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# Review Articles

## Stem Cells: a Scientific, Ethical, and Political Overview

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### Abstract

Today, the issues surrounding stem cells (SCs) are no longer confined to the scientific community. The future applications and uses of SCs will also be shaped by decisions made within the general public and in the halls of government. Because the involvement of citizens will play a major role in these issues, a basic understanding of SCs and related issues is needed by the public. However, the sheer volume of published work on the topic is so great that it can be daunting for readers to easily gain an understanding. This paper recognizes that challenge and addresses the ethical and political concerns surrounding stem cells in addition to covering the scientific basis. We hope that educators interested in incorporating elements of civic engagement in their curriculum and those with general interest will find this paper useful.

### Introduction

At the dawn of this century, advancements in science and technology have made us more capable than ever before of shaping our world and controlling the outcomes of our future. However, with new powers in hand, we must

seek to understand and accept the responsibilities that accompany such progress. Today, human societies worldwide are confronting 21st century issues of how to utilize these new advancements, issues -- like those of our approach to the application of stem cell research -- that have global and long-term implications. SCs possess great potential to generate cures for countless human diseases, but there is a chance that unlocking the power of SCs may result in atrocities, in the authors' view, particularly in the process of procuring human embryonic SCs (hESCs). Because SC issues affect all members of a society, decisions related to the use of SCs should be collectively made by members within that society; there must be civic engagement if we are to make informed decisions relating to these issues.

In light of the explosion of publications on the topic of SCs, this paper offers a multifaceted overview examining the intersecting scientific, ethical, and political aspects of SCs. The information presented in this paper was taken from various reviews and research articles. Here we provide a basic synopsis of what SCs are along

with some of their current and future clinical applications, and present SC-related ethical and political concerns.

## Science of SCs

Since their discovery in 1963, SCs have held the potential to revolutionize the field of medicine. Unfortunately, through the last half century, the true potential of SCs has remained largely latent. In recent years, however, technical and scientific advancements have placed scientists at the edge of unlocking the full range of SC applications. The study of SCs has blossomed into a rapidly developing field, attracting numerous scientists and promising to radically redefine medical treatments of human diseases.

### What Are SCs?

Within a living organism, SCs are believed to form the cellular basis for organ homeostasis and repair. Although SCs are pursued by scientists due to their ability for self-renewal and for producing daughter cells that can differentiate into one or multiple cell lineages, identifying a SC is not an easy task.<sup>1</sup> There is no quick and easy approach to identifying whether or not a cell is a SC. However, there are three basic morphological and functional traits that are common among many varieties of SCs. Morphologically, most SCs are visually undifferentiated, meaning that they do not possess the appearance of a cell specialized for a specific task. In terms of function, SCs have an indefinite potential to divide symmetrically, to self-duplicate, throughout the life-span of the organism. In addition, SCs can also divide asymmetrically to give rise to differentiated cells. When a SC divides asymmetrically, the result is

one undifferentiated and one differentiated daughter cell. The undifferentiated daughter cell remains a SC, while the differentiated daughter usually becomes a progenitor cell, an intermediate between SCs and terminally differentiated cells. It is the progenitor cell that undergoes cell division to produce terminally differentiated daughter cells such as skin cells, muscle cells, red blood cells, etc.<sup>2</sup> In addition to these main characteristics, scientists have also been able to rely on cell surface markers to identify SCs and even to distinguish among their subclasses in some cases.<sup>3</sup>

SC researchers usually don't have to identify and isolate their own SC samples; rather, they can obtain samples from existing SC lines. A SC line is a population of SCs with the same genetic makeup that is maintained and grown in culture. This is possible due to SCs' potential for unlimited symmetrical division in the laboratory environment.

### SC Types

All SCs have the ability to produce differentiated cells, but the range of cell lineages to which a SC can give rise differs from one type of SC to the next. There exist terminologies to distinguish this ability in SCs, ranging from totipotent to unipotent SCs.<sup>4</sup> In presenting these SC types, the human model is used to provide examples. Although these types of SCs also exist in other mammalian species, the developmental timeframes will differ.

- *Totipotent*: Only the fertilized egg and the embryo prior to the eight-cell stage can be considered totipotent, capable of

differentiating into all cell types found in embryonic, fetus, and adult developmental stages.

- *Pluripotent*: Past the eight-cell stage, the potency begins to be restricted and the SCs are referred to as pluripotent. Pluripotent SCs can still differentiate into most cell and tissue types, but they lack the ability to form certain tissues found in early fetal stages of development such as placental tissue.
- *Multipotent*: From two to twelve weeks after fertilization, each germ layer gains its own multipotent SCs. Multipotent SCs are more restricted in potency than either totipotent or pluripotent SCs, but they can still differentiate into multiple cell and tissue types.
- *Unipotent (Progenitor cells)*: The most restricted of SCs are unipotent SCs. These tend to be somatic stem cells (SSCs), SCs found in the adult body that can only differentiate into one specific lineage of differentiated cells.

In addition to classifying SCs according to their potency, they are also classified according to their source. To date, most SCs can be classified as either embryonic SCs, somatic SCs, cord blood SCs, placental SCs, or amniotic SCs.

#### *Embryonic SCs (ESCs)*

ESCs are derived from a blastocyst, a five to seven day old embryo. Within the blastocyst, there is the inner cell mass which is a cluster of pluripotent and undifferentiated cells, ESCs. Unfortunately, the procedures used to gain access

to the inner cell mass often result in the destruction of the embryo. This has created an ethical controversy when scientists are dealing with human ESCs (hESCs). In addition, controlling an ESC's direction of differentiation can be quite a challenge with current, incomplete knowledge of the mechanisms regulating its differentiation. Furthermore, ESCs have also been known to cause tumors in mice<sup>5</sup>; it is not clear whether they have the potential to do the same in humans.

Despite the controversy and technical difficulties, many scientists still support hESC research. Due to their pluripotent nature, hESCs are believed to have more potential for medical treatments than any other type available.<sup>4</sup> Although *in vivo* hESCs only exist during a small window of time in the five to seven day old embryo,<sup>6</sup> *in vitro*, under the right nutritional and growth conditions, ESCs can self-replicate indefinitely, and in theory, can be manipulated to give rise to any differentiated cell type found in the adult organism.

A cloning technique called somatic cell nuclear transfer can be used to create ESC lines. The technique involves transferring the genetic material of a normal body cell into a denucleated oocyte, an egg cell. As the resulting embryo develops, ESCs that have identical DNA to that of the body cell's donor can be harvested from the inner cell mass. This process, referred to as therapeutic cloning, can be used to create hESCs that match the patients' DNA, thus eliminating immunogenic complications. However, the same cloning technique can potentially be used for reproductive cloning, creating a human clone.

This concern has further added controversy to the potential application of hESCs.

#### *Somatic SCs (SSCs)*

SSCs are also known as adult SCs or tissue specific SCs. These unipotent or multipotent SCs are derived from ESCs and are present throughout an organism's lifetime within its organs and tissues. Because many tissue types have their own SSCs, SSCs are also referred to by tissue specific names such as hematopoietic SCs (HSCs), mesenchymal SCs, peripheral blood SCs, periosteal derived SCs, etc. With tissues such as skin or tissues in the intestinal tract which have high rates of cellular turnover, there is a rationale for the persistence of SCs into adulthood. However, even in tissues not known for their regenerative abilities (such as heart and brain tissue), the presence of SCs has been proven through isolation, subsequent growth, and differentiation in culture.<sup>3</sup> In fact, SSCs have been isolated from many tissue types, ranging from bone marrow to peripheral blood, cornea, retina, dentine, liver, skin, gastro-intestinal tissue, and even hair follicles.<sup>7</sup>

Unlike ESCs, which most scientists are confident have the ability to differentiate into any cell types of the adult organism, for decades the multipotent SSCs were thought to be limited to just the cell lineages present in the tissue in which they were found -- thus the name "tissue specific SCs." However, since 2001, the validity of this notion of lineage restriction in SSCs has been challenged. Research showing neural SCs differentiating into blood cells, skin SCs to brain cells, brain SCs to heart cells, etc. strongly suggests that SSCs have

greater potency than was originally thought and that they possess the capability for transdifferentiation (the ability for a SSC isolated from a particular tissue type to give rise to a cell lineage native to a different type of tissue).

Nevertheless, for many scientists, SSCs still cannot be placed on an equal footing with ESCs. SSCs' potency, though greater than what was originally thought, is still more restricted than that of ESCs, and skepticism remains over the functionality and sustainability of the transdifferentiated cells.<sup>3</sup> Furthermore, SSCs exist in minute quantities. For example in human bone marrow, HSCs (a type of SSCs) account for a mere 0.01% of all the cells.<sup>8</sup> A lifetime of environmental exposure is also believed to make SSCs more prone to DNA errors, and thus less effective than ESCs.<sup>9</sup>

#### *Cord Blood SCs*

Traditionally classified as a medical waste by-product, today umbilical cords have become a rich source of SCs. SCs extracted from umbilical cords are known as cord blood SCs. These are believed to be the forerunners of the hematopoietic system and, similar to some SSCs, they are multipotent.<sup>10</sup> In contrast to ESCs, cord blood SCs are not clouded by an ethical controversy, and their cost and accessibility are far more favorable than those of ESCs and SSCs, which means they have some clear advantages over both ESCs and SSCs.<sup>11</sup> Cord blood SCs are also less immunogenic, which helps minimize complications in engraftments.



### *Placental SCs*

First isolated by Taiwan's National Health Institute in January 2005, placental SCs were described as a new SC type somewhere between ESCs and SSCs.<sup>12</sup> Now, the placenta has become a source for both epithelial and mesenchymal SCs. Both types of placental SCs express ESC surface markers indicating that they might be pluripotent. In fact, placental epithelial SCs have demonstrated the ability to differentiate into cells with lineages from all three germ layers. The immunoregulatory properties of placental cells that allow them to evade the mother's immune system have also made them particularly interesting in the context of clinical applications.<sup>13</sup>

### *Amniotic SCs*

The recent discovery of amniotic SCs in amniotic fluid by researchers at Wake Forest University and Harvard University was announced in January 2007. So far, these SCs have shown capabilities to differentiate into several tissue types including brain, liver, and bone. The researchers believe that amniotic SCs hold much potential, but human preliminary tests are still years away.<sup>14</sup>

## **SC Clinical Applications**

The clinical use of SCs is not new. In fact, HSCs from bone marrow have been used over the last forty years in bone marrow transplantation to treat leukemia, lymphoma, and other blood disorders.<sup>15</sup> However, despite SCs' long history of clinical application, the types of SCs in actual use have remained relatively static over the last half a century. Currently, only SSCs and cord blood SCs are utilized for medical treatments in

human patients. Other SCs types are either too new or their applications are hindered by socio-political concerns. Techniques for isolating and growing hESCs *in vitro* were only possible by 1998, and it would not be until August 9, 2001 that the U.S. government began funding hESC research.<sup>9</sup> These and other factors have kept the SC repertoire available for treatments limited to mainly HSCs, mesenchymal SCs, and more recently cord blood SCs. Nevertheless, through tissue engineering, cell therapy, and gene therapy, novel uses for these few SC types have been and continue to be discovered.<sup>10</sup> With cord blood SCs alone there are now over forty current medical applications.<sup>16</sup> Therefore, the listing below is only meant to give an impression of what is and might be possible with SCs and is not in any sense exhaustive.

### *Current Applications*

- Blood - HSC derived red blood cells may be used for transfusion in individuals with rare blood types.
- Cardiac SC therapy - Over the past few years, hundreds of heart patients have received direct injections of SCs with the belief that the SCs would differentiate into and regenerate heart tissue.<sup>17</sup>
- Skin - Skin can be grown *in vitro* for grafting from keratinocytes -- skin SCs obtained from a hair follicle.<sup>18</sup>
- Orthopedics- In the field of orthopedics, bone, cartilage, and muscle tissue grown *in vitro* are used to treat a wide range of problems. These problems include critical bone defects and non-union, cartilage repair, spine fusion, muscular



dystrophy, anterior cruciate ligament reconstruction, and intervertebral disc degeneration.<sup>19</sup>

- Dendritic cells- Dendritic cells are specialized immune cells derived from bone marrow SC. Clinical trials have shown that these cells have the ability to counteract the immunosuppressive effect of tumors, making tumors vulnerable to the body's immune system.

#### *Future Applications*

- Orthopedics - SSC therapy has been successful in mice leading scientists to believe that spinal cord regeneration might one day become a possibility for human patients.<sup>20</sup>
- Neurodegenerative diseases - Cell therapy with hESCs is also believed to have the potential for curing many neurodegenerative diseases such as Alzheimer's, Huntington's, and amyotrophic lateral sclerosis.
- Type I diabetes - In early April 2007, preliminary human trials have shown promising results that SSCs can be used to treat type I diabetes.<sup>21</sup>

### **Ethics of SCs**

While SC research has the potential to develop cures for many devastating degenerative diseases such as Alzheimer's, the debate over whether this type of research should be done is far from being settled. Of all the SC types, hESCs in particular seems to have become ethically controversial, because the process of deriving hESCs requires the destruction of a human embryo (but see next

section).<sup>22</sup> Therefore, for the general public and government officials the great divide in this controversy is how these laboratory embryos should be perceived; as human life or as clumps of cells which can be used as cures for diseases.<sup>23</sup> Additionally, the SC issues have also expanded into other areas such as the exploitation of women,<sup>24</sup> research fraudulence,<sup>25</sup> and proposed solutions to ethical concerns.<sup>26</sup>

#### **Life or Not?**

An example of the controversy over whether a laboratory embryo qualifies as human life was seen in August 1999 when the National Association for the Advancement of Preborn Children (NAAPC) challenged the National Institutes of Health's (NIH) policies in the Mary Scott Doe case at one of California's district courts, arguing that embryos were "born" in the U.S. and thus deserved rights. The NAAPC's objective was to argue that the laboratory use of embryos violate rights given to those embryos by the Thirteen and Fourteenth Amendments and ultimately to prevent the passing of California's Proposition 71, which would provide state funding for hESC research. Though the case was eventually dropped when NIH policies were changed with the election of President George W. Bush,<sup>23</sup> this legal incident does demonstrate a belief that early stages of human post-fertilization development do merit rights and respect because they are "symbols of future human life."<sup>27</sup> There is of course a consensus that human life should be respected, the real dispute in the ESC controversy is whether the laboratory embryos used in SC research truly qualify as human life or, more specifically, as human embryos.<sup>23</sup>

For now, differing values and beliefs frame this issue,<sup>25</sup> and science itself has no clear-cut answer. Legislators in many countries tend to rely on scientific understanding to help them formulate laws concerning SC research, but because science has yet to establish any clear criteria concerning what qualifies as an embryo, legislation often varies from nation to nation. While the Human Fertilization and Embryology Authority in the United Kingdom defines an embryo as a two-cell zygote, Spanish laws maintain that an embryo is a fertilized egg after the fourteenth day of development.<sup>27</sup> In addition, religious institutions often have their own stance of this issue. For example, the Roman Catholic Church contends that human life begins at the point of fertilization.<sup>28</sup> Members of the general public tend to rely on personal values, which often include both religious values and personal scientific understanding, to construct their view on this issue.

This conflict of values has divided people worldwide into groups of proponents, opponents, neutral, and undecided about questions of allowable hESC research. Proponents, who either believe that laboratory embryos are not alive or that although they may be alive the benefits merit their use, often emphasize the therapeutic benefits that might be derived from hESC research. Proponents of hESC research have also used science in an attempt to prove that laboratory embryos are not true human embryos but rather “quasi-embryos” or “lab artifacts” by pointing out some characteristics of these embryos that are different from natural embryos such as the lack of uterine implantation or the lack of asymmetric

division in the stem cells derived from laboratory “embryos.”<sup>22</sup> Even the media have been criticized for being biased, taking the proponent side by focusing on “personal interest” stories that glorify the potential benefits of hESC.<sup>29</sup> Opponents, who view that the embryos currently used in laboratory experiments are indeed human lives, question the morality of the instrumental use of those embryos. Then, there are those who have chosen to remain neutral on the topic. Some neutrals have offered views on what might qualify as an embryo without openly supporting or opposing stem cell research.<sup>27</sup> However, due to the ethical complexity and the scientific ambiguity associated with hESC research, many are still undecided for a variety of reasons. Some believe that this situation will remain at a standstill because “personal or religious values and scientific arguments are mutually separated.”<sup>23</sup>

### **Dishonesty in Research**

In 2004, when Hwang Woo-Suk reported in *Science* that he had successfully cloned hESCs,<sup>25</sup> it seemed as though South Korea was now at the leading edge of SC research. This was a scientific breakthrough carrying the promise that in the future, custom-made stem cells could be created to match the patient’s genetic makeup. By November 2005, however, evidence was presented that proved Hwang’s results were fabricated; in fact, at least nine of Hwang’s alleged eleven cell-lines never existed.<sup>25</sup>

In response to such fraudulent behavior from the researchers involved in the Korean scandal, fraudulence in research has since become a major

concern in the field of SC research. To some observers, it appears that certain conditions within the scientific community such as the lack of public oversight in research, the overwhelmed peer-reviewing process, and the publishers' general demand for ground-breaking research are all factors contributing to a conducive environment for fraudulent research.<sup>25</sup>

### **Exploitation of Women**

While the role of the embryo has traditionally taken center stage in this hESC controversy, the welfare of women involved in the process has often been neglected.<sup>29</sup> However, in recent years this trend is changing, and especially after the Korean scandal, renewed and unprecedented attention has been brought to women and their role in hESC research.<sup>30</sup> To some, the conduct of the Korean researchers in obtaining oocytes from women was seemingly in violation of voluntariness, a core commitment of modern research ethics.<sup>30</sup> Among the allegations were that some of the female donors were employees of the organization, around twenty women were each paid a total sum of \$1400 for their eggs,<sup>25</sup> and that the researchers actually accompanied their donors during the egg extraction process.<sup>30</sup> Incidents such as these have given rise to questions among the general public as to whether these women willingly donated their eggs or were coerced by the socio-economic and relational power researchers had over them.

