Stem Cells Across the Curriculum Philosophy & Pedagogies

By Katayoun Chamany, Associate Professor of Biology, Eugene Lang College The New School for Liberal Arts

Rationale

Advances in stem cell biology and its related applications have captured the interest of nearly every sector of society. For stem cell research to move from the isolated pages of scientific journals to national agendas demonstrates the need for an informed public. These times call for a citizenry that “does not demonize” opposition but engages in measured and respectful debate using “fair-minded” language (Obama, 2010). As states move to appropriate funds for stem cell research (SCR), and nations grapple with legislation to expand or limit SCR, education for an informed democracy is of utmost importance. Students who view cell biology as more than a collection of static facts will develop as citizens capable of keeping up with new stem cell advances and thinking intelligently about the ethical, legal, and social dimensions (ELSD) of these scientific advances.

The *Stem Cells Across the Curriculum* (SCAC) project intentionally uses ELSD instead of the ethical, legal, and social implications (ELSI) that are more commonly used. By shifting our language from “implication” to “dimension” we highlight the transactional nature of SCR and the important role that non-scientists play in directing scientific research in ways to promote equity. We refrain from considering the non-biological aspects as simply downstream issues. It is not only the implications of SCR that engage these perspectives but, rather, the very nature of conducting the research in the first place. For instance, a curriculum can juxtapose a discussion of the biological and technical processes involved in egg provision and egg procurement with discussions regarding 1) compensation 2) equity and access to medical research and treatments, 3) health risks 4) informed consent and 5) and the role of regulatory bodies such as the Human Fertilisation and Embryo Authority, Institutional Review Boards (IRB), and new ethical oversight committees (ESCROs). because these aspects highlight the transactional nature of the field and the important role that non-scientists play in directing scientific research in ways to promote equity.

Not surprisingly as stem cell biology and its related technologies advance, so too does an approach to educating students about this exciting field. New undergraduate stem cell science majors, advanced-level textbooks, and funding opportunities designed to provide the scientific background and training for a new stem cell workforce have all emerged (Bradt, 2009; CIRM, 2009; Workforce Development in Stem Cell Research, 2011). Alongside these efforts, a number of instructors have developed courses for non-biology majors that integrate the scientific and social perspectives, thereby identifying common misconceptions associated with stem cell biology and related policies (Halverson, 2009; Halverson, 2010). These educators often develop their own curricular materials because there are few resources that provide a sophisticated and integrated analysis of these topics. What results are selected chapters from the National Institutes of Health (NIH) primers entitled *Stem Cells* and *The Future of Regenerative Medicine* and *Stem Cells: Scientific Progress and Future Research Directions* (NIH), spliced with popular trade books (Fink, 2004). Although the NIH resources include colorful and detailed diagrams for those who are well versed in science, most non-biology majors struggle to grasp the technical details. The problem of disciplinary jargon is not limited to the natural sciences; the same can be said for publications in professional journals for law, ethics, and policy. For science majors accustomed to succinct research articles, the sheer length of publications in these professional fields that address applied science are often deal breakers, resulting in a truncated, or spotty, understanding of the plethora of issues associated with the procurement of biospecimens, the design of clinical trials, and compliance with regulatory bodies. Thus, one challenge for those who educate non-science majors is a lack of curricular resources that provide an integrated, level-appropriate analysis of stem cell research and its ELSD.

As Paulo Freire and Myles Horton highlight in *We Make the Road by Walking: Conversations on Education and Social Change* (Horton & Freire, 1990). The idea that biology can be taught without any social context is a fallacy as they aptly discuss in a section of the book within a chapter of Ideas titled “Is it possible to just teach biology?” Though they promote a synergistic approach to education, the challenge of undergraduate stem cell education is a lack of curricular resources that provide an integrated, level-appropriate analysis of the life sciences and its social dimensions (Scott, 2015).

Components and Format

Stem Cells Across the Curriculum fills this void by providing a collection of modules that integrate the biological, ethical, legal, and social dimensions of SCR. Each module is adaptable and can be used either on its own or in combination for courses that span the liberal arts curriculum. Our topics and pedagogies cater to students interested in the sciences, arts and design, gender studies, bioethics, culture and media, and policy and social justice. Although our curriculum was delivered in semester-length courses offered by the Department of Natural Sciences and Mathematics at our home institution Eugene Lang College for Liberal Arts, and The New School, instructors from a wide range of areas and institutions have successfully used our resources because we contextualize these topics in ways that make biological principles and concepts relevant and tangible, using a social justice framework. (see Figure 1).

