applicable to other academic areas.

Although my fifth grade students are yet young, they are awakening to and love reality when it is presented to them. They eagerly look around for evidence that the information they have learned is substantiated by reality away from the classroom setting. I encourage them to doubt what I have said and challenge them to come up with ideas of how to prove or disprove my teaching. In this way I find that I share in a very, very small way the philosophy of Abelard, Grosseteste, and St. Anselm. My unit will, therefore, be prepared to include information about scientists of the Early or Formative Middle Ages, some machinery used during the period, and the evidence of enduring cultural carryover into the New World: our world.

Much of the information can be incorporated into the lesson plans when I cover specifically required objectives. For example: the unit on Force and Motion can be enriched with data about machinery used or invented during the period between 800 and 1400 A.D. The same or similar information can be used when the unit on Energy is covered because some of the machinery made effective use of Aeolian or hydraulic energy. Mechanical precision and subsequent functionality greatly depend on the accuracy of mathematical and geometric application.

Of special importance for me is to teach them about natural and human-induced ecological changes when the objective about the planet Earth is covered. I feel that it is most important for them to know, for the sake of their civilization, continuity of life style and general security that in diverse parts of the world human impact on the ecosystems has resulted in enduring devastation and curiously, widespread disease. Among the parallels to be drawn from the effect that Europeans had on their ecosystem while in pursuit of progress are: the downfall of the Mayan civilization and the disruption of the Toltec way of life.

I selected these from among the many examples of devastated ecosystems because they represent the same mistakes made by the people from the new world long before contact with the Europeans. By realizing this students will understand the importance of mediating scientific discoveries, land and resource use, and satisfying the cultural ego with ever-larger statements of power. When they are older and take their place in the decision-making of their communities, I hope they will look back to their science classes and remember to consider all aspects and consequences before making their choices.

There can be little doubt that our society inherited an impressive and complex legacy from the Middle Ages, be it from England, France, Germany or Spain. Much of that legacy is worthy of admiration and respect. The open-mindedness that permitted philosophical questioning and thought from whichever corner of the world that it came from and the resulting scientific developments is one. Another is the recognition of the value and applic ation of arithmetic and geometry to astronomical observation and calculation. It was also admirably applied to the construction of buildings and machinery. The former exalted man's ability to create enduring beauty for the glory of God and the other reduced labor, eased the life of many, and increased productivity for all. The general well-being and dynamics of everyday life for many cannot be overlooked, as cannot be the sense of hygiene and sanitation during that period.

But there are lessons to be learned from the mistakes made by those people. Their obsession for construction of ever-larger churches and castles, beautiful as they are, forced large scale quarrying and logging. Improved agricultural and pastoral proceedings changed the life style of the people from subsistence to a surplus economy, but it also required large expanses of forestlands to be cleared. The new machinery used metals that needed melting down before reshaping to meet the required needs. The first had to be mined at great destruction of the landscape; the second necessitated large amounts of fuel, consisting of wood. Before two centuries of progress were over, the resources were much depleted and waterways and air densely polluted. Famine, pulmonary diseases, and religious and social unrest were the stage upon which the Black Death appeared in the middle of the fourteenth century.

LESSON I

Human Impact on Ecosystems

The most important objective in the Fifth Grade Science curriculum is Biology, although we call it Life Sciences. Off and on during the year we cover different aspects of it. One of those aspects combines with geography and geology, which we call Earth Sciences. In Earth Sciences the students learn about biomes and to consider the different types of fauna and flora that would naturally thrive in them. Of course, as we live in the Houston/ Galveston region, the lessons focus on coastal wetlands. For this lesson, which will take two or three 90-minute periods, I will draw upon the similarities between our coastal wetlands and those of Western Europe and Eastern England. The students will be expected to reflect on the impact that humans can have on the ecosystem.

There is a book called *The Saxons* which I will read aloud to my students as I show them transparencies of the excellent pictures within. It relates the way of life and culture of the early Saxons and their periodic bellicose incursions into England during the first millennium. I will explain that at that time there were a number of southward migrations from Northwestern Europe that seem to be related with increasingly inhospitable climatic conditions. As we read on, the students will realize that the Saxons settled in and became milder tempered when the "Little Climatic Optimum" made agricultural pursuits more dependable.

The next lesson will be about the Normans, a second group of people to invade England, although for different reasons. I will point out that regardless of the causes behind migrations they are always invasive and disruptive to the established society's way of life. The transparencies of the book's illustrations will provide evidence of how the Normans began to modify the landscape with their forts and castles. The Norman presence in England corresponds to the entire Medieval Period and their land management strategies were reflective of those on mainland Europe, especially France.

An activity that can accompany these two lessons will be to have enlarged topographic maps of Central Europe on which the students can trace events and natural resource distribution. The activity will involve the principal agricultural, mining, and industrial centers accompanied by the transportation of commercial goods to different markets and ports. The game will be played with dice that will determine the distance that a player must move. The direction will be established by cards that will specify type of merchandise being transported and its destination. The student must be able to plan his or her transport needs abiding by the topographic constraints.

Among the resources being transported will be timber, grain, bales of fleeces, iron ore, and stones that will be represented with miniatures. As the product is transported, it will also be removed from the board. That way the students will be able to notice the impact that their activities have on the non-renewable resources. They will also realize that although plant life is renewable some of it requires a relatively long span of time to revitalize. While it does, man must either do without or pay large prices to acquire it. What about the other creatures that depend on those plants for their survival? How many of those creatures did man depend on for his sustenance? Hopefully from this game students will realize the effect that human activity can have on their ecosystems.