This appears to be the complex ethical reality in which we find ourselves when it comes to oocyte donors and hESC research. The olden days of ethically simplified, inter-familial donations no

longer apply to many of today's oocyte donation cases. Along with the changing times, more and more women are donating eggs for various purposes with the expectation of payment.<sup>31</sup> In light of this development, scientists are becoming alarmed about the possibility that uninformed and economically challenged women might be exploited in an oocyte market that some have deemed to be more interested in commercial and personal gains than in the public good.<sup>24</sup>

Scientists are concerned about the monetary payments that some women are receiving for their oocytes. Current U.S. laws prohibit any kind of monetary payments for organ donations, and many scientists believe that this idea of altruistic donation should also apply to oocytes, which would help ensure that women are donating voluntarily and are not being forced into the procedure by their economically challenged circumstances.<sup>30</sup> Another concern is that scientists have arranged deals with the so-called "therapeutic misconception". The field of hESC research is clouded with difficult terminologies, such as therapeutic cloning, and many scientists fear that prospective oocyte donors may not fully understand their meaning. These scientists believe that it should be made clear to oocyte donors that by donating oocytes to hESC research, they themselves are not receiving any therapeutic treatment nor is it guaranteed that their donation will result in any therapeutic treatment for anyone else since treatments have yet to be derived from hESCs.<sup>30</sup> Scientists are also very concerned for the well-being of these women. Some are questioning the risks involved in the oocyte procuring procedure, which subjects

donors to hormonal treatments in order to harvest multiple oocytes. This situation deserves more attention from both scientists and the general public, since some of the drugs currently in use are not FDA approved, and many have not been studied for long-term effects.<sup>24</sup>

### **Proposed Solutions**

In the face of these ethical controversies surrounding hESC research, scientists are already at work proposing and experimenting with possible solutions. Addressing the ethical belief that the laboratory embryo is indeed a human life, scientists are proposing methods to spare the embryo's life and loopholes to circumvent the controversy altogether.

In Chicago, the Reproductive Genetic Institute (RGI) offers a solution to this problem by utilizing a technique already in common use, preimplantation genetic diagnosis (PGD). PGD is a technique currently used to test an embryo for genetic diseases before it is implanted in the mother's uterus. Material is removed at an earlier eight-cell stage called a morule, and the procedure does not result in embryonic death. Though no successful experiment has been carried out, early research has shown that it is possible to create a SC line from a single hESC. RGI is convinced that with sufficient funding this procedure can create healthy lines of hESCs without harming the embryo.<sup>23</sup> At Columbia University, researchers propose another solution to the controversy, claiming that certain chemical markers can determine when an embryo has lost the potential for developing into a human being. Harvesting hESCs from an embryo exhibiting

these chemical markers would eliminate the immediate source of controversy.<sup>30</sup>

While the aforementioned proposals are focused on modifying hESC extraction procedures to appease ethical concerns, other scientists are deliberately designing so-termed "dead-end embryos." At MIT, the approach to "dead-end embryos" has been with mouse embryos to which genes were added that made the embryos unable to attach to the uterine wall. In this way the embryos' potential to develop into adult mice has effectively been eliminated.<sup>32</sup> Stanford University has another approach to creating these "dead-end embryos"; by using a technique called altered nuclear transfer, it was possible to create ESCs that did not have the embryonic structure that normally accompanies them.<sup>32</sup> However, this approach has been criticized and has itself become controversial.

In addition, proposals are also beginning to address the ethical concern of the possible exploitation of women. Some scientists are proposing oocyte-independent approaches as solutions to this ethical problem. Based on successful experiments performed on mice, scientists assert that it might be possible to derive oocytes from existing hESC lines. Another oocyte-independent approach would be to stimulate somatic cells to revert to a totipotent state by injecting them with hESC or oocyte-derived "reprogramming" factors. If these methods turn out to be possible, they will eliminate the need to put women through the risks of the egg-procuring process.<sup>26</sup>

## Politics of SCs

On November 6, 2003, the U.N. made a decision to postpone the establishment of legislation relating to reproductive (human) cloning and hESC research, despite opposition to postponement from countries such as Australia. The main problem when establishing this type of legislation is the general misconception that the human identity is universal.<sup>33</sup> Even in Australia, there were considerable discrepancies in public opinion related to the universality of the human identity. As in the past, there has been a trend of scientific advancements outpacing the legislative process.<sup>34</sup> With many major scientific discoveries, there have been social and economic ramifications which lawmakers have tried to regulate and accommodate with the most benefit to their society. In dealing with reproductive cloning and hESC research, which promises potential cures to devastating degenerative diseases while posing ethical problems about human identity itself, legislative bodies in the U.S. and those in other countries worldwide are attempting to strike a balance between the potential benefits and the possible negative ramifications of this technical advance.

## International Perspectives

Confronting reproductive cloning and hESC research, legislators from nations spanning from the Americas to Asia are finding themselves juggling economic and scientific interests with those of religion and culture.<sup>35</sup> While most nations seem to agree on how to approach reproductive cloning, their different attitudes toward hESC research have resulted in a

patchwork of legislation varying greatly in permissiveness from one country to the next.

Among nations that currently have laws concerning these issues, there appears to be a near consensus to ban reproductive cloning. Many such as the United States, Japan, Australia, Israel, Italy, Sweden, Belgium, Costa Rica, Hungary, Ireland, Switzerland, and Peru have explicit laws prohibiting the cloning of a human being.<sup>34</sup> Examples of these legislation include the United States' Human Cloning Prohibition Act of 2003 and Australia's Prohibition Against Human Cloning Act passed in 2002.<sup>33</sup> According to Singapore's Bioethic Advisory Committee, which was created in December 2000 to advise the country's legislators, reproductive cloning is not a "sustainable" practice because it will likely have profound bearings on future generations.<sup>34</sup> One exception to this near consensus is the United Kingdom whose Human Fertilization and Embryological Act of 1990 does not explicitly ban reproductive cloning.

The legislative variations among the nations considering SC legislation are seen primarily with laws concerning hESC research. The main questions that must be answered by these nations are whether hESC research should be allowed, and if so, to what extent. In examining the different countries' attitude toward hESC research, it becomes evident that religious and cultural values are influential in the legislative process. Countries whose populations are composed significantly of Roman Catholics such as Costa Rica, Peru, Ireland, Belgium, and Switzerland appear to have taken the same stance



as that of former Pope John Paul II. In these nations, the right to life is recognized at conception and hESC research is banned entirely.<sup>34</sup>

Meanwhile, other nations are making decisions a bit differently. While recognizing the need to be ethically responsible, countries such as the United States, Singapore, and the United Kingdom have also decided to allow development in hESC research by having more permissive legislation. Nonetheless, even among countries that do allow this type of research, varying degrees of permissiveness are in place. To some observers, the policies of the United Kingdom, Sweden, and Singapore are liberal, while those of Australia are seen as moderate and the policies of Austria and Germany are deemed as restrictive.<sup>35</sup>

In Singapore, which in 1994 was the first country to observe scientists' isolation of hESCs from five-day old embryos, hESC research including therapeutic cloning is allowed. As is true in the United Kingdom, a regulatory or licensing body exists to approve and monitor hESC research.<sup>34</sup> Singapore allows for the creation of embryos for research purposes but only when the reasons are merited and the embryos used are less than 14 days old.

In Australia, therapeutic cloning is considered illegal under The Research Involving Human Embryos Act passed in 2002. Though research is allowed, researchers are only permitted to use excess *in vitro* fertilization (IVF) embryos that existed prior to April 5, 2002.<sup>33</sup>

In Germany, however, legislation is relatively restrictive toward hESC research. Even procedures such as PGD and cryopreservation, which are not controversial elsewhere, are prohibited by the Germany's Embryo Protection Act (EPA) of 1990. The current policies are the result of the IVF debates during the late 1980's during which a joined effort by feminists and pro-life lobbyists lead to the passing of EPA. Under the EPA, totipotent embryos have a right to life and can neither be destroyed nor cryopreserved. Therefore, researchers in Germany can only work on imported hESCs, and furthermore these must have been derived from embryos that existed by July 1, 2002.<sup>36</sup>

### **Legislation in the U.S.**

At the federal level, U.S. legislation reflects the same attitudes toward reproductive cloning as are seen with many other foreign governments. The U.S. Human Cloning Prohibition Act of 2003, made reproductive cloning illegal with a penalty of up to \$1 million in fine and 10 years imprisonment.<sup>34</sup> The U.S. is a relatively unique case in hESC research, however; while federally funded research is regulated, privately funded research has almost no restrictions.<sup>34</sup> Whereas in almost all countries where hESC research legislation exist, the regulations are applied to all research performed in the country's territory, U.S. federal laws concerning hESC research seem to be ambivalent in this sense.

Therefore, the debate among U.S. politicians surrounds the topic of federal funding for hESC research, more specifically President Bush's 2001 National Institute of Health (NIH) policies.

Under President Bush's NIH policies, the hESCs used in federally funded research must have been derived before 9:00 P.M. EDT on August 9, 2001, the embryos must have been created for reproductive purposes, were no longer needed, and consent from donors must have been obtained.<sup>37</sup> These criteria, mainly the first, have limited U.S. federally funded researchers to only twenty-one NIH approved hESC lines, most of which are deemed by many researchers as unsuitable for use in humans. The reason is that these twenty-one hESC lines have been grown on mouse feeder cells, and thus pose the risk of transferring a mouse virus to a human patient.<sup>35</sup> Due to these limitations and concerns, the U.S. legislative branch has made unsuccessful attempts to overturn the President's policies. The most recent of these attempts took place in January of 2007. At the start of 2007, the new Congress, with a Democratic majority, was trying to make many reforms within its first 100 hours, among which was the attempt to lift the President's NIH limitations on hESC research. The new bill, the Stem Cell Research Enhancement Act of 2007, will not fund the creation of embryos, but it will allow for the use of approximately three hundred newer hESC lines that were created after August 9, 2001.<sup>38</sup> By April 11, the bill had passed through both the House and Congress without a sufficient majority to overturn President Bush's promised veto.<sup>39</sup>

The hESC situation appears to be in gridlock at the federal level, which might explain why at the state level legislators are implementing their own initiatives for regulating hESC research. Perhaps the most well known and influential of these

initiatives is California's Proposition 71. Passed in 2005, Proposition 71 should provide three billion dollars in funding to hESC research in the state over the next ten years.<sup>40</sup> California was certainly not the first state to pass legislation regarding hESC research. In fact, Arkansas, North Dakota, South Dakota, Iowa, and Michigan all had laws restricting hESC research prior to Proposition 71. However, it was the passing of Proposition 71, which promised a large financial funding for hESC research, that really got attention of people worldwide, especially the attention of other U.S. states. In 2005, soon after Proposition 71 was passed, thirty other states were also considering hESC legislation.<sup>35</sup> In this environment, there is diversity in how the states balance their economic, scientific, cultural and religious interests and values resulting in a patchwork of legislation similar to what is happening at the international level. While some states restrict or prohibit hESC research, others are finding ways to fund it. In Illinois, for example, research funding is provided through surcharges added to cosmetic procedures performed in the state.<sup>35</sup>

Though the states do have ways to circumvent federal restrictions, states programs such as Proposition 71 are not free of problems. Procedural, economical, and ethical problems, such as how transparent the research should be, whether or not researchers should be allowed to patent their findings, and how the rights of female donors should be protected still have to be resolved.<sup>40</sup>



## Concluding Remarks

Having examined SCs from the angles of science, ethics, and politics, we can see that many of the issues are in their infancy. Even though SCs hold much promise for future medical applications, our scientific understanding on SCs remains limited, however, and ethical and political concerns are far from being resolved. The 20th century witnessed their discovery, but it is this century that has the potential to see the development and widespread application of SCs.

In the 21st century, however, SCs continue to be an ethical and political minefield. Therefore, in addressing the major issue of how SC technology should be used, societies cannot rely on their scientists to tackle this problem unilaterally. If there is to be hope that SC technology will change our world for the better, the decisions on the use of SCs must be made through a cooperative endeavor between scientists, politicians, religious and cultural leaders, and the general public. But for civic engagement to be successful, the public must be informed. In this sense, educators are in a key position to help societies tackle this grand challenge by educating today's youth on issues of SCs so that they will grow up to be tomorrow's scientifically informed and socially engaged citizens.

## Note Added in Proof

Since the initial submission of this manuscript, a major breakthrough has occurred in the field of SC research. In the November 20, 2007 editions of *Cell* and *Science*, two groups reported that they have successfully reprogrammed adult human skin cells to behave like pluripotent SCs by

introducing four particular genes into the cells' DNA via viral vectors. These cells have been termed human induced pluripotent SCs (hiPSCs).<sup>42,43</sup> This development is exciting and significant because the method of producing hiPSCs eliminates most ethical issues that have plagued hESCs, since the destruction of embryos is not required in procuring hiPSCs. Although the hiPSCs produced by the methods used by Takahashi et al.<sup>42</sup> and Yu et al.<sup>43</sup> have safety issues, this development opens an avenue for producing patient-specific and disease-specific, transplantable cells for therapeutic purposes. However, as pointed out by Takahashi et al., hiPSCs are not identical to hESCs and further studies are needed to determine if the hiPSCs can replace hESCs in a variety of applications.<sup>42</sup>

Furthermore, currently there are many unknowns, questions, and concerns regarding hiPSCs. To mention a few: 1) What is the origin of these cells (fibroblasts or progenitor cells)? 2) Are these cells the result of introducing only four genes or are there other necessary genetic mutations that have been introduced by the integration of viral DNA into the cell's DNA? 3) Will these cells give rise to tumors and/or transdifferentiate when introduced into patients? Despite these concerns, the potential use of hiPSCs in basic scientific studies and in developing future therapies is encouraging.

**Glossary**<sup>41</sup> ( definitions marked with \* were taken from <http://dictionary.reference.com/>)

- \*Amniotic fluid: The fluid within the amnion that surrounds the fetus and protects it from injury.
- Cell therapy: The medical procedure of injecting SCs directly into injured tissue. It is expected that the SCs will perform their natural function and repair the damage.
- \*Cryopreservation: Maintenance of the viability of excised tissues or organs by freezing at extremely low temperatures.
- Daughter cell: The cell that results from another that has undergone cell division.
- Dead-end embryos: An embryo that has been genetically altered so that it no longer has the ability to develop into the adult organism.
- \*Dendritic cell: A highly specialized white blood cell found in the skin, mucosa, and lymphoid tissues that initiates a primary immune response by activating lymphocytes and secreting cytokines.
- \*Differentiation: The process by which cells or tissues undergo a change toward a more specialized form or function, especially during embryonic development.
- \*Engraftment: To transplant or implant (living tissue, for example) surgically into a bodily part to replace a damaged part or compensate for a defect.
- Epithelial SCs: SCs derived from epithelial tissue, the thin, membranous tissue that lines most of the internal and external surfaces of an animal's body.
- ESC-Embryonic Stem Cell: cells obtained from an embryo in the blastula phase, when they are still only a few days old. Because they have only begun to differentiate, these cells have the capability of developing into any cell in the human body, a fact which makes them potentially important in medicine.
- Feeder cells: Cells that are used to provide SCs with a base to which they can attach and grow. Feeder cells are usually irradiated so that they no longer undergo cell division, and they also release nutrients into the culture.
- Gene therapy: A medical procedure for curing genetic diseases. In terms of SCs, it is believed that hESCs with “cure genes” added to them can be used therapeutically.
- \*Germ layer: Any of three cellular layers, the ectoderm, endoderm, or mesoderm, into which most animal embryos differentiate and from which the organs and tissues of the body develop through further differentiation.
- \*Hematopoietic: Pertaining to the formation of blood or blood cells.
- hESC: Human Embryonic Stem Cell
- HSC: Hematopoietic Stem Cell: SCs that give rise to many types of blood and lymphatic cells.
- \*Immunogenic: Relating to or producing an immune response.
- \**In vitro*: (of a biological process) made to occur in a laboratory vessel or other controlled experimental environment rather than within a living organism or natural setting.

- *\*In vivo*: (of a biological process) occurring or made to occur within a living organism or natural setting.
- *\*IVF-In Vitro Fertilization*: The fertilization of an egg in an artificial environment outside of a living organism.
- Mesenchymal SCs: SCs from mesenchymal tissue. These are capable of developing into connective tissues, blood, and lymphatic and blood vessels.
- NIH: National Institute of Health (in the United States)
- *\*Oocyte*: A cell from which an egg or ovum develops by meiosis; a female gametocyte.
- PGD- Preimplantation Genetic Diagnosis: a medical procedure of checking the genetic makeup of an embryo often for genetic diseases before the embryo is implanted in the mother's uterus.
- Progenitor cell: Derived from SCs, a cell that can differentiate into a more specific cell type. However, unlike SCs, it cannot renew itself indefinitely.
- *\*SC - Stem Cell*: A cell that upon division replaces its own numbers and also gives rise to cells that differentiate further into one or more specialized types.
- SSC: Somatic Stem Cell: SCs found in the body of the postnatal organism. Their purpose is believed to be in tissue replacement and injury repair.
- Tissue engineering: The process of growing tissue outside of the body for grafting.