Procedural Justice

Ethics Committee Composition

Clinical Trials & Regulation

Oocyte Payment

Embryo Research

stem cells across the curriculum

Social Justice Framework

Basic Science of SCR

Disability Discrimination

Commercialization of Patents

Public & Private Biobanks

SC Registries & Licenses

Distributive Justice

Figure 1: Using a Social Justice Framework to Make Biology Relevant. Topics related to stem cell research are deliberately organized to consider issues of procedural and distributive justice.

Issues surrounding intellectual property, patents, biobanking, and disability discrimination are considered using a distributive justice approach that considers who benefits from the goods produced from stem cell research. Controversies concerning ethics committee composition, oocyte payment, and just participant selection in clinical trials are considered using a procedural justice framework that questions who directs stem cell research be they scientist, human research subject, or a policy makers. To provide cohesiveness and context for these diverse topics, we created four modules that span these areas to support deeper learning in particular areas of interest.

CURRICULAR MODULES

Module Title	Biological Concepts & Principles	Ethical, Legal, & Social Dimensions
HeLa Cells & Genes: Immortality & Cancer	cell structure, cell cycle, mitosis, cancer, cell line registry, cell differentiation, viral integration, telomerase, and cell signaling	history of cell culture, bodily goods, privacy, ownership, compensation, human subjects research, race, class, gender
Eggs & Blood: Gifts & Commodities	reproductive biology, meiosis, fertilization, IVF, immunology, embryogenesis, PGD, ESCs, fetal, cord, ovarian, and menstrual blood SCs, adipose-derived stem cells	history of gamete payment, bodily goods, IRB, FDA, OHSS, eugenics, saviour siblings, bioethnicity, public v. private banking, clones, cybrids, gender
Disease, Disability & Immortality: Hope & Hype	neurodegenerative disease pathways, extracellular matrix, stem cell niches, nuclear reprogramming factors, iPSCs, immunology, scientific method	stem cell fraud, therapeutic misconception, cure vs. care, disability rights and justice, social v. biomedical models of health, enhancement
Stem Cells & Policy: Values & Religion	cybrids, SCNT, gastrulation, primitive streak, microarray gene expression technology, nuclear reprogramming factors, ESC, ASC, iPSC	religion, moral status of the embryo, ethics committee composition, pluralism, stem cell registries, social justice, international/ national/local policies, injunctions, lawsuits

The learning activities associated with each module draw upon a broad array of resources related to SCR from informative pieces in the press and television, to textbook excerpts and secondary and primary scientific literature. Instructors have a wide array of choice in determining which of the suggested readings and media items are most appropriate for their specific course or group of students. The selection of scientific readings were chosen to help students learn that science is a gradual process, namely, a series of experiments built on previous findings conducted by members of a community who strive to increase their understanding of the world around them. The secondary literature and video excerpts were chosen to place these incremental advances in scientific understanding within a larger conceptual context, by reviewing the prior research, summarizing the impact of the present discoveries, highlighting unanswered questions, and pointing to future experiments and applications while paying close attention to the social, ethical, and legal dimensions. Perhaps what is most exciting about stem cell research is that the story, on either the scientific or social level, is not yet complete. With respect to scientific research, the identities of many growth factors involved in cell differentiation, and the details of genetic reprogramming, remain unknown. New applications for the stem cells and the methods are being proposed, and this in turn leads back to questions regarding the social impact of science. In addition, all these avenues of research offer students a view into the world of high-tech biology. Because of the interdisciplinary nature of our approach, we provide tools and resources that support both instructor and student. Each Module contains:

Synopsis:	A quick snapshot of the disciplinary perspectives, topics, and cases associated with the module.
Essential Readings & Resources:	A bibliography with secondary and primary resources appropriate in length, scope, and depth for undergraduates and organized by media format.
Learning Activities:	A list of learning activities highlighting specific learning goals, pedagogies, and time needed to execute the activity. Assignments are downloadable as pdfs and zip files.
Teaching Notes:	Each activity is accompanied by teaching notes that provide step-by-step implementation. Because activities are intended to be flexible, the teaching notes provide alternatives and choices, and instructors are encouraged to modify the activities, swap components, or simply use the suggested media resources to complement a course. The notes also contain learning outcomes, appropriate assessment techniques, and rubrics
Timelines	Historical maps of events that allow students *to see* the field take shape across space and time and emphasizing the importance of facing our past and imagining a different future.
Infographics	Graphics address visual literacy by highlighting the dynamic and interrelated nature of basic science and its applications and give details for biological techniques such that each infographic serves as a mini-visual textbook chapter.
Discussion Questions	A list of questions that are under investigation, spanning biology, feminism, disability, social justice, policy, values, and economics.
Power Point Slide Sets	Editable slide shows making the invisible *visible* and containing embedded links to video, animations, interactive websites, and Notes Pages for further learning.
Case Studies	Peer-reviewed case studies explore real-world controversies, maintain student engagement, motivate deeper learning, and incorporate discussion, role-play and/or critical essay writing, and are accompanied by grading rubrics and teaching notes.
Primer:	A synthesis of the essential interdisciplinary content designed to ground instructors in disciplines outside their expertise and to be useful as “references chapters” containing bibliographies that point to literature and multimedia, for quick in-depth learning.

Pedagogical Approaches

Interdisciplinary Teaching

“We are not students of some subject matter, but students of problems. And problems may cut right across the borders of any subject matter or discipline”(Popper, 1963).

Nearly two decades have passed since critics of science education first challenged the disciplinary-focused approach of general education science courses. In 1990, Shelia Tobias demonstrated that scientific content delivered without adequate attention to interdisciplinary connections is lost on non-science majors who lack the cognitive organizational structures to place and retrieve such information (Tobias, 1990). Moreover, as biomedical research has come to depend on human bodies, tissues, and cells, students pursuing life science education will need to better understand the ethical issues associated with the procurement of biospecimens including controversial views on ownership, compensation, and privacy. Connecting the natural sciences to the social sciences and humanities highlights the epistemological similarities and differences among these disciplines and guides students from the familiar to the unfamiliar (Christakis, 2013). As students begin to see science as central to the problems and events of everyday life, they become better able to view science from a critical standpoint. This approach gives students the permission to question science, thereby dispelling the misconceptions that science is about remembering facts, obtaining the “right answers,” and remaining separated from the general public. By dismantling the exceptional status of science in the undergraduate curriculum, students are better able to demythologize experts, recognize whose expertise and which voices are missing from the conversation, and become more comfortable with the ambiguity that accompanies solving complex problems.

Extending the notion of science taught through context, feminist philosopher Sandra Harding and science historian Evelyn Fox Keller highlight the dangers of presenting science in a vacuum (Harding, 1998; Fox-Keller, 1985). The American Association of Colleges & Universities (AACU) published a call to action from the National Leadership Council of Liberal Education and America’s Promise. In this report, entitled *College Learning for the New Global Century,* community, business, policy, and educational leaders advocated for change in higher education that will enable today’s students to make choices and compose their lives in the context of “scientific and technological innovations, global interdependence, cross-cultural encounters, and changes in the balance of economic and political power” (AACU, 2007). The AAAS also issued a call to action in their *Vision and Change In Biology Education* report in 2009 (AAAS, 2009). Scott Gilbert, author of the well-known textbook *Developmental Biology* and Anne Fausto-Sterling, professor of biology and gender studies, champion this approach. They argue that we should change the developmental biology syllabus to educate for social responsibility, and Fausto-Sterling has gone to so far as to revamp her traditional embryology course to one entitled “Embryology in Social Context” (Gilbert & Fausto-Sterling, 2003).

Collectively, these publications highlight the urgency for educators to address the problems that are beyond the scope of a single discipline. The Development Team assembled for this project is by its very nature interdisciplinary and our approach to teaching and learning signals our understanding of the definition of the fractious problem in science and technology as one that is “novel, ethically fraught, complex, divisive, and one of unavoidable public concern”(Barry, 2007; Anonymous, 2013). Problems like these require creative thinking to “restructure problems and produce solutions or products that are novel, useful, and critical” (DeHaan, 2011). Moreover creativity can promote higher-order thinking skills and encourage students to balance the drive for innovation with equity, such that scientific progress benefits society as a whole.

