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Integrating Alternative Energy Production into the Public School Science Curriculum

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A Prospective Teacher's Watery Solution to the Perceived Insurmountability of Demanding Curriculum Requirements

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ABSTRACT

In the next few years, many teachers will be challenged in new ways. Student engagement will be at a premium and state standards will be more specific, shifting their focus towards college readiness, integration of curriculum, and developing sound reasoning and critical thinking skills. While the education field is accustomed to adapting and adjusting “on the go”, it may be ill-prepared for this fresh round of changes. Teachers and curriculum directors need resources to help them adapt the classrooms to reflect the more comprehensive design implied by the new standards (Next Generation Science Standards, 2012). This paper promotes a spiral water wheel design deeply rooted in history, engineering, and problem solving. The project detailed in the paper addresses the challenges listed above. It takes a project-based learning (PBL) approach, simultaneously affording students multiple opportunities to expand and strengthen their understanding of mathematics, science, engineering, history, and language arts concepts and skills; they also are introduced to hydrology and small scale sustainable energy. Also built in to the water wheel project are the ideal conditions for the development of logical thinking, problems solving skills, cause and effect relationships, and critical thinking skills. All of these elements are purposely embedded in the overarching project to prepare students and teachers for the future. It provides students with the content knowledge and scientific skills demanded of them by our future society. And it grants educational teams the freedom to integrate their required curriculum into a relevant, real-world challenge to enhance learning.

INTRODUCTION

With the problems facing today's (and soon, tomorrow's) teachers, engaging and relevant projects are needed to prepare students for a world that requires scientific thinking and logical reasoning. For most people, the words "alternative energy", probably conjure up images of solar panels, hybrid cars, and acres upon acres of wind turbines covering the California landscape. But there are many other forms of harvesting and transforming energy from nature that are often overlooked. If we continue to think that alternative energy comes only from the sun or wind, we will miss out on a wonderfully wet opportunity to use our streams and rivers as energy producers and educational tools.

This project does not aim to discuss large-scale, grid-feeding supplies of electricity harvested from the oceans and hydroelectric dams (Maczulak, 2010) although those are certainly wonderful things. It is turning the conversation toward the educational realm and highlighting the bountiful benefits of adapting a small-scale hydrology project for use in the modern classroom. To demonstrate this, a specific project has been chosen which consists of a stream-driven spiral waterwheel which pumps water to a pre-determined height for storage in large quantities. From there, the water can be used as irrigation, a water supply for livestock or as a means of powering a generator (Bonta & Snyder, 2008; Schumacher, 2000).

WATER AS ENERGY

Harnessing the power of water is an ancient practice. The weight of water has been employed as a driving force over wheels (or chains of cups) and around shafts for millennia (Miller, 1938; Sprague de Camp, 1963). The current produced by flowing streams and rivers can be used by a paddle wheel to also drive a shaft. And finally, water lifting devices such as the famous Archimedes screw are able to create head (or pressure from a vertical drop), which in turn avails itself to many applications.

Various forms of each of these devices have existed since the earliest civilizations. Since water was (and continues to be) an invaluable resource, it is not surprising that early peoples invented ways of managing, transporting, and utilizing the precious commodity. Aqueducts, such the well known Roman system, were a common occurrence in many communities (Kirby, Withington, Darling & Kilgour, 1956). They were used for two main purposes: fresh water supply and the preservation of elevation of water to create head in the city (Sprague de Camp, 1963). Archimedes developed his famous water-lifting screw in the 3rd century B.C. in order to lift water from low lying sources to irrigation canals, although some suggest it was accomplished up to a century before his time by Sennacharib (Hirshfeld, 2009; Dalley & Oleson, 2003).

The ability to use water as an energy source has been marginalized in many parts of the country (Saavedra, 2011). For Michigan, set in a region with abundant water resources, this is a shame. There are a many large-scale projects in place (think hydroelectric dams, tidal turbines and wave-driven generators) to convert the kinetic energy of water into mechanical or electrical energy (Maczulak, 2010), but they do not garner the same level of attention as solar and wind power projects (Root, 2011), especially in the Midwest. Consequently, the positive buzz, press time, and available research dollars do not typically fall to those with “water on the brain” (Robertson, 2012). And since the ingenuity of today’s best minds seems to be aimed at nuclear energy, until the Fukushima tragedy in Japan in March, 2011 (Conant, 2012; Macalister & Harvey, 2012), and long-range electric car batteries (Berman, 2011; Brandon, 2012; Levitan, 2012), it is unlikely that hydro power will be making a large splash in the scientific community in the near future. However, there does exist a small, vibrant community of micro-hydro stalwarts that remain committed to their craft and area of expertise—low head, low flow hydro power. But that is okay. This project is not trying to turn the world of science around either. The discussion will turn from the scientific side of the issue for a brief dip into the history of the specific spiral design, and then dive into a few problems facing today's public education classrooms.