- Transdifferentiation: The ability for a SSC isolated from a particular tissue type to give rise to a cell lineage native to a different type of tissue.
- *\*Zygote*: The cell formed by the union of the nuclei of two reproductive cells (gametes), especially a fertilized egg cell.

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## Research Articles

### Environmental Science and Communication: An Interdisciplinary Venue for Teaching

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#### Abstract

To provide a more integrated learning experience, two professors at the college level in Biology and Professional Writing modeled their interdisciplinary project on the K-12 EIC (Environment as an Integrating Context) program. Over a succession of four semesters, their project involved students in Environmental Science and Technical Communication. Addressing the statewide issue of mercury levels in South Carolina's freshwater fish, the project required students to research secondary information, develop an audience analysis of South Carolinians in terms of their fishing and fish consumption habits, design and produce multiple documents, develop audience analyses of potential readers, conduct formal review cycles with editorial recommendations, and present their research at a scientific meeting. The project culminated with the production of useable brochures that warn of the dangerous levels of mercury in freshwater fish. The brochures were presented to the local Department of Health and

Environmental Control for their use and distribution.

**Keywords:** environmental education, team projects, interdisciplinary, project-based learning, EIC, service learning, engagement

#### Introduction

In the last decade a renewed interest in different approaches to teaching and learning has focused on improving the quality of teaching in higher education.<sup>1,2,3</sup> One problem that crops up repeatedly is writing skills. A report by the National Commission on Writing in America's Schools and Colleges says student success hinges upon increasing writing proficiency in the nation's schools. Using extended writing exercises in every subject is important.<sup>4</sup> Many students are not used to thinking consciously and deliberately about whom they are addressing when they write – they often view the task narrowly, as course-based assignments whose sole audience is the instructor and whose purpose is to obtain a satisfactory grade. Students can



make more informed decisions about all aspects of their writing once they understand the needs and expectations of their readers.<sup>5</sup> The second problem is the implied lack of connectedness between subjects. Students frequently assume there is none. But when subjects are integrated in interdisciplinary courses, students who participate gain an increased ability to appreciate different perspectives, to respond with sensitivity to ethical issues, and to analyze, synthesize, and integrate the complexities of real world problems.<sup>6,7,8,9,10,11</sup> The importance of improving American's scientific literacy is a serious goal and is fulfilled only when students are taught to use and communicate their knowledge and intellect to apply scientific information to their own lives,<sup>12</sup> and for the good of their communities.

To combine environmental knowledge with communication skills and persuasive strategies, an interdisciplinary project was undertaken involving students in Environmental Science, Technical Communication and Business Writing. Funding was provided by the Sustainable Universities Initiative (SUI)<sup>i</sup> with additional support from Science Education for New Civic Engagement and Responsibility (SENCER).<sup>ii</sup> This project took place over the course of two years (four semesters), involved two faculty and more than 100 students, and culminated in an interdisciplinary team-taught honors course with a service learning component.

The project addressed a prominent local concern (mercury contamination of freshwater) and integrated environmental science, technical communication, and business writing by

requiring students to design documents centered around the theme of water quality. The documents included a PowerPoint presentation, formal business letters, brochures, posters and a presentation at a scientific meeting. The primary goals of the project were to foster a deeper understanding of mercury levels in freshwater and to increase student awareness and involvement in local environmental issues.

Environmental education techniques offer effective models for interdisciplinary curricula and provide students opportunities to learn critical thinking, problem solving, communication and effective decision-making skills. These advantages are seen at all grade levels including college. But instilling environmental awareness in our students is hampered by the U.S. system of compartmentalizing school subjects, which, according to David Orr<sup>13</sup> fosters the misconception that one discipline has nothing to do with another.

Luckily, a trend towards comprehensive interdisciplinary programs using environmental themes as a focal point is gaining widespread use. One such K-12 program is the EIC (Using the Environment as an Integrated Context for Learning), now modeled in Pennsylvania, Wisconsin, Maryland, Minnesota, and South Carolina. This program infuses environmental education into all subject areas and grade levels through curriculum requirements, pre-service and in-service training, opportunities for small grants for teachers, resource guides, and statewide advisory councils.<sup>14</sup> EIC programs have been shown to improve academic achievement in



writing, reading, math, science and social studies at the K-12 level as well as increase environmental awareness. As an added benefit, discipline problems are reduced and enthusiasm for learning increases.<sup>15</sup> With the lowest high school graduation rate of all 50 states in 2002, South Carolina adopted the EIC program, in hopes of gaining the benefits listed above.

Interdisciplinary programs are equally important at the college level. Research indicates loss of interest when students perceive that there is no practical or real world application to their work. Students need to ask questions like “Why? How come? So what?” and it has been shown that environmental themes “hook” student interest and promote this type of questioning and interest.<sup>15</sup> Adapting a program such as EIC into a service-learning project combines all of the necessary components: using interdisciplinary skills to solve local problems, improving student writing skills and scientific literacy, and fostering a sense of connectedness between seemingly disconnected subjects. Students are more engaged with a subject when they can test it and use it in combination with other disciplines. Furthermore, working on a project with some prospect of actual implementation boosts a student’s sense of political efficacy: they know their voice will be heard and may even count – they can make a genuine difference.<sup>16</sup>

Programs such as EIC are designed to improve test scores, motivate and interest students in their own learning, and increase knowledge about the environment and its associated issues. This approach, it is hoped, will lead to greater concern

for environmental issues, which will lead to actions promoting better environmental quality.

Three goals were addressed in the FMU study: (1) increasing writing proficiency across disciplines; (2) using an integrating theme over a variety of classes at the college level; and (3) using service learning to move students beyond awareness towards engagement. The main objective is for students to experience the need, opportunities and difficulties of interdisciplinary cooperation and to learn to communicate what they know for the greater good.

### **A Brief Description of the Mercury Problem**

Mercury, a “persistent heavy metal,” has become a common and controversial issue in the political arena<sup>17</sup> primarily because of a lawsuit settlement between the Natural Resources Defense Council and the Environmental Protection Agency (EPA) to regulate mercury emissions from power plants by March 2005. Nationwide, over 45 states have some type of fish consumption advisory due to mercury; South Carolina has 16 lakes and 37 rivers that contain fish unsafe to eat.<sup>18</sup>

Coal-fired power plants are the largest source of harmful mercury emissions in America. Mercury from power plants settles over waterways, polluting rivers and lakes and contaminating fish. Once Mercury enters the air, biological processes transform it into methylmercury, a very toxic form of mercury. This type of mercury bio-accumulates in fish and other animals that eat fish causing it to move through the food chain. Humans are primarily exposed to mercury through consumption of fish and other seafood products. Mercury concentrations are 1,000 to

10,000 times higher in fish than in any other food humans consume.<sup>19</sup>

Exposure to mercury for an extended amount of time can damage the brain and kidneys and the developing fetus permanently. The National Academy of Sciences reports that children who were exposed to mercury while in the womb have impaired memory and attention spans, speech impediments and delayed motor development. This exposure increases the number of children who have trouble keeping up in school and need special education. Depending upon the area of the brain affected by the mercury, a variety of symptoms may occur. These could include problems with muscle coordination, vision, hearing loss, and memory, changes in personality (shyness, irritability, or nervousness), tremors, and loss of sensation.<sup>20</sup>

As of 2001 the FDA and EPA state that women 14 to 44 years old and children 12 and under should not eat more than 12 ounces of any fish, or 6 ounces of freshwater fish, per week and that no king mackerel, swordfish, shark, or tilefish should be eaten at all.<sup>21</sup> In 2004, the EPA estimated that 1 in every 6 women of childbearing age has enough mercury in her blood to pose a risk to her child.<sup>22</sup> However, many people are unaware of these advisories and so put themselves at risk when they consume certain types of fish.

Lastly, there is some difference of opinion over who will be the most affected by consuming fish with high mercury content. Many believe that wealthier people are more health conscious than all other socioeconomic groups. As a result, they tend to eat more fish—because they are low fat,

high in protein, and contain high levels of omega 3 fatty acids. Dr. Jane M. Hightower, an internist at the California Pacific Medical Center in San Francisco, conducted a study of her wealthiest clientele and found that some had mercury levels exceeding the EPA's federal safety limit by four to fifteen times.<sup>23</sup> However, in a national health interview survey, other researchers concluded that groups such as Hispanics, Native Americans, and African Americans are more prone to mercury contamination because their diets, perhaps influenced by their culture, consist of larger amounts of fish than Caucasians.<sup>24</sup> Impact on these populations may also be linked to increased rates of subsistence fishing in these generally less wealthy groups. In addition, the USDA Women, Infants and Children (WIC) program, designed to help poor American families with nutritional information and lower prices on healthy foods, only provides financial assistance when they buy albacore tuna, which has three times the toxic mercury levels as chunk light tuna.<sup>25</sup>

Although the groups named here seem dissimilar, they do share a connection in their susceptibility to mercury. This study attempted to determine who in South Carolina may be most at risk of mercury toxicity due to eating contaminated fish and culminated in a service-learning project to develop brochures and flyers designed to warn these target groups of the dangers of fish consumption. Because of the controversy, this interesting and relevant problem was chosen as the focus for a problem-based learning experience.

## *Methods*

During the Fall of 2003, two of Professor Pike's environmental science classes and three of Dr. Hanson's professional communication classes (one technical writing class and two business writing classes) coordinated assignments and worked together to produce a PowerPoint synopsis of the problem. Professor Pike's students in environmental science researched South Carolina freshwater mercury contamination and related fish consumption advisories, provided the information to Dr. Hanson's writing students, and assisted in selecting appropriate graphics and developing drafts of the documents. Under Dr. Hanson's direction, the technical writing and business writing classes designed the layout for the PowerPoint presentation, developed an outline, and conducted audience analyses of the multiple groups who would view the PowerPoint presentation. When the planning phase was complete, the writing classes drafted the text and graphics of the presentation and conducted review cycles—in tandem with the Environmental Science students—to prepare for final publication. The presentation was reproduced on CD's and, along with formal letters of transmittal, sent to all South Carolina legislators and Department of Health and Environmental Control (DHEC) offices. An additional downloadable file was posted on Francis Marion University's school server (at <http://alpha1.fmarion.edu/~mercury/mercury.html>) and formal letters to South Carolina science teachers directed these potential readers and users to the web site.<sup>26</sup> Table 1 shows the coordinated class assignments.

During Spring 2005 the project culminated with a team-taught Honors Colloquium (Pike and Hanson) in which seven students enrolled. The honors class synthesized all of the previous information, and filtered it through the lens of the proposed Clear Skies Initiative (a 2002 controversial proposal by President George W. Bush to cut power plant emissions and reduce air pollution using a market-based cap and trade approach). The students designed brochures and flyers, giving the rights to the content and designs to the Department of Health and Environmental Concern (DHEC) for use in their clean water campaign. DHEC officials were invited to view the brochures and the student poster presentation of the project at the Carolina Undergraduate Social Sciences Symposium in April 2005. The project was also presented orally at the Southern Regional Honors Conference (April 2006).

Finally, in both the first year and the second year of the project an environmental knowledge and attitude survey was administered at the beginning and end of the semester to the classes involved: environmental science, technical writing / business writing, the honors seminar, and two control classes (classes who did not participate in the mercury project). This survey was adapted and updated (by Pike) from Maloney, Ward and Braucht (1975)<sup>27</sup> who developed an attitude scale with four subscales designed to measure knowledge, concern (affect), willingness to act (verbal commitment) and past behavior (actual commitment). All classes, as well as two control groups, took the survey at the beginning and end of the semester as a pre- and post-test.

## Results

The results of this project were fivefold: (1) Information on mercury contamination was disseminated as a teaching resource for South Carolina science teachers in the form of a PowerPoint presentation downloadable from <http://alpha1.fmarion.edu/~mercury/mercury.html>; (2) A CD-ROM copy of the PowerPoint presentation was sent to South Carolina legislators and DHEC officials with accompanying letters of transmittal; (3) Flyers and brochures were designed and presented to DHEC; (4) Results were presented at two professional meetings. The honors class presented their semester long project at the Carolina Undergraduate Social Sciences Symposium in April 2005 and the instructors presented a panel discussion on the experience at the Southern Regional Honors Conference a year after the class was over, in April 2006. (5) Environmental attitude data from pre-tests and post-tests was collected.

The team-taught Honors 397 Colloquium further developed an audience analysis to help identify characteristics of South Carolinians who may eat fish, the types of media that would be appropriate to spread warnings about mercury toxicity, and the areas to post and distribute such media. The audience analysis focused on both groups most likely to be affected: the wealthy South Carolinians, who may be eating more fish as part of a health-conscious diet, and poor minority sectors of society who might be eating more fish to supplement their diets inexpensively, as shown in Table 2.

Table 2 depicts two main groups that our class targeted for the development of information on the hazards of ingesting methylmercury through fish. Table 3 shows the list of proposed media and locations for fish consumption warnings.

After producing these lists, students paired each medium with the most feasible display locations. For example, posters could be displayed in offices, schools, marinas, and boat ramps. Video displays could be presented in stores and doctor's offices but not at most piers. With this plan in place, students then developed sample displays and offered them to state DHEC officials.

In terms of attitudes about the environment, when pre-test scores on the environmental knowledge and attitude survey were compared to post-test scores, it was found that there were significantly higher scores on the post-test for both Fall 2003 environmental science classes who participated in the project as well as the control environmental science class (Figure 1). The English classes that participated in the project also scored significantly higher on the post-test. The control English class showed no difference from pre-test to post-test. The second year, the Honors 397 Colloquium took the same pre- and post-test knowledge and attitude survey. Results show that there were no significant differences in the pre- and post-test scores ( $p>0.05$ ); that scores were high (= more environmentally friendly) on both the pre and post-test, which left little room for improvement.

When evaluating all tests by subscales, only the knowledge subscale showed a significant difference. Attitude scales showed no change

with one exception - the control environmental science class showed a significant increase in positive answers to verbal commitment on the post-test (Table 4). At the end of the semester, these students seemed to be more committed to helping the environment, which was one of our desired outcomes for the class. While we had these same expectations for the environmental science class that performed the mercury project, the results showed no attitude change as measured by the sub-scales of the assessment. This perhaps could be due to "topic fatigue" - by the end of the semester the repeated exposure to our topic could have dampened the students' enthusiasm. In summary, three classes showed statistically significant gains on the knowledge scale during the semester while only one class showed a significant change in attitudes.

## Discussion

In a similar manner to Kokkala (2002)<sup>28</sup> the first part of this project involved Biology students and English students in reciprocal author-editor relationships as a way to teach writing within the two disciplines. The goal was to use a common theme centered around a local environmental issue to teach research, writing and collaboration skills. The benefits included science students gaining additional writing instruction applied within their field, English students gaining a greater awareness of environmental science and its impact, and all students working on a real-life project that culminated in tangible, usable end products.

Other studies have also shown that classes involving real projects rather than content-based

lectures give students a more positive learning experience and an attitude of empowerment or a feeling that their voices make a difference.<sup>29,16</sup> For example, during evaluation of our courses one student wrote that, "the real-life situation made the assignments more enjoyable because there was a point in doing them." Another student stated that, "working on the mercury project gave me the unique opportunity to learn textbook knowledge in a very real world scenario. The project raised my knowledge of mercury contamination and it hit close to home, too close." A representative from Sonoco who saw the presentation on mercury later called and asked to use the presentation in a teacher workshop, and legislators and the governor wrote letters of acknowledgement for the CD-ROM.

Positive environmental attitudes appear to last longer than the simple recall of content. Edwards and Iozzi (1983)<sup>30</sup> performed a study on teachers attending a summer institute, which showed that both knowledge and attitude had increased by the end of the institute. Yet, two years later, a subsequent test of the same group showed a significant decline in the participants' knowledge. In contrast, their environmental affect and commitment remained high. It is clear that gains in knowledge are easier to measure, but knowledge alone will not ensure responsible environmental behavior,<sup>31</sup> especially for groups like business majors (who comprised the largest part of the business writing classes taught by Dr. Hanson), and who have been shown to be least likely of all college undergraduates to undertake



environmental action.<sup>32,33</sup> Yet these students are very likely to be engaged in their careers in the conflict between economic growth and environmental protection. Consequently, educational projects concerning environmental issues should (a) strive to instill in students a conceptual awareness of how individual and collective actions can influence environmental quality, and (b) provide practice in the communication skills and persuasive strategies necessary to take positive environmental action.

Our goal was to foster an environmental attitude in the students that would increase and remain high long after the project ended. Unfortunately, our project did not produce these changes in attitude over the semester-length course, perhaps for a variety of reasons. The post-test was administered during the final exam period when student stress is typically at a high level. Additionally, students had been intensely focused on the project for the entire semester and were experiencing topic fatigue. If students were tested again one year later, as Edwards & Iozzi (1983)<sup>30</sup> suggest, one could expect attitude scores to remain the same and knowledge scores, which often reflect simple memorization of facts, to decline.