Case Study Teaching and Learning and the 7E Learning Cycle

Case Based Learning (CBL) in the sciences has become a popular approach to interdisciplinarity because the story of the case requires students to view science through a wider, more humanistic lens (Herried, 2006). A case is “an account of real events that seems to include enough intriguing decision points and provocative undercurrents to make a discussion group want to think and argue about them” (Barnes et al., 2000). Using case studies in the classroom has a long tradition in higher education, especially in the areas of medicine, business, and law, and was originally pioneered in the Kennedy School for Government and Public Policy. The premise of CBL is that the cognitive conflict offered by complex real-world problems stimulates learning and initiates inquiry and collaboration by students.

More recently, the case-based approach has been extended to the teaching and learning of science at the undergraduate level, because of its ability to promote inquiry-based learning that is modeled on the **7E learning cycle** (Eisenkraft, 2003)**.** The 7E learning cycle begins by *engaging* students with a relevant real world dilemma, *eliciting* students’ prior knowledge and alternative conceptions, providing activities that require *exploration* and *explanation* in the form of oral and written communication to their peers, culminating with *elaboration* and *extension* to a related phenomenon, and finally *evaluation* of the best ways forward. CBL has been shown to attract student interest, cause student attendance to soar, increase a student’s positive attitudes towards the subject matter, and increase retention of material and higher-order thinking for multiple science courses (Dori et al. 2003; Herreid, 2005).

Because CBL requires a multidisciplinary approach and significantly more time dedicated to learning through discussion, some instructors are reluctant to adopt this pedagogy. They may be concerned that CBL cannot be adapted to traditional lecture formats, but recent studies demonstrate that CBL has been successful in this regard (Fink, 2002). Perhaps the most significant barrier to adopting CBL is the initial time investment required to develop case modules that will stimulate the necessary degree of inquiry (Allen and Tanner, 2003; Chamany 2008). For this reason, we connect our case studies and accompanying teaching notes to four topic areas that are hotly debated in the SCR arena.

Each Case Module can be used on its own, or in combination, and all cases emphasize the value of counter narratives that challenge the dominant narrative. Using visual narrative construction, language analysis, and role-play, students construct knowledge together. They identify areas of conflict among stakeholders who hold different values and use ethical reasoning to propose policies that promote scientific innovation and socially responsible practices.

Collectively, the Case Modules move from the history of tissue culture research, to the identification and isolation of embryonic stem cells, to the identification and manipulation of adult cells to enhance cell plasticity, to policies regarding cloning, embryo creation and destruction, biospecimen and egg provider compensation, and biobanking in the public and private sectors. *HeLa Cells & HPV Genes: Immortality & Cancer* reviews basic cell biology, tissue culture, and human subjects research in the context of privacy, ownership, and access to the goods and products of research. *Eggs & Blood: Gifts & Commodities* traces the history of compensation and the sacred value placed on some bodily tissues/cells and not on others. *Disease, Disability, & Immortality: Hope & Hype* explores the natural physical and cognitive variability in the human population and questions the goal of a "cure" in biomedical research. *Stem Cells & Policy: Values & Religion* analyzes how policy is shaped in pluralistic societies in ways that can promote tolerance of different points of view.

Perry's Model of Intellectual Ethical Reasoning Development

The case studies associated with the SCAC curriculum present students with a dilemma that demands a firm understanding of complex scientific evidence as well as the ability to make and defend recommendations using multiple perspectives. As mentioned earlier, our curricular modules can be used on their own, but learning activities are sequenced such that students develop ethical reasoning as they progress within each module and among the modules. We incorporate William Perry's Model of Ethical Reasoning**,** recognizing that most students will initially engage with the case and experience very strong dualistic thinking. They will then explore and investigate the case components more deeply, grappling with murkiness and cognitive dissonance. In arriving at the final activity of a module, students become secure enough in their understanding of the material to select policy proposals that solve the problem and align with personal and social values (The Perry Network; Rapaport, 2011; Belenky et al. 1986; Perry, 1981).

The SCAC case studies are designed to demonstrate making policy in a pluralistic society requires tolerance of multiple points of view and the space for compromise. Thus, cases move away from *debate* and instead encourage *dialogue* and involve a range of stakeholders that represent people in academia, activism, and policy. To see the difference in using debate, discussion or dialogue, with special attention to issues of identity, status, and power, see this chart compiled and adapted from Rahnesh Nagda, Patricia Gurin, Jaclyn Rodriguez, and Kelly Maxwell's work on Intergroup Dialogue (IDG), Diana Karda and Todd Sevig's work on IGRC, and Sally Berman's paper on this topic from the Dialogue Group of the Boston Chapter of Educators for Social Responsibility (ESR). Additionally, reviewing this adaptation and summary of Daniel Yankelovich (Magic of Dialogue) and Mark Hicks' explanation of how dialogue can contribute to Multicultural Communications Competencies may also prove helpful for instructors and students.

