

# Standards as an Element of Liberal Education Fosters Scientific Literacy

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## Introduction

Standards are a ubiquitous aspect of life in modern society, and yet their sheer existence is frequently unrecognized or completely invisible to the average citizen. Standards play a vitally important role to the functioning of our current day globalized economy, have striking impacts on environmental and human health, and can have significant social implications. Yet, standards are so taken for granted that they rarely are the topic of consideration among circles beyond their negotiated creation and implementation. Actively engaging students with standards, as an embedded element of an undergraduate general education curriculum, provides an opportunity to shine a light on this largely unrecognized aspect of modern society, and can support the achievement of foundational learning outcomes recognized as essential to a broad liberal arts education.

The development of *standards literacy*, the ability of students to explain what technical or regulatory standards are, the combination of factors that potentially impact how they are developed (scientific, social, economic, lobbying, etc.), and the potential implications of their implementation (environmental, economic, social, political, etc.), is arguably an essential component of many degree programs and disciplines. Engineering is among the most obvious disciplines, in which students must develop a comprehensive level of standards literacy. In the development and manufacturing of consumer goods, or in the design, construction, and maintenance of roads, bridges, dams, and buildings, there are literally volumes of standards that must be adhered to in order to assure quality production and the health and safety of consumers and citizens. There are also obvious and clear applications of standards literacy for Communication majors, Agriculture Technology majors, and the majority of STEM based majors, each of these being disciplines where technical and regulatory standards play an essential role. As part of a broad liberal arts education, including for students outside of these

most obvious disciplines, isn't there still a great inherent value in elevating the degree of standards literacy of every college graduate? Standards literacy can support students' career-readiness, but it can also prepare them to participate as well-informed members of a democratic society. The availability of financial support and educational opportunities for the development and implementation of standards education, provided by a variety of federally funded agencies (NIST, ANSI, ISO, etc.), is a clear indication of the emphasis being placed on standards literacy as an essential aspect of US workforce professional development.

## Approaches to Standards Education

When considering the implementation of standards education, there are two approaches that can be adopted. Most typically, what takes place is the development of courses with a direct emphasis on standards as the primary content, asking students to directly consider the various aspects of standards development, negotiation, and implementation. This approach was in fact initially proposed several years ago at Michigan State University. The colleges who were approached with this proposal however (College of Engineering and College of Natural Sciences), indicated that the preexisting credit requirements of their respective degree programs were already far too burdensome for students. Students in these majors were already challenged to complete their degree requirements and achieve graduation in a timely fashion. In spite of recognizing the potential benefits of adding standards coursework to their students' curricular experiences, these units were unwilling and unable to impose an additional credit burden on their degree programs.

An alternative and completely unique approach to standards education is what has now been adopted at MSU. Standards literacy has become an embedded component of the general education curricula, but instead of developing courses that directly engage students with standards as the

primary topic, our team has set out to embed standards as an essential yet secondary element of course delivery. Students are being asked to conduct research and evaluate real-world situations that have relevance to their local communities and their own lives, but for which standards are an integral and interwoven component.

The structure of general education delivery at MSU has greatly facilitated the adoption of this alternative approach to standards education. MSU has taken a relatively unique approach to liberal arts education. Most typically, general education is delivered through what is best described as a *distribution model*. This is a curricular design in which students majoring in any discipline complete their general education requirements (i.e. science, social science, arts and humanities, etc.) by taking disciplinary courses along with students majoring in that field. For example, an English major would complete biology requirements by taking the same introductory biology class that is taken by a premed biology major.