Tests for long-term retention of attitude need to be conducted to verify whether our goal was actually achieved. Structuring and scheduling an effective test is problematic when assessing a one-semester course at the college level: once students graduate or even start a new semester, it is very hard to get enough of them together again to administer another post-test.

Service-learning is a method of class participation that substitutes real, tangible projects for hypothetical, academic exercises and that can give students a greater sense of ownership during their class projects. By integrating a service learning project with an interdisciplinary approach, we sought to achieve even more: coaching a group of students to cultivate the skills and knowledge to become active, engaged citizens of the world. We selected a local environmental problem—one that could directly affect the students themselves—and required a variety of writing assignments that focused on warning readers of potential health hazards. Despite the National Science Education Standards (NSES) correlation between science literacy and stewardship of natural resources,<sup>34</sup> knowledge alone is not enough to promote learners to take action. Ownership variables — anything that makes the environmental issue personal — are critical to responsible environmental behavior.<sup>34</sup> In addition, the skills and means necessary to actively take part in changing a perceived problem are very important. Thus, environmental education must include providing sufficient ecological knowledge, developing a conceptual awareness of how individual and collective actions can influence environmental quality, and developing skills necessary to take positive environmental action.<sup>35</sup>

Service-learning within the environmental science curriculum can combine goals of increasing knowledge and attitude with a learning method that enhances the skills to make informed decisions and become responsible members of civic society. McDonald and Dominguez (2005)<sup>12</sup>,

who had their classes complete environmental projects combined with service-learning, found that service-learning made instruction more student-centered, and that it made classroom study more relevant and satisfying for the students. Our experience at FMU validated this finding, but also revealed the difficulties in trying to measure the project's level of success.

Conducting an interdisciplinary project at the university level has both advantages and disadvantages. A more typical implementation strategy for interdisciplinary learning is found in high schools where students' enrollment in a communication course and an environmental science course can be facilitated more readily. Block scheduling in a university setting is far more difficult and rare. Consequently, coordination tasks are more cumbersome for professors who want to reinforce concepts in both courses, and the project's cohesiveness is less evident to students. However, at the university level, all students have usually reached voting age, which gives them more clout as they write to state legislators about their environmental concerns.

This study illustrates the advantage of teaching environmental science across the curriculum as an avenue for providing students with knowledge of environmental issues and the tools to act on environmental knowledge. The next clear research problem illuminated by this study is the need for a viable method for measuring long-term attitudinal changes in college-level students who participate in interdisciplinary service-learning projects. Students may need a longer period of

time for attitudinal changes, once content and action skills are learned. But because long-term post-tests are hard to conduct with college students, no data exists to prove that environmental attitudes are long-lasting. In addition, students are not aware of the feedback they receive on their work after the course is over. Consequently, they may not fully understand the true benefits and impact of their project on the community they sought to serve.

#### **List of Acronyms used:**

EIC: Environment as an Integrating Context, a state Department of Education program to address the underperformance of K-12 students on science tests.

WIC: Women, Infants and Children, a Federally funded (through the United States Department of Agriculture) program to provide low-income Americans with quality, nutritional, low-priced foods and information on nutrition.

SUI: The Sustainable Universities Initiative (see endnote).

SENCER: Science Education for New Civic Engagements and Responsibilities (see endnote).

DHEC: The Department of Health and Environmental Control, a South Carolina state agency.

FMU: Francis Marion University, where this study was conducted. It is located in Florence South Carolina.

EPA: The Federal Environmental Protection Agency.



FDA: The Federal Food and Drug Administration.

NSES: National Science Education Standards.

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<sup>i</sup> Clemson University, located in upstate South Carolina, the Medical University of South Carolina (MUSC) in Charleston, and the University of South Carolina (USC) with its main campus in Columbia, the state's capital, have developed a productive partnership — the S.C. Sustainable Universities Initiative (SUI). In 1998, the presidents of the three schools signed a pledge to cooperate in leading the way toward a more sustainable future through teaching, research, community service, and facilities management. In 2000, the state's General Assembly appropriated one-time funds to expand the program to other state-supported institutions of higher education. To date, 13 four-year and technical schools have joined, including Francis Marion University. <http://www.sc.edu/sustainableu/InitiativeDescription.htm>

<sup>ii</sup> SENCER, Science Education for New Civic Engagements and Responsibilities, is a comprehensive national dissemination project funded by the National Science Foundation. SENCER engages student interest in the sciences and mathematics by supporting the development of undergraduate courses and academic programs that teach “to” basic science and mathematics “through” complex, capacious, and unsolved public issues. <http://www.sencer.net/index.cfm>

**Table 1: *The course design with coordinated class assignments.***

<b>Pike's Honors Environmental Science (Bio 103) Classes (Fall 2003 and Fall 2004)</b>	<b>Hanson's Technical Writing (Eng 318) and Business Writing classes (Eng 305) (Fall 2003)</b>	<b>Pike and Hanson's Honors 397 Colloquium (Spring 2005)</b>
Primary research (Fall 2003 and 2004)	Design a PowerPoint presentation using primary research from Pike's 2003 class	Design original brochures and posters using research from 2003 & 2004 environmental science classes
Review and Critique PowerPoint (Fall 2003)	Review and critique the PowerPoint	Present at Carolina Undergraduate Sociological Student Symposium (April 2005)
Present research at National Honors Convention (Spring 2004)	Send the PowerPoint to SC legislators and teachers (December 2003)	Present brochures to DHEC (April 2005)
		Present at the Southern Regional Honors Convention (April 2006)

**Table 2: *Audience analysis for mercury information.***

<b>Largely Middle Class</b>	<b>Largely Poor</b>
Not informed	Not informed
Largely Townies	Largely Rural
Largely Caucasian	Largely Minorities
With More Higher Education	Largely K – 12 only

**Table 3: Selected media for mercury warnings and appropriate locations for display.**

Media	Location
Fliers	Doctor's offices & exam rooms
Tri-fold brochures	Especially:
Big posters & signs	Ob/Gyn offices
Newspaper articles	Pediatrician's offices
Coupon for a mercury-free life (included in the newspaper)	Dentist's offices
Coloring book for children	Health clinics
Comics targeting children	Hospitals
Video News Bulletin (Info-tainment)	Bait & tackle shops
Power Point presentations	Hunting & fishing lodges & stores
Bobbers (merchandise with message)	Public service TV channel
	Many local newspapers
	Elementary schools & day care centers
	Nutrition counselors' offices & others
	Marinas, boat ramps, & piers
	Other waterway accesses

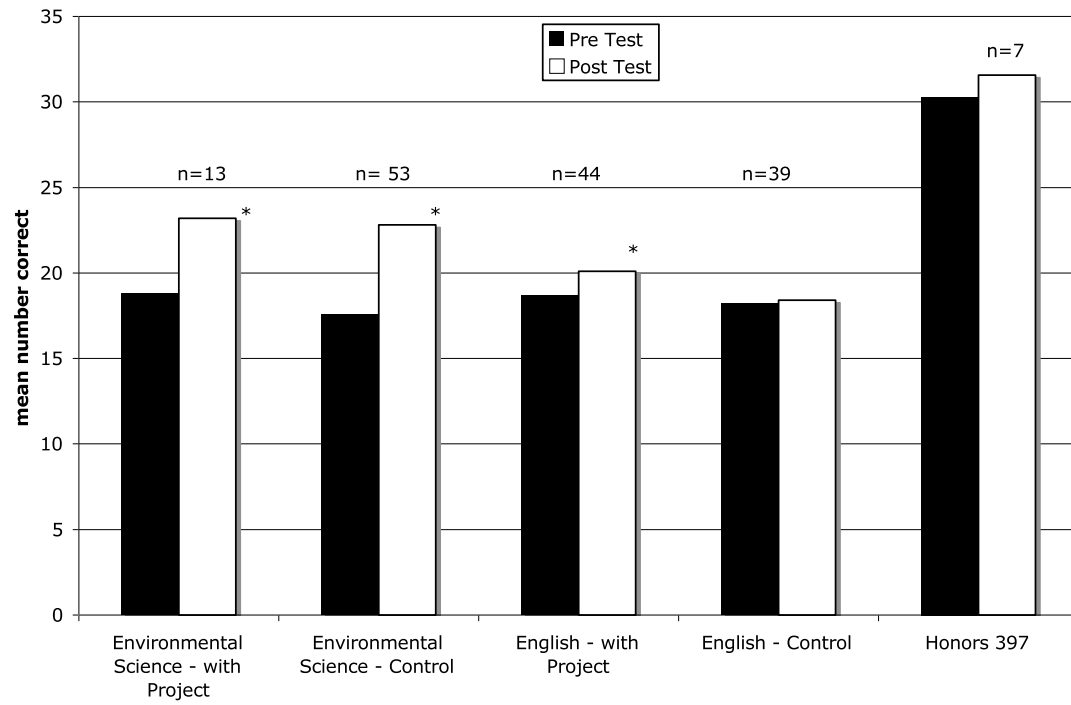
Table 4: Statistical analysis of the environmental attitude and knowledge pre- and post-tests.

Class	Score	Verbal Commitment (Q 1-10)		Actual Commitment (Q 11-20)		Affect (Q 21-30)		Knowledge (Q 31-45)	
<b>Environmental Science – Honors</b>		<b>PRE n=9</b>	<b>POST n=13</b>	<b>PRE n=9</b>	<b>POST n=13</b>	<b>PRE n=9</b>	<b>POST n=13</b>	<b>PRE n=9</b>	<b>POST n=13</b>
	Mean	5.70	6.30	2.80	2.90	5.90	6.60	4.44	7.46*
	SD	1.73	2.56	1.92	1.77	2.20	2.66	1.81	1.61
<b>Environmental Science – Control</b>		<b>PRE n=52</b>	<b>POST n=53</b>	<b>PRE n=52</b>	<b>POST n=53</b>	<b>PRE n=52</b>	<b>POST n=53</b>	<b>PRE n=52</b>	<b>POST n=53</b>
	Mean	5.30	6.70*	2.30	3.41	5.30	6.80	4.67	5.85*
	SD	2.18	2.31	1.90	2.49	2.74	2.39	2.09	2.46
<b>English 305 / 318</b>		<b>PRE n=49</b>	<b>POST n=44</b>	<b>PRE n=49</b>	<b>POST n=44</b>	<b>PRE n=49</b>	<b>POST n=44</b>	<b>PRE n=49</b>	<b>POST n=44</b>
	Mean	5.10	5.20	2.50	2.70	5.20	5.10	5.88	7.09*
	SD	2.20	2.55	2.08	2.21	2.70	2.66	2.29	1.74
<b>English 305 / 318 – Control</b>		<b>PRE n=37</b>	<b>POST n=39</b>	<b>PRE n=37</b>	<b>POST n=39</b>	<b>PRE n=37</b>	<b>POST n=39</b>	<b>PRE n=37</b>	<b>POST n=39</b>
	Mean	5.12	4.92	2.41	3.02	5.71	5.01	4.95	5.51
	SD	2.26	2.35	2.21	2.37	2.40	2.87	2.31	2.47
<b>Honors 397</b>		<b>PRE n=7</b>	<b>POST n=7</b>	<b>PRE n=7</b>	<b>POST n=7</b>	<b>PRE n=7</b>	<b>POST n=7</b>	<b>PRE n=7</b>	<b>POST n=7</b>
	Mean	8.29	8.57	2.00	2.71	8.29	7.29	13.57	13.00
	SD	3.30	3.82	1.63	0.95	2.63	3.45	1.90	3.31

\*The one-tailed t-test showed a significant difference with  $p < 0.05$ .



**Figure 1. Mean Scores on Environmental Attitude and Knowledge Scale for all Classes**



# The Absence of Class Time Effect On Science and Civic Engagement

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## Abstract

This paper compares student perceptions and interests in science and civic engagement in an introductory environmental science course delivered in both online and traditional formats. The materials, quizzes, activities, assignments, tests, and instructor used by each format were identical in all respects, with the only difference being that the materials were discussed in person in the traditional format and delivered over the Internet in the online format. Both formats used online activities and assignments from the Environmental Science Activities for the 21st Century (ESA21). Results from pre- and post-surveying of student opinions using the Student Assessment of Learning Gains instruments are reported.

## Introduction

In a literal sense, distance education has been around since the earliest forms of writing that allowed for information to be transmitted from one person to another without the two of them being in audio or visual contact. Throughout the ages, the manner and speed with which this information has been transmitted has changed, as with first the printing press, then mail, and then electronic media; these advancements have changed the landscape of distance education, increasing both the amount of information and

speed with which it can be delivered. In the last two decades, the development of the Internet has radically changed distance learning by making the information delivered very fluid and the speed with which it is delivered almost instantaneous.

Studies about the efficacy of using the Internet to deliver education were somewhat rare during the 1990's, but have become much more prevalent in the last five years. Many of these studies have focused on student learning, the reasons why students sign up for online courses, student satisfaction with the course delivery method, or analysis of what aspects of the course were most helpful to students.<sup>1</sup> Some studies report that online delivery formats were superior to traditional classes, while others report that student interest or attitude was negatively affected in online courses. Some studies have reported conflicting results, such as students in an online course simultaneously performing better on tests while being less satisfied with the overall experience.<sup>2</sup>

With the advent of online learning tools and the integration of many of these tools into traditional courses, the ability to accurately define a course as online or traditional has become nearly impossible. Classes today fall along a wide

spectrum between what was classically considered online to what was classically considered traditional. For example, a lecture class today might contain online homework sets, computerized simulations, chat rooms and threaded discussion boards that are to be used when the students are not in class, while a class without a traditional lecture might have synchronous compressed video or Web meeting lectures or problem solving sessions with the instructor or teaching assistant that provide face-to-face interactions. For this reason, professors can no longer accurately and consistently differentiate between the two, and must now clearly define what they are doing in their classes and what particular aspect of the course they are investigating when reporting any kind of study.

#### **Methods**

This study investigates only the effect of classroom instruction on student perceptions and interest in science and civic engagement, and does not address other aspects of a course. The course for which this study was done is an environmental science course that looks specifically at energy use and its impact on the environment.<sup>3</sup> This course uses activities from the Environmental Science Activities for the 21<sup>st</sup> Century (ESA21) to civically engage students by having them investigate how their own lifestyle impacts the environment. These activities are a mixture of field and Internet based experiences that require the students to measure aspects of their lifestyle. They then use these measurements to investigate how they could change their lifestyle in an economic manner that will reduce their impact.

This particular course was offered in both a no face-to-face instruction format (what we will call *online* for the purposes of the rest of the paper) and a traditional lecture format. With few exceptions, all aspects of the course were delivered in exactly the same way for both formats. The content for the course was divided into weekly modules, and both course formats covered the same content material with the same course objectives each week. Reading assignments and lecture materials were accessible on the Internet for both formats, with students in the traditional class being able to discuss them in person with the instructor. Identical quizzes were given at the conclusion of each week, with online students taking the quiz via WebCT and traditional students taking them in person. Two tests and a final were given in person for both formats in order to verify student identity. The activities were delivered using the Internet, with traditional format students handing in their assignments in person and online format students sending in their assignments via the Web. The activities used were drawn from the ESA21 activities and were coordinated to meet the content discussed during that week. Both formats utilized the same instructor.

For both formats, student-to-student interaction was completely voluntary. The traditional lecture did not involve group projects or cooperative learning discussions. The online students were offered the opportunity to use chat rooms and an online discussion board, but there was no mandate that they do so. In both cases, the students were encouraged to study together or

discuss issues on their own, but no class or extra credit was given for doing so.

## Results

Student attitude and opinions were assessed using the version of the SALG instrument sponsored by the Science Education for New Civic Engagement and Responsibility (SENCER) program. Between the spring of 2004 and the spring of 2007, the course was offered five times in an online format and twice in a traditional format. In total, 96 students in the online course took the post-survey, with 81 of these also having taken the pre-survey. In the traditional format, 66 students took the post-survey, with 56 of these having also taken the pre-survey.

Most of the questions on the SALG are multiple choice/forced response questions that use a Likert scale to allow for comparison and quantitative analysis. Students are given a range of questions regarding their interests in doing science and community activities, their understanding of science, and which aspects of the course aided their understanding the most. The survey was administered as a pre-survey during the first two weeks and a post-survey during the last two weeks of class. The SALG website allows for the individual responses between pre- and post-surveys to be tracked in an anonymous fashion so that comparisons can be made on common questions about changes that may have occurred over the course of the semester with each student.

For the purposes of this analysis, we will concentrate on the responses to questions about the confidence and interest of students to perform various activities. Table 1 lists the questions of

interest. To analyze the data, responses from the pre- and post-survey were matched up for each student on those questions that were the same on both surveys. The pre-survey Likert values (1=Strongly Disagree, 5=Strongly Agree) were subtracted from the post-survey ones, averages of the differences were computed, and the distributions of differences were then compared using a standard t-test to see if the two groups were different. Table 1 shows the average difference for each group and the t-test scores for the distributions of the two sets of data.