HISTORY OF THE SPIRAL WATER WHEEL

Invented in 1746 in Switzerland by H.A. Wirtz, the spiral pump, which created pressure to deliver water farther than the reach of the machine itself, is a *relatively* new development in the water lifting quest (Tailer, 1986). The earliest spirals were turned by human or animal power (Kirby, Withington, Darling & Kilgour, 1956; Miller, 1938). They were effective for lifting water, but were not as efficient as the up-and-coming steam engines being developed. The Wirtz pump (or spiral pump) soon became obsolete. Peter Tailer, former curator of the Windfarm Museum in Martha's Vineyard, MA, uncovered a few technical writings from the nineteenth century that described the Wirtz pump, and recreated (and improved) the efficient design in his farm in Massachusetts. Peter Morgan of the former Blair Research Laboratory (now the National Institute of Health Research in Zimbabwe) also constructed a similar spiral wheel in the 1980's. He is largely credited with rediscovering and publicizing the spiral pump (Tailer, 1986).

PERSONAL INTEREST IN THE SPIRAL WHEEL AS AN EDUCATIONAL TOOL

Although the spiral water wheel is not an obsolete technology, the concept has not been heavily utilized by scientists or even small-scale hydrology engineers until recently. An article written by John Hermans surfaced in an Australian magazine called Earth Garden (Hermans, 2003). The online publication summarized his project and described a spiral water wheel he constructed for Jill Redwood, a staff person at Earth Garden Magazine. It piqued my curiosity four years ago, and I was not able to think of my upcoming (some would say looming) honors thesis without wondering if the spiral water wheel was destined to become my own project. Merely building the wheel did not seem to satisfy my desire to create a truly meaningful thesis. So I began to think of ways I could marry the excitement and enthusiasm I had to embark on the construction project with another passion of mine: education.

The conclusion was reached. The study could head in two related yet distinctly divergent directions; it could provide a primarily technical analysis of the variables affecting the efficiency and output power of the wheel, or it could be concentrated on designing a plan for implementing a similar project into the classroom. After reflection upon the perceived difficulties teachers will face in the coming decades, I chose to take the path more closely related to my profession, and more relevant to my peers.

PROBLEM-BASED LEARNING AS A SOLUTION TO THE PROBLEMS AND CHALLENGES FACING TEACHERS

There are numerous systemic problems facing our educational system, as anyone keeping up with the times can recount, but this paper does not aim to lay blame or point fingers, for many of them are out of the control of teachers. The public perception of teachers and schools has been faltering (Peterson, 2009); standardized tests, along with the copious amounts of classroom preparation time required and anxiety associated with them have invaded the school and robbed students of valuable learning experiences; and bad teachers are allowed to continue to influence the minds of children due to a heavily flawed tenure and incentive programs. These issues are largely out of the individual teacher's realm of control and even influence.

Here, the challenges individual teachers can address themselves will be spelled out, and a clear, simple solution will be offered. PBL is certainly not to be received as a silver bullet, or as an exclusive remedy. However, it *is* meant to address the multiple difficulties within the classroom that teachers are able to overcome (science curricula in particular). Therefore, the magnitude or breadth of these select problems should not detract from the simplicity of PBL and the spiral wheel project. The troubles discussed are challenging both in a general sense (facing most teachers in the country) and at a more specific level (pertinent to secondary science teachers in the next decade).

Compartmentalization

Science, math, history, economics, writing, research, and all other topics of study must be taught in a seamlessly integrated fashion if there is to be hope for a better world for our posterity (Hmelo-Silver, 2004). One cannot be a productive member of society and lack proficiency in any one of the aforementioned topics. That is not to demote anyone who is not a scholar by “trade”. It simply is meant to convey a sense of urgency about the fact that our students need to be taught all subjects in conjunction with each other. The compartmentalization of our students’ education should not be the method of transmission of knowledge from one generation to the next. In other words it is imperative educators (and society members, at the most basic level of responsibility) choose to transfer content to our future generations in a fully integrated way.

Problem based learning (PBL) is a way to accomplish this. The main premise of PBL is to embed curricular content into the context of a real-life “problem” or project (Hmelo-Silver, 2004; Ronis, 2008). As students work out possible solutions to the problem, they learn the appropriate content from math, science, social studies and language arts. It avoids the segregation of subjects in school, and centers the focus and learning of students on a relevant issue (Ronis, 2008). While students are learning the core content for each topic, they are also developing critical thinking and reasoning skills which are not often found in other methods of instruction (Kek & Huijser, 2011). The benefits of PBL are well-known and widely accepted, yet many teachers still balk at the idea of transitioning into “PBL mode”, largely due to unfamiliarity with the process. So here's an example of what problem-based learning can look like in a classroom.