Twenty-five years ago, MSU adopted an *Integrative Studies* model of general education, where the common core of the general education requirements are delivered through three *Centers of Integrative Studies* (Arts and Humanities, Social Science, and General Science). In this integrative studies model, coursework can be better crafted to serve different students across different disciplines. For example, English majors would complete their biology or physical science requirements by taking an *Integrative Science in Biology* (ISB) or in *Physical Science* (ISP). STEM majors would not typically be in these same courses, as they would instead be developing *scientific literacy* skills in the required courses of their chosen discipline. This *Integrative Studies* approach at MSU affords a structure that supports a community of teaching and learning, targeting a common set of institutional learning goals, through which to disseminate a common core curriculum to every student at MSU. The specific goals adopted by the *Center for Integrative Studies in General Science*

(CISGS) are ideally suited to be complimentary with efforts in standards education.

## Alignment with Institutional Learning Goals

MSU has adopted five primary *Undergraduate Learning Goals* (ULGs) for its students. Broadly described, these are *Analytical Thinking, Effective Citizenship, Effective Communication, Cultural Understanding, and Integrated Reasoning*. Helping students to achieve these broad goals is the responsibility of all academic units, but the coursework provided through the three Centers for Integrative Studies are largely viewed as where students principally achieve these goals. Above and beyond the ULGs, the core mission of the CISGS is to enhance the *scientific literacy* of all MSU students. In this vein, MSU wants to prepare its students to be able to: (1) *Understand the process of science as it applies to technology and society*, (2) *Apply the process of science to evaluate claims relevant to their daily lives*, (3) *Recognize the value of science to inform decision making*, and (4) *Effectively engage in evidence-based argumentation*. Standards education can be an ideal vehicle by which to help students see the relevancy of science in their own lives, achieve many of the multiple dimensions of the ULGs, and also help to enhance their *scientific literacy*.

Over the course of several months, our collaborative team developed a combination of standards curricular materials, case studies, and experiences that would support these institutional goals, as well as to help students achieve an enhanced degree of standards literacy. These curricular materials were implemented in the context of two large two-credit *Integrative Studies* laboratory programs, one with a biological emphasis (ISB), another with a physical science emphasis (ISP). There are typically thirty sections of each of these courses each semester, and each section has a maximum enrollment of twenty-seven students. These are the two largest integrative studies lab programs at MSU, serving nearly 3,000 students per year. As is the case in any curricular initiative, there needed to be clearly stated learning outcomes and also opportunities to conduct validated assessment of student gains. For this project, our standards project goals were for students to be able to

1. explain what a *technical standard* is;
2. explain how standards are developed based on a combination of science, technologies, societal history, political lobbying, etc.;
3. explain the organizational means by which standards are created, implemented, and regulated in both governmental and commercial settings; and
4. explain and predict the implications (economic, social, political, etc.) of implementation of certain standards.

Both the standards case studies, as well as the assessment instrument and data collection protocol, were piloted in the spring and summer of 2016. Our collaborative team made revisions and our final curriculum was administered in the fall semester of 2016. This had been the first time that standards education and its formal assessment had been implemented on such a large scale, targeting thousands of students per year, in the context of general education courses.

## Curricular Implementation

In ISB 208L, *Applications in Biological Science Laboratory*, students focus on fundamental concepts in biology, particularly as applied to a range of local- and global-scale contemporary issues. Students engage in a variety of activities including original investigations, data collection and analyses, creative and evidence-based problem solving, and evaluation of information in popular media. A two-part unit on standards was incorporated into this lab with the goals of introducing the scope of standards (technical, environmental, regulatory, etc.), the roles of science in the development of standards, and the effect of standards implementation on various stakeholder groups (scientists, business owners, manufacturers, consumers, etc.). Pre and Post assessments were administered to identify student understanding and efficacy of the activities developed.

Part one of the standards unit began with a prelab reading (*A Brief Introduction to Standards*), and was followed-up with an in-class lecture highlighting the various standards and regulatory agencies involved with the production and labeling of genetically modified foods (GMOs). Students were then engaged in class discussions and asked to identify the various stakeholder groups—people or groups who would be

concerned, invested in, or involved with the issue of GMO food labeling. Consistently, students identified lawmakers, politicians, manufacturers, business owners, and consumers as common stakeholder groups with particular interest in the implementation of GMO labeling standards. With this list compiled, students were broken into smaller groups for further research and discussion about stakeholder viewpoints and potential impacts of a new law that required all GMOs foods to be labeled. After these breakout discussions, each group shared specific stakeholder's positions with the rest of the class.