## Discussion

The data show no significant differences in changes in the confidence to perform activities from the two student groups, with the exception of one item. The increase in confidence for the statement "I can give a presentation about a science topic in your class" was significantly higher for the traditional class than in the online section. This might be expected, as the traditional students were able to verbally interact in person with their colleagues and the instructor several times a week, which might aid in the development of these skills, whereas the online students received no such formal exposure. For all other statements on confidence in abilities, the differences were not large enough to be considered significant. Furthermore, the increases in confidence over the course of the semester were similar to those seen in other groups of students in environmental science classes that have used the ESA21 activities.<sup>4</sup>

The data on changes in student interest in various activities do not show this same pattern, though,

as responses to several of the statements did show significant differences between the traditional and online classes. In particular, students in the traditional classes increased their interest in discussing science with friends and family, taking an additional science class, exploring career opportunities in science, joining a science club or organization, attending graduate school in a science-related field, and teaching science significantly more than students in the online classes. On the other statements (reading about science and its relation to civic issues, reading articles about science in magazines, journals or on the Internet, and majoring in a science-related field), the interest increased more for the traditional class, but the differences in distribution of responses was not large enough to declare it significant.

Before jumping to any conclusions, it should be reiterated that these data represent the change in response from the beginning of the semester until the end and not the absolute response. The fact that the traditional class saw a significantly greater increase does not mean that students in that class have an overwhelming interest in doing these activities; in fact, the average scores on the post-survey for these statements was somewhere between a 1.7 and a 3.0 on a 5.0 Likert scale. The placement of the raw data means that even the traditional class students average from Neutral to Disagree with these statements. Therefore, the traditional class format can hardly be seen as a magic bullet for getting students interested in science activities.

The data do support, though, the conjecture that face-to-face interaction is important in increasing student interest in science. This has tremendous implications, especially as more and more science departments adopt online classes for their general education courses. For these classes, they might want to consider some method of creating opportunities for personal interaction.

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**Table 1: Average difference in Likert values for traditional and online classes along with t-test values for the distributions of differences**

Traditional vs. Online Energy Class Using Online ESA21 Activities			
Average Difference			
Traditional	Online	t-test	Statement
			<b>I am confident that I can:</b>
0.66	0.40	0.08	Discuss scientific concepts with my friends or family
0.73	0.53	0.07	Think critically about scientific findings I read about in the media
0.64	0.49	0.24	Determine what is -- and is not -- valid scientific evidence
0.76	0.64	0.25	Make an argument using scientific evidence
0.78	0.57	0.34	Determine the difference between science and "pseudo-science"
-0.13	-0.03	0.09	Interpret tables and graphs
0.07	0.10	0.42	Understand mathematical and statistical formulas commonly found in scientific texts
0.19	0.15	0.45	Find scientific journal articles using library / internet databases
0.39	0.32	0.39	Extract main points from a scientific article and develop a coherent summary
0.46	-0.05	0.03	Give a presentation about a science topic to your class
0.19	-0.03	0.35	Obtain scientific data in a laboratory or field setting
0.02	0.15	0.09	Understand how scientific research is carried out
0.47	0.19	0.08	Pose questions that can be addressed by collecting and evaluating scientific evidence
0.38	0.10	0.11	Organize a systematic search for relevant data to answer a question
0.38	0.24	0.26	Write reports using scientific data as evidence
			<b>I am interested in:</b>
0.66	0.11	0.002	Discussing science with friends or family
0.36	0.00	0.06	Reading about science and its relation to civic issues
0.27	0.13	0.35	Reading articles about science in magazines, journals or on the internet
0.47	-0.14	0.0004	Taking additional science courses after this one
0.19	-0.05	0.16	Majoring in a science-related field
0.33	-0.14	0.01	Exploring career opportunities in science
0.40	-0.02	0.01	Joining a science club or organization
0.47	-0.10	0.0003	Attending graduate school in a science-related field
0.53	-0.05	0.0003	Teaching science

# Science Education and Public Policy

## The Global University: The Restructuring of Undergraduate Science and Engineering Courses and the Development of International Partnerships

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At the dawn of the 21<sup>st</sup> century, the United States is the leading nation in terms of its economic, technological, and military capabilities. At the same time, the American public is faced with the challenge of embracing and understanding different kinds of thinking and ways of life around the world while simultaneously learning to work with foreign entities in a mutually beneficial way. Indeed, for the American people, an international perspective can represent the difference between peace and global collaboration, and continuing conflicts and wars; a by-product of such an international perspective is the ability of our country to be competitive in the global economy. This need for an international perspective by Americans has been articulated by writers such as Thomas Friedman in The World is Flat: A Brief History of the Twenty-First Century,<sup>1</sup> and by an increasing number of university educators, such as President Richard Levin of Yale University.<sup>2</sup>

The basic issue is, then, how can Americans achieve such an international perspective? More particularly, how are students to be prepared for a truly global workplace in which they must think and act in ways that are drastically different from those they are accustomed to? The answer is that the education process must be transformed to incorporate an international focus. The globalization of our education system is assuredly a civic issue that has profound implications for our economic well-being and our relations with other countries.

For a college or university, what constitutes a “global university”? According to President Levin,<sup>3</sup> a global university contains four central components:

1. Curriculum with international focus
2. Research in an international context
3. Establishment of partnerships with foreign universities



#### 4. Interactions with new constituencies

The present article shows certain steps that faculty members at the University of Maryland, College Park (UMD) have taken in beginning its transformation to a global university.

##### **Initiative at the University of Maryland**

The initiatives at UMD are taking place at a time when many institutions are beginning to think about education with an international component. In 2000, the American Council on Education (ACE) prepared a series of surveys funded by the Ford Foundation. The surveys involved 752 U.S. colleges and universities, 1027 undergraduate faculty and 1,290 undergraduate students; the data gathered was used to examine views on internationalization in U.S. postsecondary education. Interestingly, students, faculty and the public were found to be strongly supportive of internationalization; half of the students reported having taken at least one international course during the 2000-2001 academic year.<sup>4</sup> By contrast, the majority of students and faculty had not actually participated in international activities.<sup>5</sup> By far the largest number of international programs involved the sending of students abroad for a term or year of study. However, the most recent statistics (for the academic year 2002-2003) show that of 174,629 U.S. students studying abroad, only 16% were science, technology, engineering or mathematics (STEM) majors.<sup>6</sup>

This signifies that of the relatively small number of students nationwide who study abroad, a small fraction are STEM students – and the majority of the STEM students who do study abroad are

unlikely to be pursuing activities directly related to their fields of study. And this is at a time when organizations such as the National Science Foundation emphasize the need for a scientific work force that is globally aware.<sup>7</sup> President Levin has emphasized the importance of science and engineering in generating new knowledge and applying it to the solutions of major problems in health, economic development and the environment.

In 2002 a group of faculty from STEM disciplines at UMD embarked on an approach toward internationalizing undergraduate science education that would have two thrusts. The first thrust would entail globalization of courses within undergraduate STEM courses on campus. This is by far the least frequent and the most difficult and challenging approach to a more global education, and yet has the potential to affect the largest number of students. After this effort was solidly underway, the faculty would turn to development of a partnership with a foreign institution that would initially consist of substantial study abroad programs involving studies and research projects of undergraduates in STEM subjects. While these two efforts by UMD faculty would involve only the first and third of the four components proposed by President Levin, we will make the case that the two components establish a platform that can be expanded into serious research efforts and the creation of broader links to new constituent groups. The conceptual approaches and methodologies developed at UMD deal with issues common to all universities as they evolve

into global institutions, and can be equally applied to most if not all disciplines.

### **Curriculum Change: The Design of the East Asia Science and Technology (EAST) Program**

The first UMD project by the STEM faculty incorporated East Asian themes into STEM courses. The group of faculty and staff members that took part in this initiative called itself EAST, the abbreviation for East Asia Science and Technology. The mission of the EAST program was implemented through three components:

- Course projects initiated by individual faculty members who were chosen for combining research abilities and teaching skills.
- A variety of course models developed in order to meet the different curricular needs of both the students served and the STEM programs that were involved.
- A major effort to develop innovative teaching approaches and materials. The participation of library and information technology staff and the Center for Teaching Excellence (CTE) in the EAST project was invaluable in that respect.

Central to the EAST project has been the desire to affect as large a number of undergraduates as possible. The success of the EAST project very much depended on the active participation of faculty and staff and the principle of faculty-initiated projects. This was achieved by the selection of thirteen colleagues called EAST Fellows: ten faculty from four STEM colleges and three staff members. The EAST Fellows received a small annual stipend, in return for which they

agreed to attend an annual summer workshop and participate in regular monthly EAST meetings. Since there was a strong expectation that they would be involved in developing a variety of course projects, both workshops and monthly meetings focused on the concepts and mechanics of creating interdisciplinary and cross-cultural courses and the development of Asian cultural modules for integration into existing STEM courses as well as making effective use of library and technology resources.

Over a period of three years, the EAST program developed, modified and taught East Asian themes within STEM courses. The interdisciplinary and cross-cultural courses that were modified or created included required science courses for various STEM majors, general education science courses for non-majors, and honors seminars. A number of different pedagogical approaches were used. These included: new Asian theme modules within existing courses, new courses that provide an East Asian perspective within STEM, and transnational courses that were developed in collaboration with Asian universities. The new modules and courses necessitated innovative pedagogical approaches, because traditional lecture/test formats were deemed unlikely to address cross-cultural issues effectively. These approaches focused on research, active learning, student team work, student oral presentations and peer reviews, case studies and problem-based learning. They were constructed in ways that highlighted how history and culture affects our understanding and application of science and

technology. This EAST project was supported with funding from the Freeman Foundation.

Since course text materials in English containing STEM topics from an East Asian perspective are rare or nonexistent, several of the EAST course activities were developed using WebCT ([http://www.courses.umd.edu/webct\\_overview.pdf](http://www.courses.umd.edu/webct_overview.pdf)) as a virtual class space to complement classroom participation. Student team projects led to extensive research on current themes, and students often took advantage of personal research assistance from experienced librarians both at the University of Maryland and by attending an informal research seminar at the Library of Congress.

### **A Progress Report of The EAST Curriculum Project**

During the period 2002-2004, EAST Fellows modified or created 18 courses, with a total enrollment of approximately 1600. Five courses were at the introductory level, eight at mid-level, and five were advanced courses. Most of the courses included a newly designed module introduced into an existing course. More demanding were the five newly created courses that provided an East Asian perspective to science and engineering: four of them were seminars for honors students, while the fifth was an interdisciplinary course which fulfilled a general education requirement. There were also two highly unusual types of courses: one for the Young Scholars Program, which prepares high school students for college. The other involved student groups in learning experiences in Asia or Asian students coming to College Park. One group of UMD students traveled to China and

Vietnam for a three-week study abroad experience in January 2006. In addition we note a particularly noteworthy educational experiment that involved a group of 20 visiting undergraduates from Tokyo's Meiji Gakuin University that participated in a 2-week mini-course on Landscape Architecture at UMD. The mini-course involved 10 UMD undergraduate Landscape Architecture students learning with Japanese students, including a special session at the International Monetary Fund with a group of students from the UMD honors seminar on Biotechnology in Asia. The course instructor has also developed a transnational course that will be taught simultaneously with classes at UMD and at Taiwan National University.

Finally, most of the EAST courses have been subject to assessment with the collaboration of the University of Maryland's Center for Teaching Excellence. Student response to the EAST modules and courses has been very positive. Case studies, oral presentations, role-playing and peer review provided opportunities for experiencing a diversity of cultural environments and related them to work situations. Students who have taken EAST courses report that the experience influenced them in many ways, both in regards to their understanding of science and perhaps more importantly of the role of science in a broader social, economic and cultural context.

### **Two Examples:**

1. BSCI 122: "Microbes and Society," taught by Professor Spencer Benson

BSCI 122 Microbes and Society is a non-majors general education course that introduces students

to science by looking at the roles that microorganisms play in modern human existence. To introduce students to the societal, cultural and human dimensions of AIDS, student teams are required to explore the biology, epidemiology, medical, legal and sociological aspects of HIV/AIDS in China, South Korea, Japan, Vietnam, Taiwan, Philippines or Thailand. The teams then present their finding using a standardized web-based poster tool developed by the Carnegie Knowledge Media Laboratory. In this multi-week learning module the students also construct an informational poster that is disseminated to the class. In addition student teams do an in-class presentation on HIV/AIDS in their assigned country and, individually, students write an essay comparing the epidemiology, medical, legal and sociological aspects of HIV/AIDS in their assigned country to an appropriate demographic group in the US.

2. HONR 228E: “Traditional Chinese Medicine as a Complementary Approach to Modern Western Medicine,” taught by Professor Robert Yuan

This honors seminar covers the philosophy and theory of Traditional Chinese Medicine (TCM), its therapeutic approaches, scientific validation and clinical proofs, and the obstacles to its adoption by the US health care system. In addition to the instructor, there are presentations by a number of TCM practitioners (e.g., tai chi master, acupuncturist). The pedagogical approach focuses on active learning through research projects, oral presentations, demonstrations, and role-playing supported by the use of WebCT.

## Framing a Partnership

EAST’s next step was to develop a partnership with a foreign university that could provide a platform for student and faculty exchanges and research collaboration. Again, a fundamental consideration was to create an arrangement that could be leveraged to affect many more students and faculty than those directly involved. Such a complex partnership raises three major questions: Which foreign institution? Who would be involved in the partnership? How would the partnership be affected?

1. **“Which foreign institution?”** This is a question of due diligence, a process that is too easily ignored. We began by selecting a target country. This was particularly easy for us because UMD President Dan Mote had made the development of relations with Asia, and China in particular, a priority for our university.<sup>8</sup> We first reviewed those institutions ranked among the top 20 by the Chinese government. Institutional type, geographical location, development of international links, and history, all served to rapidly shrink this to a handful of possibilities.

We decided to focus our due diligence on Sichuan University (SCU), **which has the following special characteristics:** First, it is located in Chengdu (capital of Sichuan Province, with 100 million inhabitants) in southwest China, and has been chosen by the Chinese government to be the principal research university in Western China. Second, Sichuan University, with some 70,000 students, is the result of a merger of three institutions (a comprehensive university, a school of technology and a school of Traditional Chinese

Medicine), and has particular strengths in civil engineering, hydrology, ecology and environmental studies, biology and Traditional Chinese Medicine, and is a major center for the study of the panda and of minority groups. Third, Sichuan University had already been involved in student exchange programs with the University of Washington - Seattle (UW) and Pacific Lutheran University, and several scientists familiar with China supported the idea of a partnership between UMD and SCU. Finally, there were personal introductions to SCU administrators by the exchange program director at UW. Without such personal introductions the creation of a partnership would surely have stalled. The establishment of a network was promoted by the two visits to SCU by the co-directors of the EAST project, along with EAST fellows from the appropriate colleges.

**2. Who would be involved in the partnership?** The foundation of a partnership with SCU was based on a defined need in the Chinese system of higher education: the Chinese system apparently does not have a way to educate the best and brightest of its students.<sup>9</sup> This was the principal reason for SCU's excitement about the University Honors Program at UMD, and immediate support of the Ministry of Education for the creation of an honors college at SCU. In principle, both universities agreed to move towards an exchange for a period of up to one year of 25 highly selected STEM undergraduate students. The SCU students would spend their period in the UMD Honors Program, living and studying with American honor students. The UMD courses would be selected so that the presence of the

Chinese students would have a positive impact on the learning process in the classroom, consistent with our policy of affecting as many US students as possible. The initial cadre of UMD students would be chosen from UMD's Honors Program, and would be accepted into SCU's new honors college. The theme of the exchange would be "Our Best Working and Living with Your Best."

A key aspect of the student experience we envisioned was to have each student work on a research project while attending classes. In the case of the SCU students attending UMD, this would involve a scientific project in the laboratory of a UMD faculty mentor. This would be expected to offer no big problem, after identifying appropriate faculty mentors in a variety of STEM disciplines. For the UMD students attending SCU, one would hope to use as a model the project areas that UW had identified for UW students attending SCU, which included biodiversity, work with non-Chinese minority groups, Traditional Chinese Medicine, pollution control, panda biology. However, for UMD students the situation would be more complex, partly because of differences in research opportunities for UMD students, and partly because of the language limitations of UMD's students.

Both American and Chinese scientists and engineers believed that the student projects at the two institutions could be expanded into research collaboration at the faculty level (e.g., the University of California system is looking at the possibility for a center for environmental research



at SCU). This would address President Levin's second component of a global university: international collaborations in research.

**3. How would the partnership be affected?** The proposed partnership outlined above is, by necessity, a long-term enterprise that needs to proceed by stages. The first stage is the exchange of STEM undergraduates with the adjustment of honors courses and the assignment of the students to research projects and mentors. The second stage would require joint collaboration in the development of special "global" courses in both campuses. A particular aspect of this would require faculty development workshops for Chinese faculty and their American collaborators, probably on the UMD campus. The third stage would probably involve the expansion of student research projects into major efforts that would draw on the collaborative efforts of faculty from both campuses. At this time, it is too early to envision the fourth component of President Levin's global university -- the creation of new partners -- but it is likely to involve government agencies and industrial firms interested in applying new technologies to economic growth and commercial opportunities.

The previous sections described working concepts and practical steps towards globalizing a state university. This platform has been based on curriculum change, student and faculty exchange, and student research with the establishment of a partnership with a major Chinese university. This platform can be used to move into research partnerships and the exploration of new constituencies for the university. But can such a

platform be created and allowed to grow without parallel changes in the university as a whole?

### **Can you create a Global University Inside a Box?**

It has taken four years to establish a course of study that incorporates major international themes and to begin the process of establishing a partnership with a foreign university that can provide a hub for educational and research activities in China. Most of our time and energy has been dedicated to academic, organizational and logistical issues. However, discussions at major educational conferences and, in particular, a conversation with a senior U.S. government official with extensive experience in international educational exchanges, indicates that there is a challenge that trumps all others. Can the transformation to a global university be accommodated in the existing structure of most U.S. universities and colleges?