The topic of bird migration is used as an example. As birds travel, they encounter several problems. They require food, water, and places to rest (not to mention a good tail-wind). So analyzing migration and feeding patterns, building feeders and houses, and observing birds in the field are just a few components that could be utilized in "solving the problem(s)". Geometry, measurement, and cost analysis could be the focus of a bird feeder building lesson. Bird watching could involve studying local, regional, and national geography; and the careful analysis of land use and climate maps would be useful for determining migration patterns. Students could be easily guided to write both technical and narrative compositions during this unit, which is a difficult task in a traditional curriculum. Conservation and other character development lessons can be easily embedded, and technology skills are able to be sharpened as an integral part of any lesson. As it is well known and documented, PBL does not require the lines between content areas to be blurred. The subjects are still distinct, just presented in a meaningful and realistic relationship with each other. And due to the real world context used for each unique problem, PBL promotes a high level of engagement (Downing, Ning & Shin, 2011), which is something our students desperately require. This is another present challenge teachers must face.

Engagement

There is a great need to captivate the minds of students. Everywhere a child turns there is a new, exciting distraction. It could be an advertisement, a video game, the TV, or hopefully (yet rarely), their teacher's next lesson. More than ever, children (and parents!) expect to be entertained (TIME, 2005; Kroll, 2006). They demand fun, exciting activities and refuse to be satisfied with anything that does not make them feel as though they are playing a game or learning something about themselves. It can *easily* be argued that the American society is becoming increasingly self-centered, yet no matter the theory for the cause of this shift, it is not possible to argue that teachers should be the ones to "turn us back" to a simpler way. Teachers must reach each student where they are, as opposed to creating a well-intentioned, but detached and irrelevant lesson. They *must* be entertaining (in a way) in order to reach the students of today.

Unfortunately, many science lessons are *un*inspiring and *dis*engaging for both teachers and students (Thornton, 2003). Without using PBL or a similar method, teachers who are widely viewed as the experts in "learning," have delivered instruction to students via a relationship that promotes isolation. Boring facts, abstract laws and theories, and unimportant concepts are currently being taught as best practice, and that should not be the case. PBL addresses the issue of engagement by providing real-world problems. Curricular content is connected with realities that exist in the lives of students, and activities become a much more effective teaching tool.

Consider the goal of science education. We aim to foster a healthy and rich environment where students can grow and develop into responsible citizens in our society. More precisely, we wish for our students to graduate with a certain degree of science "literacy." Not only do we expect them to have a knowledge and appreciation for the processes of science, we want them to reason logically, think critically, and process the world scientifically so they *become* the most valuable and productive members of our society (NGSS, 2012). If we truly hold ourselves to those standards, we will reach the conclusion that the "old" method has got to be kicked to the curb! The teacher must become the guide, and the students must be engaged at all times in a meaningful task.

The Future of Science Education

As the goals of science education are considered, it becomes even more crucial to have an engaging curriculum plan in place as the Next Generation Science Standards (NGSS) are put into practice in the next few years. The new educational standards shift the emphasis of instruction to integrate engineering design and scientific inquiry processes in a much more fluid manner. This will require students to demonstrate, apply, and understand concepts as well as processes, as opposed to memorizing decontextualized facts (NGSS, 2012). The notion of crosscutting concepts is also included in the new standards, which means that students will be explicitly taught to think and work in ways which are adaptable and appropriate across the sciences. This will give them the skills necessary to process and act scientifically in the professional world.

The following is an excerpt from the *Framework* put out by the National Research Council as part of their specific plan for engineering design and technology standards:

> *In some ways, children are natural engineers. They spontaneously build sand castles, dollhouses, and hamster enclosures, and they use a variety of tools and materials for their own playful purposes. Thus a common elementary school*

activity is to challenge children to use tools and materials provided in class to solve a specific challenge, such as constructing a bridge from paper and tape and testing it until failure occurs. Children's capabilities to design structures can then be enhanced by having them pay attention to points of failure and asking them to create and test redesigns of the bridge so that it is stronger. Furthermore, design activities should not be limited just to structural engineering but should also include projects that reflect other areas of engineering, such as the need to design a traffic pattern for the school parking lot or a layout for planting a school garden box.

Middle school students should have opportunities to plan and carry out full engineering design projects in which they define problems in terms of criteria and constraints, research the problem to deepen their relevant knowledge, generate and test possible solutions, and refine their solutions through redesign.

High school students can undertake more complex engineering design projects related to major local, national or global issues. Increased emphasis should be placed on researching the nature of the given problems, on reviewing others' proposed solutions, on weighing the strengths and weaknesses of various alternatives, and on discerning possibly unanticipated effects (p. 70).