LESSON II

Calculation of Time: Earth's Rotation and Its Orbit around the Sun

Not too long ago, after a lesson on the rotation of the planets and their orbits, one of my students wanted to know how we know a full year had elapsed. While I explained, two thoughts came to me: the first was to comprehend the magnitude of Grossteste's observations regarding the planets and light and the second was to realize that he must have built upon the knowledge of previous cultures from such centers as Stonehenge. Let me explain: On the summer solstice the sun's rays should shine on a given, unmovable space at sunrise. If one marks the exact place and then observes the sunlight every day one will notice that it will, following a circular pattern progressively strike a different place. Eventually (~365 days later) the sunray will strike the original space again. From this it is obvious that the observational process requires constancy, precision and many years to be able to establish any kind of theory that the beginning and the end of a year equals an orbit around the sun.

The unit on time keeping that I am proposing will be taught during five 60-minute periods during the month of January when the science objective about the solar system is taught. To begin the unit I plan to use a model of the Earth rotating on its axis and orbiting about the sun. After the students watch it long enough, I will ask them to draw a picture by which they could keep time by watching the Sun/ Earth relationship. All drawings will be acceptable and we could discuss how they would be or not be accurate. The next day I will begin the class showing transparencies of early man's intent to keep time and progress to the present. We will then compare the student drawings with those in the transparencies and discuss such concepts as rotations and orbits. When the discussion reaches a certain point, I will introduce propagation of light in straight lines and the resulting observation on the angles of insulation. That will take us back to Grossteste's observations about light and time.

For the next period it will be important for my students to read *Ancient Astronomy* by Isaac Azimov, a children's book that is not only comprehensive and unbiased, but well informed. From it I hope the students will learn that:

> ...all our knowledge of the Universe started with ancient people who looked at the sky and wondered. They did not have our instruments. They had only their eyes. Even so, they managed to study the objects in the sky, to observe how they moved, and to work out reasons for that movement. Our knowledge of the Universe began with these ancient astronomers. We could not have come as far as we have without their ability to get things going. (Azimov, prologue)

LESSON III

Making a Model of a Water Driven Grist Mill

One of the objectives to be covered during the fifth grade is Force and Motion. Being a child of the second half of the twentieth century, I have often thought of a cataclysm brought about by the enemy: whoever or whatever it might be. I have wondered if I were to survive, what skills would I have to begin life again. Would I know how to make a ceramic vessel? Would I really know how to make fire? What about machines? Would I be able to make any that would make my life and that of the other survivors a bit easier? Sadly I usually have to admit that there is precious little that I would be able to offer. Like so many of us, we know how to use the machines, but not so often do we know how to make them from nothing.

Students are quite blasé about machines designed hundreds of years ago, often referring to them as simple and disregarding them as obsolete. My intentions for teaching this lesson is not to humiliate the students, but to make them aware of the complexity of mind, calculation, and manual dexterity that went into such machines. Hopefully they will learn from those who preceded us and paved the way for us to have the machinery that make our lives so much easier than theirs. So, for next year I will have my students design and make a models of the most impressive innovations used during the middle ages: a water driven mechanism to make flour out of grain, a hoisting machine and a simple observation lens.

There is a very practical book called *Science Crafts for Kids* that my grandson gave me when he heard me talking about the need for a practical working model of a water powered grist mill. This model requires time and patience, but when the students are finished, they'll be able to see clearly one way that waterpower can be harnessed to do the work.

The list of **tools** needed to make the model are a jigsaw, medium grit sandpaper, a sanding block, 2 C-clamps, a pencil, a drill or brace and bit, a 1/4 inch drill bit, a ½ inch drill bit, a 1 inch expansion bit, wood glue, a ruler, a hammer, a flathead screwdriver, a can opener, and a crosscut saw. The **materials** include 2 by 2 feet of 1/4 inch plywood, 36 inches of 1/4 inch dowel, 11 inches of 1 inch dowel, 10 inches of 2 by 4 inch lumber, 10 by 6 inches of 1/8 inch plywood, 4 - ½ feet of 1 by 4 inch lumber, 13 inches of 3/4 inch doweling, 6 inches of 3 by 1 inch balsa wood, a 1 inch or 1 - ½ inch long wood screw with a flat head, a washer to fit the screw, 1 plastic washer, a large, empty tuna can, with both ends remove, 1 inch of 1- ½ inch plastic pipe or hose, several scraps of 1/8 inch plywood.

Usually we try to get parents to provide the materials, but we often get a motley assortment that may or may not be suitable for this project. The tools and the materials can be gotten from funds allotted for science. I will probably try to enroll the help of the fifth grade math teacher because the model requires that all the materials be measured and cut with accuracy, a fifth grade math objective.

In the interest of time and behavior management I will break the class into various groups with the assignment to make specific parts of the model. They will be required to come up with designs and measurements for the parts of the machine and to keep a logbook recording the procedures as faithfully as possible. The log must reflect the discussions held about observations, the ideas to improve, reports on successes, and suggestions about ways to overcome failures. When the parts are complete and acceptable we will begin to assemble the gristmill. This is likely to take a few days (60-minute periods), as the parts will need to dry and set.

When the gristmill is ready to be tried out we will take it to the school pond and turn on the water to see how well it works. The students may or may not be successful at creating the desired machine, but they will have learned many lessons. The first one will be to recognize the complexity of making a functional machine from nothing. A second one will be to discover the usefulness of applied mathematics and geometry in the creation of the machine. A third will be to recognize that the origins of the machines we use and are so proud of, are also improvements of previous people's innovations. Lastly, they will undoubtedly recognize the value of water as an energy source and an alternative to fossil fuels.

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