The evolving model for a global university involves a complex series of activities, including:

- Course and curriculum design
- Transnational courses
- Faculty development
- Educational assessment and evaluation
- Internationalization of research agendas
- Language training
- Education abroad

On the one hand, almost all of these activities require the energy and creativity of faculty and researchers that typically are members of the



colleges that form a university. On the other hand, in most American institutions, the principal responsibility for international programs has been the administration of study abroad. In such cases, the Office of International Programs serves mainly as an administrative arm of either Undergraduate Studies or the Office of the Provost. In any case, it lacks the expertise, manpower and authority to initiate and coordinate the kinds of activities mentioned above. In other words, the transition to a global university is not simply a question of adding a function to an existing administrative structure; it requires a rethinking of the functions of the university and the ways in which its structure needs to change. These are not purely theoretical considerations; the existing administrative arrangements deeply effect both curriculum transformation and international collaboration projects in very direct ways. For example:

- Both curriculum change and international collaboration depend on faculty-initiated efforts and cannot be mandated from above. The momentum of such efforts requires both recognition and some degree of financial reward (e.g., a stipend).
- The success of the EAST program was directly linked to faculty development, and the same is likely to be true in the creation of joint US-China courses and the establishment of an honors college in China.
- Curriculum development and the creation of university partnerships require new funding. While the extent of funding lies within reasonable limits, it requires long-term

commitment and a high degree of flexibility.

- Study abroad is often a profit center for the institution. And yet the process of globalizing the university is an additional cost that should be integrated into the educational and research functions.
- The creation of international partnerships requires a matching of resources from both parties. This is inherently difficult because of fundamental differences in cost structures and the ways in which they can be subsidized or amortized over periods of time. This can only be resolved on the basis of university-to-university agreements.

The globalization of university education brings great opportunities but also daunting challenges that require new ways of thinking. Our efforts at UMD are the first steps in a journey without maps. Our experience does suggest that the ingenuity and energy for such efforts comes from the most important resources of any great university, its faculty and staff. But the coupling of such resources to the successful creation of a global university requires novel administrative structures and vision and intelligent leadership at the top.

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# Project Reports

## Air Toxics Under The Big Sky – A High School Science Teaching Tool

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### Abstract

A project has been developed between Big Sky High School and The University of Montana (UM) which has brought together high school students and teachers, university scientists, and county environmental health officials in a multi-layered research experience focusing on the collection and analysis of specific air toxics, and investigating their relationship to respiratory

diseases. The Air Toxics Under the Big Sky project allows students to benefit from an independent experience linking science, research, and local environmental issues. We see this as a long term project which will be built upon and expanded by future students during each new school year and as new schools are added. This project will foster a long-term scientific collaboration between UM and Montana high schools, and establishes high school students as valuable contributors to the scientific community while educating them about environmental issues.

### Introduction

Over the past decade there has been a growing trend to change the way sciences (including chemistry) are taught at the K-12 level.<sup>1-2</sup> An increasing focus seen in the educational community is the shift to more inquiry-based lectures and laboratory experiences, including discussions on inquiry-based instruction in reference to teachers' knowledge and practices<sup>3</sup>

providing insight into students' responses and opinions.<sup>4,5</sup> Laboratory exercises are being changed from 'cookbook' style preparatory experiments to 'guided inquiry' experiences.<sup>6</sup> Insight and evaluation of inquiry-type laboratory experiments have shown improvement in student's ability to ask more in-depth questions and to critically read scientific literature.<sup>7</sup>

There has also been a successful implementation of research and socially relevant scientific topics into high school chemistry and science curricula.<sup>8</sup> In this fashion, we at Big Sky High School along with University of Montana (UM) scientists have implemented a project designed to involve high school students in a locally relevant environmental research problem relating to air quality. In 2003, a collaborative project was developed between scientists from UM's Center for Environmental Health Sciences (CEHS), UM's Department of Chemistry, and Big Sky High School in Missoula, Montana with the goal of incorporating a community based participatory research project into the curriculum of a high school chemistry class. The fundamental idea is that students will achieve a far greater interest and understanding of science principles through vested involvement within the research project, as opposed to just learning concepts from a book within the classroom.

Known as "Air Toxics Under the Big Sky," high school students collect indoor and outdoor air pollution samples from multiple households in various locations throughout western Montana in an effort to understand the environmental factors that potentially contribute to the exacerbation of

respiratory conditions such as asthma. The pilot project with Big Sky High School in Missoula was conducted during the 2003/2004 school year, where a junior high school chemistry student organized a sampling program at the homes of 14 other students. During the 2004/2005 school year, two more high schools (Hellgate and Corvallis) and Salish Kootenai College joined the program bringing the total to 69 participating students throughout western Montana.

### **Research Methods**

The program focuses on the collection of Volatile Organic Compounds (VOCs) inside and outside of the homes of the students. Several of the VOCs measured are emitted from gasoline-powered automobile exhaust, and are listed on the Environmental Protection Agency's (EPA's) list of 189 Hazardous Air Pollutants. The program begins early in the school year when a UM researcher goes to each of the participating schools and provides a presentation on air pollution, and why it is important to them as inhabitants of western Montana. Following the presentation the UM researcher provides training to the teacher and students on how to correctly operate the sample pumps and sample collection media. Sampling equipment was initially donated by UM, and later supplemented by equipment purchased through smaller grants received by Big Sky High School.

Before students begin the sampling in their homes, they must first take home a description of the study which includes a questionnaire. This questionnaire is used to elicit information on potential sources of air pollution in their

households, as well as identify incidences of asthma and other respiratory diseases. After the questionnaire has been signed by the student's parent or guardian, the students can begin the sampling program.

The students simultaneously collect both indoor and outdoor air samples at their individual residences. The air sampling equipment utilized in this program are personal sampling pumps (SKC Model Number 222-3) with reusable Supelco Carbotrap 300 sorbent tubes. Each site is sampled for twelve-hour periods with samples collected in fall and winter for a seasonal comparison. The students turn the pumps on at 7 AM, in which they operate for a 12-hour period until 7 PM, capturing the morning and evening rush hours. The samples are then analyzed in a UM laboratory by Thermal Desorption/Gas Chromatography/Mass Spectrometry (TD/GC/MS). After the samples have been analyzed, the UM researcher provides the results back to the high school students to allow them to interpret the raw data.

Students calculate the concentration of the target VOCs by using the TD/GC/MS results and the pump flow data to arrive at concentrations in ng/m<sup>3</sup>. In the second semester, after students have had the opportunity to inspect their individual VOC results, the class breaks up into three or four groups. In these groups, students generate research questions using their VOC data. Using a consensus process, the student groups narrow down their questions and select one on which to propose a hypothesis for their group research projects.

At the end of the school year, a symposium is held at UM where the students present their findings to members from UM, State of Montana Health Department, and the Missoula City / County Health Department. As a public event to showcase student research, the symposium is an excellent platform for civic engagement and gives students experience in communicating scientific findings to the general public, their peers, and researchers. Following the symposium, all of the PowerPoint presentations and pictures from the event are posted on the Air Toxics Under the Big Sky website ([www.umt.edu/cehs/k12\\_outreach.html](http://www.umt.edu/cehs/k12_outreach.html)).

## Results

The Air Toxics Under the Big Sky project has several unique outcomes. From the standpoint of meeting high school science curriculum standards, participating students learn how air pollution episodes are measured and begin to understand the human health risks involved with acute and chronic exposures to air pollution. Students are also exposed to modern instrumentation and sampling equipment. Having learned basic GC/MS theory within their high school chemistry class, students apply the instrument theory in order to investigate a relevant problem which alleviates the disconnect that students so often experience. Finally students have contact with active professional researchers at UM while studying a "real world" issue. These mentoring interactions can stimulate students to choose a science-oriented career path.

From the perspective of an institution of higher learning, UM is promoting young students'

involvement in primary investigative research: measuring the levels of VOCs inside the homes of Missoula school children. This project also fits in with the larger goals of UM-CEHS of studying the role of ambient and indoor air pollution in contributing to respiratory disease.

Given the multi-disciplinary nature of the project, teachers have flexibility in choosing a direction to complement their curriculum goals. For instance, a chemistry class might emphasize the instrumentation and analytical component, whereas a biology or physiology class might emphasize the health component. For either scenario, the overriding goal of incorporating community-based participatory research into the high school science experience is realized.

### **Discussion**

One of the most rewarding parts of the project has been the long-term involvement of students and the development of meaningful peer-led learning opportunities among different grade levels. During the 2004/2005 school year, three students at Big Sky, who had been involved as samplers during their junior year, took on the role of coordinating and running the day-to-day details of the sampling program as individual senior projects. Due to the workload, these more independent and intensive efforts are appropriate for use as seniors. Two of the three students are now freshmen at UM and are employed by CEHS to work on the laboratory component of the project. During the 2005/2006 school year, four students who participated as samplers during their junior year took on various aspects of the project as seniors. Two students managed the

VOC sampling, one worked on a GPS/GIS component, and the fourth incorporated particulate matter sampling into the program under the supervision of a former Big Sky High School student, now an undergraduate intern at CEHS.

A multi-level assessment paradigm was used to assess student learning outcomes. The first level of classroom assessment for this program consists of standard exams and quizzes to check student knowledge and understanding of the basic principles of the science and techniques used for the research. A second level of evaluation consists of monitoring how well students work in groups to accomplish research tasks such as collecting, evaluating, and analyzing data. A rubric was used to evaluate student reports and classroom discussions about data collection and their ability to think critically and analyze their data. In a third level, students generated posters and gave oral presentations of their research and conclusions. This latter exercise prepares students for the rigors of a professional presentation, and provides students a forum to learn from their peers.

The Air Toxics Under the Big Sky project is multi-disciplinary, multi-dimensional and multi-linear in its strategies and partnerships for enhancing science learning. Young students learn to apply science to their everyday lives. They experience what it feels like to be an active citizen and a useful resource within their community. In this way students are exposed to the ways and benefits of community-based participatory research during a formative part of their lives.



Whether or not they eventually choose careers in environmental or biomedical sciences is beside the point. What they gain through the Air Toxics Under the Big Sky project is the growing sense of civic engagement and responsibility as they face the challenges of the future.

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# Patterns of Life: Integrating Mathematics with Science, Culture, and Art

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## Abstract

We offered undergraduate students an interdisciplinary course *Patterns of Life* that develops mathematical reasoning strategies to solve complex problems. In its most essential form, mathematics is the study of patterns; and mathematical (patterned) reasoning is the ability to think with a plan and a purpose. Students personally experience and use patterns of reasoning in diverse disciplines, and then work in groups to form a valid strategy for solving a selected problem. *Patterns of Life* is designed as guided, on-site, active-learning experiences, in cooperation with local scientific, cultural and fine arts communities. Course goals for students include: (1) to increase mathematical understanding, find mathematical thinking more relevant to their own programs and build mathematical perspectives and strategies to become more confident problem-solvers, and (2) to develop a life-long ability to reason more effectively on a wider variety of problems, including those that may be unfamiliar or seem to have no answer. The following four activities were an integral part of *Patterns of Life*: (1) biologists at the Golden Gate Raptor Observatory engaged students in the study of the raptor population crossing the Golden Gate section of

the Western Flyway; (2) National Park Service scientists, students and instructors studied ecological, environmental and cultural patterns in Yosemite National Park; (3) students studied structure and vitality of traditional human cultures through their use of mathematical patterns: model and map-making, navigation, time, recording devices, networks, linear programming, probability, geometric growth rates, binary codes, fair division and appointment, measurement and systems of influence and power; and (4) with members of the San Francisco Bay Area Fine Arts Community, students discovered patterns in artistic expression, including symmetry, balance, scale, repetition of motif, and geometry in visual arts and architecture.

## Introduction

The information and technology age is influencing design of undergraduate education even more than content. There is dramatic change in all the ways education works: how lectures are given, how students study, how research is done, how information is saved, and how students present their final projects. Accessing historical data or current research takes students only seconds, and even a beginner's search can be far more exhaustive than was possible just a few

years ago. This development in technology dictates a radical shift in the goals of an undergraduate education. Students cannot be prepared to solve the problems of the 21st century by requiring them to “be responsible for” a certain amount of proscribed information in a variety of categories. Memorization and its related study-skills of outlining and summarizing have diminished importance as an end result, and are giving way to skills that have less to do with remembering information and more impact on building the quality of students’ thinking skills. As many universities are discovering today, we need to redesign the library and research experience, based on our rapidly growing access to information.

In this paper we describe *Patterns of Life*, a series of three integrated courses at Dominican University of California designed to engage students in understanding and solving real problems through recognition of patterns. The primary value of the series is in its process more than its content; students from various departments gather and model data together, and instructors learn with students. On-site, direct contact with professional scientists and artists creates an active, cooperative learning community. Patterns are integral to the practice and growth of all professions. They form the anatomy of the investigation and learning process.

Thoughts and conclusions are the product of the mental process of arrangement. When we organize facts or ideas with the help of mental or physical symbols, when we chart a course,

determine our preferences, weigh our alternatives, or recognize balance and symmetry, we are processing information into patterns that facilitate understanding. When we categorize, connect abstraction to meaning, plot a chain of events, create tactics or devise a strategy, we are thinking mathematically.

*Patterns of Life* is a practicum course, designed to promote student input toward learning the mathematical skill of analytic, patterned reasoning. Students investigated how patterns are discovered and used to solve problems. They explored and invented patterns themselves. Students learned analytic thinking skills by thinking analytically. Mathematics served as both the wind and the sail.

### **History and Design**

*Patterns of Life* was born in the belief that mathematical patterns are fundamental to all aspects of nature, human life and the human condition. The strength, sustaining power and vitality of all cultures lie in the recognition, generation and adaptation of mathematical, analytic reasoning patterns. This project began in 2002 as a joint lecture and discussion for students enrolled in mathematics and art classes. Participating instructors encouraged students to form connections between academic studies and concepts learned in one discipline, and the questions and challenges presented in other areas.

*Patterns of Life* was supported by Dominican University of California and by the SENCER Summer Institute (Science Education for New Civic Engagement and Responsibilities.) Throughout all stages of development, *Patterns of*

*Life* was guided by the technological and quantitative literacy goals of the New Liberal Arts Program of the Alfred P. Sloan Foundation.<sup>1</sup> We delivered *Patterns of Life* to infuse and promote quantification, analytic reasoning and application of technology throughout the curriculum. Mathematics becomes much more than calculation; it becomes a way to analyze and strategize, to expand perspective and facilitate problem-solving.<sup>1</sup>

In addition, the course directly reflects ideas found in *Implication of Learning Research for Teaching Science to Non-Science Majors*<sup>2</sup> and design elements and goals that are components of *Mathematics Across the Curriculum at Dartmouth College*<sup>3</sup>. Instructors also used ideas from *Team Teaching Methods*<sup>4</sup> and from *Models for Undergraduate Instruction: The Potential of Modeling and Visualization Technology in Science and Math Education*<sup>5</sup>.

### **Components of *Patterns of Life***

*Patterns of Life* is a true hybrid composed of three courses: *Patterns in the Natural World*, *Patterns in Cultural Organization*, and *Patterns in Artistic Expression*. *Patterns of Life* uses many of the principles of the discovery learning philosophy that have been successful in elementary education: learning is regarded as both a product and a process; each course emphasizes active, hands-on involvement and use of scientific and computer technology; and it is a common goal that students discover the structure, power and beauty of mathematics through direct connection with current research and fine arts projects. Each course contains cooperative, intensive, extended

learning experiences designed for deeper understanding of the environment, artistic expression, and cultural heritage through the study of mathematical reasoning strategies.

We believe the course helps prepare students for the modern world. Problems are solved by the courage and inventiveness of individuals who think carefully and analytically, and who dare to take huge leaps of imagination. *Patterns of Life* is designed to foster this kind of thinking and this kind of mental ability.

In works of art of all kinds, there is often what is termed a “dialogue” between form and content. The structure and physicality of an object relates intimately to its impact or purpose. Both form and content of *Patterns of Life* are unique and contribute specifically to the goals of the course.

In *Patterns of Life*, students work on-site with scientists and members of the professional fine arts community. The combination of student and professional is a natural one: it provides students a first-hand view of problem-solving strategies and offers professionals a dialogue with students of varying perspectives.

The course serves to humanize students’ views of mathematics, to widen the scope of their academic investigations, and to foster insight and creativity, generating responsible citizens who make sound decisions. Students develop perception, critical thinking skills and problem-solving strategies that are applicable in any discipline. They learn to think more mathematically and to expand the concept of what is mathematical; and they improve their

overall academic performance by enhancing their ability to visualize the mathematical component of other studies.

The vision and guiding principle of the course is that it must be organic: work must be closely tied to the natural and cultural world, and student involvement and contributions must cause the course itself to expand in complexity and practicality. National Park Service scientists and members of the San Francisco professional fine arts community engaged our students in genuine, guided scientific research and creation of art. Course instructors and invited members of the Dominican faculty and administration worked with them.

All course activities have a double focus: student work is on-site and original; and student work is ultimately personal, helping to build valuable thinking skills. Students study reasoning strategies by participating in scientific investigation. They construct models and replicate mathematical devices that contain, symbolize or transmit a culture's knowledge or beliefs. They create art, and they use technology to interpret and present data.