This gives a more detailed glimpse of the changes we can expect in the classroom in the coming years, and the traditional fact-conveyance methods of most science curricula will not be suffice. PBL is a way to seamlessly integrate engineering and design concepts in science. These two content areas are rarely addressed in the standard curriculum, and integrating them with the rest of science education via PBL would be a much more efficient way of including them in classrooms as opposed to creating new, separate content areas. PBL's reliance upon critical thinking and reasoning as learning tools for any all content aligns effortlessly with the goals and standards set forth by NGSS.

THE SPIRAL WATER WHEEL AS A PBL TEACHING APPROACH

Not only do teachers have the challenge of captivating the attention of their decreasingly attentive students, but they must also compete with the draw of highly entertaining social life students have, such as video games, sports, and computers. On top of that, they must evaluate their own teaching methods in light of what is now becoming known as best practice (inquiry, active learning, hands-on/minds-on, PBL, etc.). Many teachers balk at the idea of "straying" from what is traditional, deviating from the norm, or even teaching difficult content. With the advent of increasingly popular guaranteed curricula, teachers and especially students are allowed much less flexibility or room for creativity in the classroom (Robinson, 2006). And as if teachers need more on their plates, the state standards are becoming more career- and college-readiness oriented, which requires a substantial paradigm shift for most of them.

In response to the challenges currently faced by today's teachers, and the difficulties coming in the next few years, I have designed the spiral water wheel project to be fluidly adapted to a classroom utilizing PBL and the new state science standards. It is a project that could be used in middle school or high school, as it could fit into either classroom model listed above. There are history connections with Rome, Syria, Egypt, and Europe in general.

Circumference, diameter/radius, volume, angle measurement and so many other concepts can be used to teach math. More advanced principles such as Pascal's law, Boyle's laws, and complex ratios between variables can be analyzed in a more advanced class. The project also addresses the critical thinking and engineering aspects of the new standards much better than before. Students could create a budget and record expenses and deductions as they build the project. It is also possible (and entirely appropriate) to challenge students with different aspects of the wheel construction by presenting deeper-level questions in a classroom or community-wide discussion so students are well prepared for life, college, and the standardized tests.

Implementation and Concept Development

This chart is provided to demonstrate how far-reaching a PBL lesson can be. Content concepts are listed and practical implementation within the water wheel project is given for each topic.

Topic		Activity
Math	Angle Measurement	▪ Students analyze the number of spokes as a variable affecting the speed of the wheel. ▪ Layout during construction addresses the angle at which the paddles contact the water.
	Area	▪ Students analyze the size of the paddles as a contributing variable.
	Cost Analysis	▪ Students work within a budget and prioritize needs within the project. Or students debate trade-off between quality and price and plan accordingly. ▪ Students calculate energy bill savings if an average home used a spiral wheel well to supply all of its non-potable water. ▪ Students discuss why large-scale spiral water wheels are not used to produce the world's power.

Science	Hydrology	▪ Students examine relationships between elevation and water table height. ▪ Students analyze the water cycle and the transfer of energy within the system.
	Renewable Energy	▪ Students are introduced to a form of clean, renewable energy.
Social Studies	History	▪ Students explore ancient or modern history using water use as a theme.
	Geography	▪ Students analyze maps to determine appropriate installation locations for spiral water wheels.
	Ethics	▪ Students discuss and debate the ethics of using non-renewable and renewable energy sources.
	Economics	▪ Students research the dependency of modern economies on domestic and foreign energy sources. They will compare the value of small- and large-scale energy production.
Language Arts	Writing	▪ Students write technical reports using data from investigations. ▪ Students write evidence-based research articles related to renewable energy. ▪ Students write creative personal narrative describing the process of construction of the wheel.
	Presentation	▪ Students write a persuasive speech about a controversial topic related to the project such as, "Should we continue to use non-renewable sources of energy for fuel?"
Technology	Renewable Energy	▪ Students are introduced to a personal application of renewable energy. ▪ Students research other forms of small-scale renewable energy sources.
	Computer Skills	▪ Students create a blog to communicate progress. ▪ Students produce documentary movies about the progress of their project.

CONCLUSIONS

There are many challenges facing today's teachers. Capturing students' attention with engaging activities, integrating science and other content areas to imitate the diversity of real-world problems, and the ever-changing and demanding curriculum requirements combine to make effective teaching strategies a highly sought after commodity in the education field. These challenges also behoove existing educators to adapt their instructional practice, that they may continue to be most effective in the future. Problem-based learning is one effective and innovative way teachers can address these issues in their classrooms.

While there are many angles one could take to remedy the challenges teachers encounter, *this* project will enable *teachers* to develop students into the creative designers, collaborative workers, and critical thinkers our world needs for the future. Students will be actively engaged in valuable learning experiences. Science education will no longer be disconnected from other areas of study. Most importantly, schools will be producing exemplary citizens with the proficiencies required to serve as contributive community members.

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