Part two of the standards unit consisted of an in-class debate on the topic of GMO food labeling requirements. Preparation for the in-class debate required each student to conduct research to generate support for both sides of this debate, specifically relating to whether all foods containing GMOs should have labeling requirements. Students were then randomly placed into teams, being forced to adopt the position of either supporting the labeling of GMOs, or being opposed to labeling. These newly formed opposing teams were given time to communicate and organize their independent research and findings into a cohesive set of points and counterpoints to support that group's assigned position. These debates placed the emphasis on students having the opportunity to communicate findings to the entire class, the sources of information being incorporated into each statement being presented, and the role and value of evidence-based argumentation. Students also investigated recent policy changes with Vermont becoming the first state to impose a GMO food labeling law, and considered how the implementation of this standard might influence various stakeholder groups.

Students in ISP 203L, *Geology of the Human Environment Laboratory*, practice the scientific method through investigations of physical, chemical, and biological attributes of the Red Cedar River watershed on Michigan State University's campus. This case study emerged from evidence in the literature that chloride concentrations in surface waters often exceed the Environmental Protection Agency's current chronic chloride standard by significant amounts and duration. However, rather than simply evaluating efficacy of a current standard, students were charged with developing a

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standard for application rates of road salt on the MSU campus to minimize salt burn of the vegetation. This was to be based, in part, on their own scientific evidence. This approach aimed to highlight both the process as well as challenges involved in the development of a standard.

In preparation for the case study and to help explain technical standards, students were asked to read *A Brief Introduction to Standards*. During the first week of the case study, student groups (six per class) set up a bioassay modeled after an environmental inquiry from Cornell University (<http://ei.cornell.edu>) to test effects of various road salt concentrations on buttercrunch lettuce (*Lactuca sativa* var. *Buttercrunch*) seed germination rate and radicle (the part of the plant that develops into the primary root) growth. The setup included multiple aspects of experimental design, such as including controls, replicates, and making treatment solutions. Prior to wrapping up the first week, student groups were asked to brainstorm potential stakeholders including the reasoning behind their interest in the development of this standard. Each of the groups was then assigned a stakeholder to research prior to the start of week two.

Week two began with the analyses of class-wide bioassay data. Mean germination rates were not impacted for road salt concentrations ranging from zero parts per million (ppm) to 9000 ppm; however, there was an inverse relationship between mean radicle length (mm) and road salt concentrations. Group members shared their stakeholder research, evaluated bioassay data useful to their stakeholder, and determined a target chloride standard. Groups were then rearranged to include members from each of the six assigned stakeholders. Each member proposed their target standard and the evidence/data/reasoning for that standard prior to open debate until time expired or consensus was achieved. It was during this open debate that the value of embedding standards became apparent. Debates were vibrant, arguments were evidence based (scientific data, public safety statistics, economic, etc.) and from multiple points of view.

#### Future Directions for Standards Education in the Liberal Arts

In addition to helping our students achieve an enhanced degree of *scientific literacy*, we quickly came to realize that

standards education was also an ideal way by which to engage our students in *effective citizenship*. One of the outcomes of this MSU undergraduate learning goal is that students will *apply knowledge and abilities to solve societal problems in ethical ways*. During the conversations and structured classroom debates in our ISB and ISP lab programs, students were repeatedly and strikingly drawn to the social and ethical issues that arise from the development and implementation of certain standards. As is being reported in higher education across the US, millennial students are among the most politically and progressive generations ever, and they are eager to engage in academic conversations that revolve around social justice. In the context of role playing stakeholder debates, our students were consistently drawn to the ethical and human dimensions that would be raised. Though not initially a targeted student learning outcome of our standards work, we quickly recognized the opportunity that existed to help students achieve multiple learning goals.