They learn to ask analytical questions, to gather quantitative information, to contribute to group work and to value the contributions of others. Students discover adaptability and versatility of problem-solving strategies in a variety of disciplines. As they work alongside their instructors and members of the university, students witness the academic intent of life-long learning. Unique skills and background give every student a separate status within the group.

Working together as representatives from various parts of the campus community generates high energy and a cooperative spirit that is greatly valued at Dominican.

Students are challenged to keep mentally agile and flexible, to develop an analytic focus, and to cross-reference with each other. Course activities build students' ability to use and invent strategies by which problems are analyzed and solved in the world of constant motion and process. Each student will confront Johann Kepler's realization that "everything is shown us, and nothing is explained." The mathematics in the world is not so much applied as it is illustrated, in a continuum that contains our history and all our hopes for understanding the intellectual tenor of our times.

### **Challenging the Students**

All components of this course place unfamiliar demands on students. Academic skills conventionally honed during the undergraduate experience such as note-taking during lectures, recall of a given body of information, writing assignments from a textbook and studying for exams are all minimal or nonexistent. Working in the field is a unique way to learn, and students who are confident and successful in a traditional classroom situation can feel less secure. Also, it can be daunting for students to be working with classmates they do not know and who do not share the same interests. Serving as the representatives of their own discipline, students engaged in each learning project from their unique perspective. As the course progressed, student participation on site and in class

discussions became increasingly more aligned with their own major fields of study.

### **Student Success**

There were multiple components of success in *Patterns of Life*. The course required an unusual commitment of energy.

Mental energy was needed “in the moment” while working on site and in group discussion and presentations. Physical energy was necessary at every active-learning site. Students climbed, hiked, hauled, waded, cleaned gear, released nets from a boat, made campfires, carried boxes of food, sleeping bags and cameras, and cleaned up the group campsite. Off-campus activities in unfamiliar surroundings and conditions call for a high level of emotional energy in the form of patience, consideration and accommodation to others. Netting fish and sleeping out under the stars were easily accomplished and easily enjoyed by some students; for others they were a significant challenge and a very satisfying accomplishment.

During the course students became more active participants in their own learning. Their field book entries expanded to contain group meeting notes, lists of quantitative questions on various topics, statistical analysis assignments, outlines for research proposals, results of on-site group work, and copies of databases accessed. In the art class, students kept a sketchbook of assignments and also completed several large drawing or painting projects, evaluated by the teaching faculty.

As a final project, *Patterns of Life* students presented group proposals that applied the research process to a problem of current national or global concern. Instructors and students completed a Listeners’ Response form, giving comments on the use of technology, the discussion of the problem and the clarity of the statistical analysis. This response form also asked student listeners to write as clearly as possible, the research question and the conclusions presented by the group, as a method of confirming that the question and results were presented distinctly.

Specific skills graded by the instructors also include: method of data collection, access of scientific literature through the World Wide Web, access of relevant databases (some sites were provided), appropriate statistical analyses, use of graphs, formulation of hypotheses, and valid construction of the research process.

Specific presentation criteria were also evaluated and graded, such as participation by every member, speaking loudly and clearly enough, and directing the explanation toward the listeners rather than toward other group members. During the second series of presentations, instructors and student listeners noted improvement in these skills for every group. Also, listeners’ response pages showed students were better able to correctly and concisely state each group’s research question and results.

Students were directed to read less of their presentation; they were asked to reserve the slides for pictures, graphs and statistical analyses and not to make slides full of written information.



However, every group continued to display written information, which they then read.

### **Technology Week: Tools and Skills for the Course**

*Patterns of Life* had the good fortune to connect with two generous faculty members from other departments and facilities on campus, who agreed to help our students solidify the foundational skills necessary to blend statistics and technology into their research.

For the first week of the semester, students worked together to learn how to transfer information between word processing and spreadsheet software. For our Liberal Arts, Communications, History, English, Nursing, Teacher Preparation and Music majors, it was a less familiar experience to present patterns of data found through original research. Biology majors were more capable in these skills, and they were asked to help students who were less familiar with organizing data. Throughout the course, the guidance and instruction shared between students became a very valuable interaction. Students in *Patterns of Life* created interdepartmental connections that greatly enlarged the experience for everyone.

### ***Patterns in the Natural World: Fish, Frogs, Raptors and the Pine Forest***

The San Francisco Bay Area is home to many outstanding natural science and environmental study opportunities. During the Natural World component of the course, our students climbed Hawk Hill overlook at the Golden Gate Bridge to view raptor migration, studied wildlife and fire management in Yosemite National Park, and dragged nets and trapped fish at Tomalas Bay in

the Point Reyes National Seashore.

The Raptor Observatory in the Golden Gate National Recreation Area monitors and studies birds of prey in the Marin headlands section of the Western Flyway. Scientists helped Dominican students learn the distinguishing characteristics of the raptors' appearance and flight patterns and explained raptor observation, banding and release activities (Figure 1). The Observatory also gave our students access to data covering several years of observation, banding and tracking work.

The students learned the process of "data mining" to search for patterns in the life and movement of these raptors. Working in groups, they formed hypotheses in a chosen area of investigation, analyzed morphometric data, used statistical analysis and graphic components to explain and test it, and designed a PowerPoint presentation to share results (Figure 2). Before working at the Raptor Observatory, students learned to gather information in relation to specific, quantitative questions. Generalized questions such as "How difficult is it for a raptor to cross the Golden Gate?" can best be investigated by defining specific questions concerning the species, the distance it has traveled to reach the overlook, the method of flight, the amount of wind, and how many attempts the bird may have made recently. To keep the work focused, students were encouraged to begin their presentations with "Our investigation is directed toward answering the question..." or "Our presentation focused on the question..."

At the Point Reyes National Seashore a marine biologist helped students gather samples of fish life in a small bay by hauling nets. Students released nets from the back of a boat while others in waders caught and dragged the nets toward shore, and others collected the trapped fish in buckets. Back on campus, students used Simpson's Diversity Index and a rarefaction curve to approximate the number and type of marine life in the bay.

*Patterns of Life* students, instructors and faculty guests spent a fall weekend camping and studying in Yosemite National Park. We hiked to high-elevation waterfalls, learned to build a campfire and slept out under the stars. We met with National Park Service scientists to study bear management, meadow restoration, non-native frog populations and wildfire ecology. A Federal scientist with 40 years of experience as a fire ecologist conducting research in the park explained forest ecosystem processes. The students visited a location untouched by fire for over fifty years, another that burned about 10 years ago and one that burned just last year. They learned that variations and growth patterns in plant species contribute to or determine the type of fire that will occur in each area, and that burn areas continue for many years to evidence the type of fire that occurred there, as well as provide clues for future fire-ignition risk. Each group of students worked in a roped-off section of forest or meadow and collected information on species, spacing, growth patterns and the amount of dead material on the ground and in the trees. Back on campus, each group analyzed the impact of previous fires on the forest structure and

composition in their section.

At every field site, professional scientists guided the work, and two leading ideas structured the experience: every student actively participates in the research experience; and as the students learn about the project, they learn procedures and format of scientific investigations. A National Park Senior Scientist consulting and working in cooperation with Dominican kept the work focused and valid. The double impact of scientific progress is to increase both our understanding of the world and also our capability for influence. Knowledge of the world's natural patterns may allow us to take full advantage of the human possibilities for exploration, to learn about earth's history and future, to fight disease, to enhance our environment, to predict the consequences of our actions, and perhaps to save us from ourselves.

#### **Ethnomathematics: Culture held in Human Constructs**

Students concurrently enrolled in *Patterns in Cultural Organization*. Mathematical patterns are integral to all parts of human organization and human endeavor. Patterns found within the structure and operation of any society, provide safety and definition, and allow an openness and freedom for people who live together. The readings and constructions of this course were chosen to add complexity and texture to students' understanding of the ways cultures define themselves and provide for continuity and prosperity. Students studied structure and energy as maintained and preserved in the strategies and devices of a cultural group. The course presented

a multi-cultural view, and emphasized the seminal nature and importance of mathematic concepts in all cultures.

Mathematical patterns studied in each section were related to Western mathematical concepts. When studying the Tamil Nadu<sup>6</sup> people in southern India, they recreated the sand drawings called kolam that reflect the culture's values, rituals and philosophy. Geometry is currently a burgeoning part of mathematical studies in our own culture due to its facility for representing flow and network connections, and students analyzed kolam designs in terms of Eulerian paths, fractal design, Sierpinski and FASS Curves, and edges and degrees of each vertex. The Tamil Nadu use of units and subunits in recursive patterns was the basis of class activities drawing "turtle graphics" such as those used to introduce children to computer language, and samples of original array languages, in which final symbolic meaning is built up through successive patterns or according to specific rules of formation.

The Navajo and Sioux<sup>7</sup> are Native American people who hold unique views of the dynamic nature of the universe. The class studied the idea that nature moves and develops in circles, and that human life well-lived will result in accomplishment of an individual's goals and will show evidence of circular patterns. In Western mathematics, the Jordan Curve Theorem delineates a simple closed planar curve that determines two regions of which it is the common boundary. Following is an example of a student response to a class activity, illustrating the course of a man's lifetime and reflecting the Sioux

nation's belief that the power of the world works in circles (Figure 3). Students used a variation of a Jordan curve to map a lifetime. The darkened circles within each curve represent the aspects of the individual's life; his many accomplishments are grouped within a separate curve, his family and friends in another, and the many plans, wishes and dreams he had in another. Hopefully his life would continue through turns and circumstances that would give rise to more curves full of circles indicating richness and satisfaction. But his life ended within a circle, and only the potential for such a growth of new curves is shown. The life was over before they could develop.

The culture of the Incas in South America was a primary choice of study for this course because of its complexity, success and place in history. Although the Inca culture flourished over 600 years ago, their society of approximately 4 million people was highly organized. They were intense data keepers and sent many messages and records throughout their vast empire concerning the governing system, work force, taxes, population count, resource allocation, peace negotiations, laws and history. They had no written language. All records were encoded on arrays of colored knotted cords called quipu.<sup>7</sup>

Students studied the quipu construction and method of communication and also its similarity to modern day practice of using numbers as both labels and quantifiers. Number labels such as social security numbers, ISBN book identifiers and product codes are common in our society and will increase as we continue to use computers to

store and process numeric information. Quipu were not calculating devices; they served the Inca in the way the record-keeping aspect of a computer serves our society today. Because cotton was abundant, the Inca used cotton cord for this logical-numerical recording. Students in *Patterns in Cultural Organization* used cotton rope and cord to construct messages in the manner of those that were sent throughout the Inca Empire. Each group used the color and length, the connection of the rope, the placement of each piece of rope, the spaces between cords, the types of knots and the placement of each knot to construct an 8-foot long quipu with encoded information.

Students developed a more complex understanding of mathematics, an appreciation for the inventiveness of the Inca and an understanding of how numbers used as labels are increasing our ability to store and relate data in the Communication and Information Age. Ultimately the course goal was to open students' awareness to the fundamental and powerful nature of mathematical ideas in any culture.

The existence and success of traditional and complex cultures alike depends on mathematical ideas such as cooperation, communication, cosmology, divination, time and continuity, and systems of influence, justice, and power. It is a primary goal of this course that Dominican students recognize the structures and processes inherent in other cultures' systems that can be modeled and perhaps redefined and reinvented to serve us.

### **Patterns in Art: The Web in Which Every River Flows and Every Life is Lived**

Led by a fine arts professor at Dominican, *Patterns in Artistic Expression* combines study and creation of art with access to artists of diverse media and creative methods. Students have direct access to professionals in the visual and performing arts. They study evidence of process, motion, symmetry, opposition, balance and weight in varied art forms, and learn the relationship of form and content. They discover that in the creation of art, artists often use the systems, theories and historical models of mathematics as a starting point; and that measurement, proportion, patterning, iteration and geometry are equally instinctual to other more recognized artistic sensibilities, and incredibly rich as grounds for artistic production.<sup>8</sup>

Artistic expression can make a pattern easier to understand. In this course students relate the concepts of motif and abstraction to patterns constructed in various materials. At an exhibit of sculpture in natural materials, students talked with the artist about motion and representation of the cycle of life in materials and forms that are usually considered stable or permanent such as rocks and mountains; students then created a series of drawings that were representative of forces of change they recognized in their own life, life of a culture, or that related to their own field of study. In the initial offering of *Patterns of Life* students also toured the campus grounds with the Director of Environmental Landscaping at the University. They learned how the present requirements and growth of the university affect the property, and how the form and function of

the land interrelate. By incorporating natural forms into their art, studying art of other cultures, and meeting art in many forms, students learn that mathematical thinking can be applied in domains other than numeric. The course could be extended into the literary arts, guiding students to analyze patterns of rational argument and identify the pathways along which valid reasoning formed.

### **Assessment: Looking Back One Year**

*Patterns of Life* was delivered as a series of discovery-learning situations. The activities, requirements, challenges, and partnerships built into the course can place students on unfamiliar ground. Future offerings of the course need additional class time built into the schedule to more thoroughly delineate what the students will see and how they will participate. This will also allow more opportunity for students to discuss and help each other prepare for situations such as wading in moderately deep water, hiking, and camping without tents.

Many students are unfamiliar with active research participation. Students proficient at taking notes from a text are not equally comfortable taking notes in the field, and they may be unclear about what to write. Instructors suggest that in addition to the prepared student guides and outlines of the research process, it might also be helpful to students if instructors worked on an aspect of the research at the same time. A useful class activity during the first week specifically addressed the formation of scientific questions, which helped keep students' field notes focused.

In assessment survey responses at the conclusion of *Patterns of Life*, every participant replied positively concerning on-site work at research locations, talking with scientists and artists and working together in small groups. Also many students considered the tech-week meetings in the labs to be helpful; some students considered these sessions to be absolutely necessary and to have greatly increased their ability to participate in the course activities.

Several factors presented complications. Some students had difficulty clearing their schedules for full participation in off-campus events and group meetings. For students not returning home before the trip at the end of September, the course required preliminary preparation for clothing and equipment to be brought to Dominican in August. Several students needed to borrow appropriate camping gear to bring. Any time students assemble off campus, there are logistical complications that need to be addressed and resolved ahead of time. Students involved in a course clearly outside the parameters of regular campus life can feel apprehensive about leaving the routine of lectures, cafeteria dining, textbook reading assignments and studying for tests.

These reservations tended to fall away as students began to enjoy the work and community. Students whose paths might not have crossed, became friends. Instructors worked with students who would not have been in their classes or departments. Scientists and artists noted the energy in the group, and students who had been introduced to an area of study they would like to investigate further—art, marine biology and

wildlife management— took the opportunity to ask about professional preparation and summer internship or volunteer positions.

Final research proposal presentation days had a seminar-conference atmosphere that instructors felt held moments of high-level community learning. Students suggested there be only one presentation a day instead of two as scheduled, allowing more time for questions and discussion.

Two main concerns in the presentation of the course are the number of students, and the students' preparation prior to the start of the course. *Patterns of Life* was presented as a practicum; larger student enrollment can result in less individual involvement. Also because there are equipment and clothing requirements, the class list must be established early and finalized, so that course information can be mailed during the summer to all members. The instructors recommend the class be limited to 20 students, as compared to the 33 that registered.

Everyone considered having a diverse group of disciplines represented in the student registration a positive aspect of the course. At the heart of every learning experience in *Patterns of Life*, there was a strong reliance and dependability factor intended. Participating students' diverse talents and learning styles magnify the experience for others. Every individual's varied perspective and questions serve to increase every other member's mental landscape.

### **Tracking Student Skills**

As part of the course plan, the Instructors chose the following skills and abilities as indicators of

student success. They encompass the product and process of student participation in the learning activities presented in *Patterns of Life*.

*Development of Mathematical Literacy and Technology Skills:* Students were very successful in gathering and sorting numeric information; throughout the course, they showed increased ability to represent data in statistical form, and to write quantitative questions. Recognizing trends and using equations to model process and change are more complex skills that continue to develop with increased experience. Students were very successful with basic statistics such as taking a biodiversity quotient for a section of San Francisco Bay, but were less capable when trying to interpret information that may or may not be significant enough to indicate a pattern. Students recognized that valuable information or conclusions can also be formed when information does not support an initial hypothesis. Formation of hypotheses was an area that showed major improvement, and because it is so integral to analytical reasoning, all instructors considered student improvement in this skill fundamentally valuable.

Instructors discovered that some of the strongest thinking skills developed in *Patterns of Life* were the ones most easily translated throughout all disciplines, and we are gratified that student work in any field may be stronger or more productive as a result of this experience. Students practiced the skill of looking closely and carefully by separating sections of information or by drawing what they are looking at; they learned to ask quantitative questions by writing and



rewriting questions in valid analytic form; and they learned techniques for analyzing hypotheses that will help them solve problems in any subject area.

Technology skills also increased: students accessed databases, gathered previous research, created charts and diagrams with their own research results, read and translated numeric information, and used computer programs to design their own presentations. Many of the photographs embedded in the presentations were taken by the students on location.

Participation: Students represented departments of business, communications, nursing, psychology, history, music, biology, and teacher preparation. Within each group, students relied on each other and learned by cooperation rather than competition. Instructors saw evidence of diverse input in the final proposals, and considered the blending of research into traditionally “under-represented” major study areas to be a very positive aspect of the program.