Moving forward, the standards aspect of our laboratory courses will continue, but we are now planning on expanding the use of standards case studies into the context of large environmental science lecture courses beginning in the fall semester of 2017. A wide variety of compelling current events, with environmental, human health, and social justice dimensions, will be used as topics of research and debate. Some examples include:

*The Bioethics of Developing International Standards for Managing Insect Vected Diseases with Pesticides*. The incidence of insect vected diseases, such as malaria, is inextricably linked with poverty. Pesticides have been a primary control method in reducing insect vected diseases in most situations around the world. Inappropriate use of pesticides, however, frequently leads to insect vectors rapidly developing resistance to available pesticides. This in turn negatively impacts large-scale efforts at improving public health. This, paired with the widespread availability, trade, and use of substandard, poorly labeled, and highly toxic pesticides (“street pesticides”) in developing countries, raises additional public health concerns. The WHO has drafted a Code of Conduct on Pesticide Management. Students will examine the variety of stakeholder positions associated with the implementation of international

standards, investigating the environmental, health, economic, and social justice implications of such a decision.

*Safe Drinking Water Flows From the Tap, Right?!?* Environmental justice research finds that low-income communities and communities of color disproportionately bear the burden of contaminated groundwater and declining water delivery infrastructure. Using the Flint water crisis as a locally recognized and highly engaging issue for Michigan residents, students will participate in the process of developing water quality standards from the perspectives of multiple stakeholders. Additionally, students will evaluate the role that standards have played in ensuring maintenance of water quality and quantity. Students will review the history of lead standards in drinking water, the 1,4-dioxane standard in shallow groundwater, and disposal of TENORM (Technology Enhanced Naturally Occurring Radioactive Materials) in the lower peninsula of Michigan.

*The Effect of Water Fluoridation and Social Inequalities*. There is current debate in many communities as to whether public water supplies should be treated with fluoride to promote public health. The history of development, implementation, and social implications of national standards for water fluoridation also has deep roots in the State of Michigan. Beginning in 1945, Grand Rapids was the very first US city to add fluoride to its water supply. Although the fluoridation of water has been shown to successfully reduce dental health inequalities between socioeconomic groups, helping to greatly reduce tooth decay in impoverished communities, there is opposition to this continued practice. Some studies link fluoride intake by children, with lower IQs and higher rates of attention deficit/hyperactivity disorder. Students will investigate NSF/ANSI Standards 60 and 61, which provide guidelines for the safe implementation of chemicals to drinking water.

Our MSU team is very proud to have crafted standards education curricula as an embedded component of the undergraduate experience. The scale of our curricular delivery and assessment is impressive, with over 5,000 non-STEM students having been exposed to standards in a meaningful way over the course of the past two years. Our preliminary assessment results indicate that we are helping our students achieve an



enhanced level of *standards literacy*. Additionally, delivering our standards curriculum in the context of introductory integrative science labs has allowed standards to be a vehicle by which to help our students simultaneously achieve *scientific literacy*. We are now very excited to see this work expanded upon, crafting new standards case studies for implementation in large lecture courses, with the additional goal of fostering *effective citizenship*. Clearly, engineering is not the only discipline that can greatly benefit from an infusion of standards education.

## About the Authors

Gabe Ording ([ordingga@msu.edu](mailto:ordingga@msu.edu)) is the director of the Center for Integrative Studies in General Sciences; its mission is to enhance the *scientific literacy* of all students at Michigan State University. Ording has been involved in curriculum development and delivery of Integrative Studies at MSU for over seventeen years, and provides leadership in helping to determine the future directions of general education at MSU. Central to the work that Ording has been pursuing has been collaborative embedded curricular modules and assessment of student perceptions to STEM disciplines and student understanding of key scientific concepts. Ording was the Principal Investigator (PI) on the most recent MSU NIST award. His leadership position affords him the capacity to support the implementation of curricular changes that directly impact all undergraduate students at MSU.

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