*Understanding Quantitative Reasoning Strategies:* Students wrote outlines that followed valid, recognized components and process of research; they accurately calculated statistical analyses; they worked with a plan and under the guidance of the National Park Service scientist working cooperatively with Dominican; and they wrote proposals in the same format used by national park service scientists. In the Art class, students’ work showed real understanding of motif, pattern and perspective, and the connection of these concepts with mathematical reasoning.

*Understanding Mathematical Ideas of Other Cultures:* Students were inventive and drew a wide range of maps, charts and models. Instructors especially valued mathematical representations drawn from the student’s own life or major area of study, such as a student picture graph using the Jordan Curve theorem to illustrate the structure and living arrangement of the family unit of the Masi people in her homeland of Tanzania (Figure 4). The student explained that Masi consider any land they move across to be Masi Land. Each of the wives builds a shelter for herself and her children; the homes cluster together in a roughly circular formation. The man moves throughout the group of homes, staying at night in whichever one he chooses. The interior space in the cluster is reserved for cows. Cows are of primary importance to the Masi; her explanation included the common belief that if you have no cows, you have nothing. The cows in the center are the property of the man whose cluster of homes encloses them. If they wander off or are taken by someone else to another cluster, they become the property of the finder. The circle of homes is convenient for the husband, it helps secure the cows at night, and it marks the boundary of his wealth and authority.

*Using Mathematical Problem-Solving Strategies:* Final research proposals showed students had increased skills in collecting valid data, interpreting data and forming hypotheses. Student research and statistical analysis were well done and were understood by the student audience. Instructors felt the logistics and effect of the proposed solution needed more thorough explanation and development, in every

presentation. Social programs were suggested without enough implementation strategy. During the following discussions, listeners raised reasonable questions that had not been addressed by the group's strategy. In all group projects, students' analysis of the problem was more thoroughly and clearly represented than the proposal for solving, perhaps because the analysis aspect more closely aligned with other more familiar assignments throughout their curriculum.

### Conclusions

Effective, life-long learning is an active, constructive process. The "Cognitive Revolution" asks that learners be able to apply past experiences toward the understanding of new situations and problems. Hands-on, primary learning experiences encourage each student to participate from their own previous knowledge and skills, constituting a very positive aspect of the learning experience. Learning is a process of constructing frameworks of information blended with experiences. This scaffolding is constantly being constructed, demolished and reconstructed by the brain. Human beings have an ability to gather knowledge about specifics and construct frameworks that encompass general understandings. These understandings are very individual and unique; they evolve from personally selected specifics and the resulting constructions are personally meaningful and satisfying. Cross-disciplinary, constructed learning builds knowledge that is inwardly born and results in students becoming more effective thinkers on a wider variety of problems. The more clearly a student confronts a problem and

has participated in finding a pattern contributing to understanding or resolution, the more effective will be his or her thinking on other problems. Also, scientific advancements often mark the intellectual climate of an era, and citizens who have limited analytic reasoning skills can be cut off from the intellectual tenor of their times much the same as a person who cannot read.

We offered *Patterns of Life* as an adventure, an experience and a challenge to every student, to build a personal view of the world that provides intellectual and aesthetic satisfaction, and to become a citizen prepared to help solve public issues that require mathematical literacy, in order to more responsibly participate in keeping the democratic process alive. Throughout *Patterns of Life*, course activities are designed to show the strength of humanity in our diversity of interests and strengths, and to acknowledge and appreciate all that cultures have in common. The means by which societies establish themselves and become successful are of value to all people dedicated to the goal of knowledge in service to human rights and human progress.

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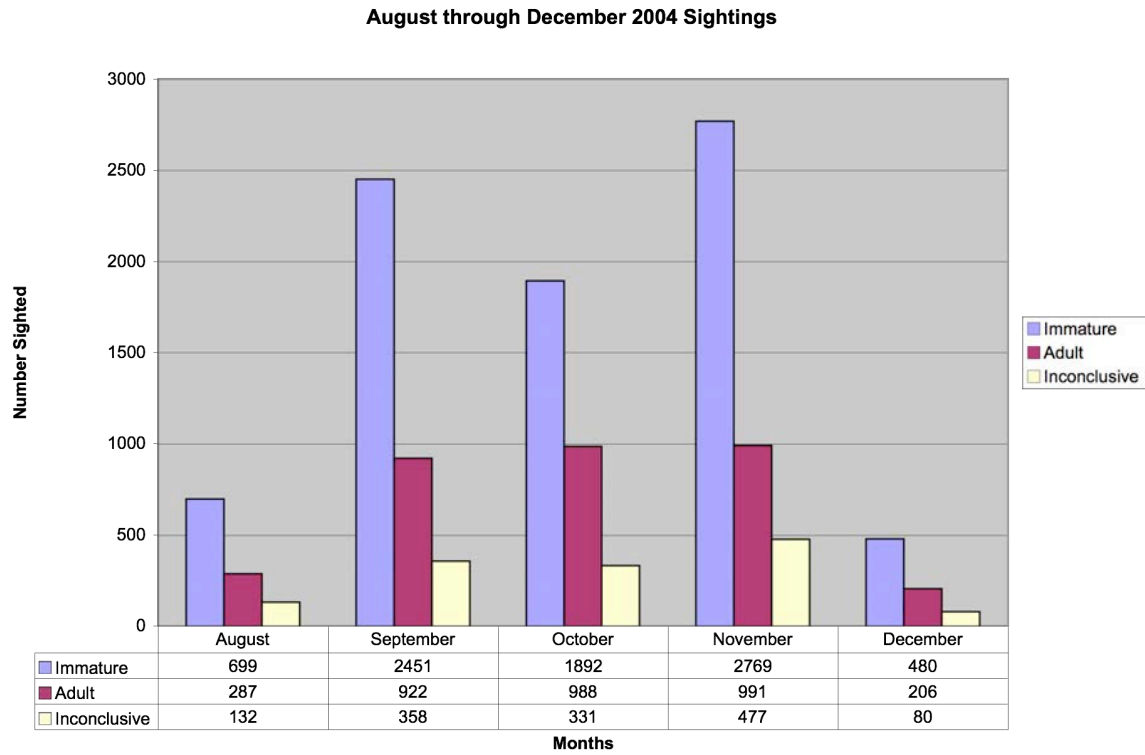
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**Figure 1: Red-tail Hawk in flight**



**Figure 2: Hawk Sightings of 2004**



**Figure 3: Jordan Curve Mapping of a Lifetime**

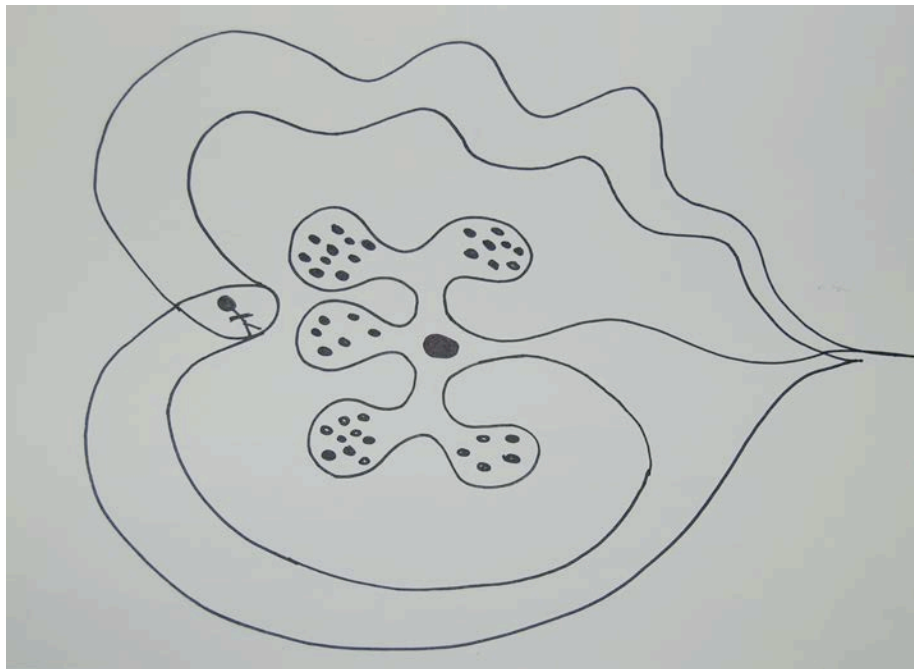
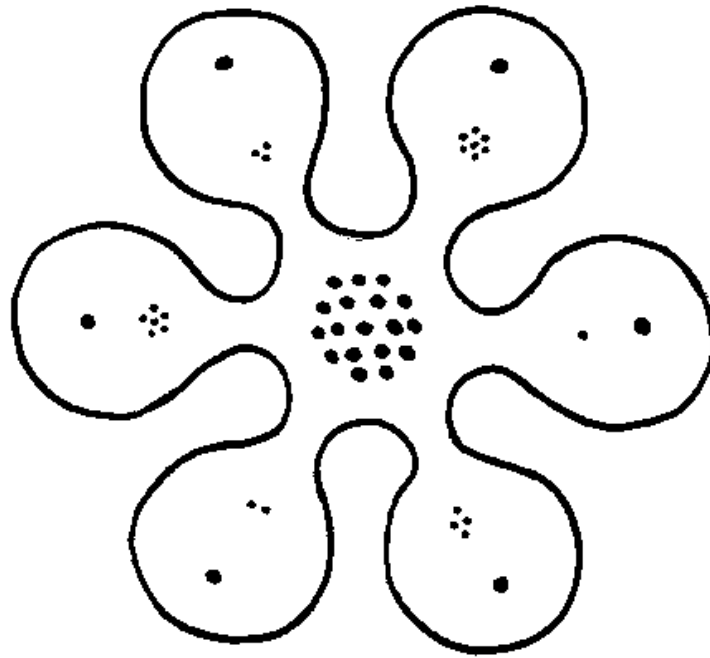


Figure 4: *Jordan Curve Mapping of Masi Homes*



# Teaching and Learning

## **An Environmental Dilemma: A Case Study in International Immigration**

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### **Introduction**

Case studies that place students in the roles of stakeholders in environmental issues are an effective way to elicit discussion on complex and controversial issues in science. In such exercises, students are presented with differing views on environmental issues and use their content knowledge, critical thinking skills, and personal worldviews to formulate viewpoints on and engage in peer discussions of civically-important science issues such as human-induced climate change, the conservation of biodiversity, and human population growth.

The case study presented places students in the role of a fictional Sierra Club member during the highly-publicized board elections of 2004 that focused on the organization's stance on U.S. immigration policy. The case is designed to have students: evaluate the economic, demographic, and environmental implications of immigration on the United States; consider the issue in light of their own families' immigration history; and evaluate existing U.S. immigration policies based on this information. International immigration is currently relevant, as recent debate concerning illegal immigration in the United States has once

again forced this controversial issue into the spotlight. The case is designed for use in introductory courses in environmental science, but could be used in many disciplines.

This paper will provide the case overview, suggestions on presenting the case, and a list of supporting resources. All characters in the case are fictional and any similarities to actual individuals are purely coincidental.

### **Case Overview**

It had been a bad day for Karen Christini. After enduring paralyzing rush-hour traffic following a miserable day at work, she was ready for some hard-earned relaxation. But no such opportunity availed itself, for tonight was decision night. While in college, Karen had joined the Sierra Club, a national organization dedicated to environmental preservation, with her boyfriend Andrew. Andrew lasted less than a semester, but her Sierra Club membership was still going strong as she entered her mid-thirties. And on this chilly April night it was the Sierra Club that demanded her attention.

The Sierra Club's budget, political lobbying, policy stances, and preservation efforts are



directed by a group of 15 elected board members. Board elections were typically not national news, but this election was anything but typical. For some time, the membership of the Sierra Club had been divided on the issue of U.S. immigration and its relationship to human population growth. In 1998, a movement within the organization put forth a proposal to replace the Sierra Club's historic "no position" stance on U.S. immigration with one that advocated reductions in the number of immigrants admitted to the United States to reduce environmental impacts associated with growing populations. Sixty percent of members rejected the proposal and the Sierra Club continued advocating controls on global human population growth with a neutral policy towards U.S. immigration. In the following years, however, three members that advocated a stance towards reduced immigration were elected to the board. There were five open seats this year, so the election of five reduced-immigration candidates would give the group a majority on the board and the power to steer the organization.

Karen had not come to a decision on her votes and the ballot had to be in the mail tomorrow. As she had done many times over the past few weeks, she sat at the kitchen table hunched over her Sierra Club ballot and began running her fingers through her hair, trying to use the rhythmic motions to force a decision from her head. She reviewed the major points of view one last time, hoping yet another analysis would yield a conclusion.

On the one hand, she thought, the advocates of reduced immigration had a point. The United

States absorbs around one million legal immigrants and several hundred thousand illegal immigrants a year, and these immigrants have average birth rates about double that of U.S.-born citizens. Unlike most industrialized nations, the population of the United States is expected to grow from around 292 million (in 2003) to about 422 million in 2050 – and up to 70% of this growth is attributable to immigration. Given the high-consumption lifestyle in modern America, this population growth will lead to increased impacts on the local and global environment, exactly the things the Sierra Club aims to reduce.

Proponents of immigration reduction also argue that international immigration causes talented and educated citizens of developing nations to leave for industrialized countries, slowing the industrialization that leads to lower birth rates. They further contend that immigration has economic costs when wages earned in the United States are sent home by immigrant workers.

But, she thought, those that support current immigration policies make several convincing arguments. They argue that while international immigration increases the U.S. population, it slows the growth of the global human population as the children of immigrants have birth rates like that of other U.S. born citizens – rates likely far lower than those in the immigrant's native country. Immigration proponents also claim that immigration improves cultural awareness in the United States, thereby promoting environmental sustainability in these countries through foreign aid initiatives.

Immigration advocates say that the United States should always be a "safe harbor" for victims of human rights abuses or armed conflict around the world. They also claim that immigrants infuse skills and labor into the workforce and improve the economy of the host country. Karen's family was a classic example. Her grandparents emigrated from Sicily to the vibrant Italian-American community in New Haven, Connecticut, in the early 1900s and prospered in subsequent generations through a dedication to education and hard work.

Karen sat back in the chair and sighed heavily. The epiphany, the tiebreaker, or the revelation she sought had once again eluded her. This wasn't going to be easy. She sat forward, propped her elbows on the table, stared at her ballot, and began running her fingers through her hair...

### **Suggestions on Presenting the Case**

I have found this case to be highly effective in personalizing the issue of immigration for students and eliciting vigorous and constructive discussions in student groups. Prior to conducting the discussions, students are provided with content on U.S. immigration from in-class meetings and/or outside readings (list provided below) to ensure knowledge of current policies. Students are also given several weeks to research their own family's immigration history, as this is an important component of the discussions.

I have seen that lively class discussions are promoted by *not* telling students of the 2004 Sierra Club election results (all five open seats were won, by large margins, by candidates espousing a neutral immigration policy) until

after the discussion, as this provides a sense of uncertainty that stimulates productive conversations.

After reading the case, students are presented with questions that promote introspection and group discussion, such as:

*If you were Karen, what would you do?*

*Describe how your family's immigration history in the United States. Did an understanding of this history affect your views on the subject?*

*Do you think the current U.S. immigration regulations are appropriate? Explain why or why not. If you think current immigration policies are inappropriate, provide specific suggestions on how they should be modified.*

In my traditional classes, students discuss the issue in groups of 5-8 individuals. They then write an opinion paper that summarizes the group discussion and details the student's views on the issues, citing information from the provided resources when appropriate. The same approach is used in online classes, with asynchronous bulletin-board discussions substituting for the in-class group discussion. This case has shown itself to be an effective and engaging way to present and discuss the controversial issue of immigration and human population growth, and enable students to personally connect with a complex and pressing issue in the modern world.

## Supporting Resources

1. Immigration: Shaping and Reshaping America (2003). *Population Reference Bureau*. Accessed August 23, 2007 from Web site: <http://www.prb.org/pdf/58.2ImmigrShapingAmerica.pdf>

Excellent one-stop reference for material on U.S. immigration.

2. The New Americans: Economic, Demographic, and Fiscal Effects of Immigration (1997). *National Research Council*. Accessed August 23, 2007 from Web site: <http://www.nap.edu/html/newamer/>

Details the economic, social, and demographic effects of U.S. immigration.

3. Immigration and Immigrants: Setting the Record Straight (1994). *The Urban Institute*. Accessed August 23, 2007 from Web site: <http://www.urban.org/UploadedPDF/setting.pdf>

Individual chapters are good overviews of the many aspects of immigration.

4. *Federation for American Immigration Reform (FAIR)*. Accessed August 23, 2007 from Web site: <http://www.fairus.org/>.

FAIR advocates limits on international immigration to the United States. Site contains editorials and other immigration-related content.

5. Ways and Means: Moving On (1998). *Sierra Magazine*. Accessed August 23, 2007 from Web site: <http://www.sierraclub.org/sierra/199807/ways.asp>

Editorial supporting the 1998 affirmation of the Sierra Club's neutral immigration policy.

6. Immigration and the Sierra Club: Did the Fuss Matter? (1998). *Center for Immigration Studies*. Accessed August 23, 2007 from [http://www.cis.org/articles/1998/IR33/sierra\\_club.html](http://www.cis.org/articles/1998/IR33/sierra_club.html)

Editorial criticizing the 1998 affirmation of the Sierra Club's immigration policy.

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