Unlike many case studies that assign students to a stakeholder's group and ask them to provide a single unified position on a controversial problem, we have intentionally selected individuals who might agree on some points and disagree on others regarding SCR. Having students commit to a particular position after this exploration is challenging, thus, we have refined our cases to scaffold the experience with sufficient guidance and opportunities for research, discourse, and reflection. Each case study moves through a surface-level exploration of individuals and communities with differing values and interests regarding SCR, progressing towards a deeper exploration of one perspective by each student, and expanding to the larger context after all possibilities are collectively analyzed, as students prepare policy proposals. Each case is accompanied by extensive teaching notes that are based on previous experience, and includes a more in-depth overview of the order and structure of learning activities alongside refined rubrics that promote critical thinking and ethical development.

Critical Pedagogy

Because SCAC cases incorporate issues of social justice, they demonstrate how diverse populations must negotiate differences in ways that move toward inclusiveness (Chamany, 2006; Tanner & Allen, 2007; Moriarity, 2007). Moreover, the structure of the case format supports constructivist learning in which students are responsible for building their knowledge base collectively and collaboratively (Bruffee, 1993; Freire, 1970). To that end, the selection of characters in the case studies are intentional and deliberate, representing diverse members of society with respect to values, socioeconomic class, ethnicity, and ability (Tanner, 2009). In general, CBL has advantages for underrepresented minority students and those who may not learn best through lecture and textbook readings (Chamany et al., 2008; Knight et al., 2008; Tanner and Allen, 2004). Indeed, CBL has been considered a promising teaching approach to help overcome the barriers that are rooted in cultural and preparatory differences, especially if combined with Intergroup Dialogue (IGD), which promotes collaboration for personal and social responsibility towards social justice (Nagda, 2009). Additionally, creating "brave spaces" where conflicting viewpoints are discussed with civility and individuals are not permitted to opt out of discussion by "agreeing to disagree" promotes learning for personal and social responsibility towards social justice (Arao and Clemens,2013).

As concrete examples of the ways how SCAC uses a social justice framework, we can look to the curricular modules and consider not only the selection of topics but resources that support social justice frameworks in these contexts. Although many campuses have adopted the book *The Immortal Life of Henrietta Lacks* by Rebecca Skloot, a critical pedagogy would caution against using this book as a singular anchor (Skloot, 2010). Though it provides a rich narrative for teaching the history of tissue culture and human subjects research, both of which are essential components of SCR it tells only one narrative. Our approach incorporates resources that offer alternative narratives, providing a more diverse view of the events associated with establishing the first human cancerous cell line. We couple this text to research articles authored by anthropologists and sociologists who tie this story to those who have been marginalized by science (Landecker,1999; Landecker, 2007; Weasel, 2004). We also remind students that, although the story took place in the past, the complexity of human subjects research still challenges us today (GAO, 2009). By including Ruha Benjamin's book *The People's Science* students are able to analyze governmental investment in SCR using perspectives from feminism, race studies, and disability studies, to imagine ways that we can simultaneously invest in science and social equity (Benjamin, 2013).

In line with our choice of resources, our learning activities also promote alternative interpretations of topics or terms that are often assumed to be value-neutral or commonly understood. In two modules, *HeLa Cells & HPV Genes: Immortality & Cancer* and *Disease, Disability, & Immortality: Hope & Hype,* we revisit the definition of “health”, and in the *Eggs & Blood: Gifts & Commodities* and *Stem Cell & Policy: Values & Religion* Modules we renegotiate the definitions of words like “religion”, “sacred”, “secular”, and “dignity”. By dedicating time to explore how language and differently lived experience place value on our practices and beliefs, SCAC questions one’s assumed shared values and creates space for open dialogue and acknowledgment of different points of view.

Infographic Thinking and Visual Literacy

The visualization of relationships such as the hierarchical nature of laws, ethical frameworks, and processes that require a clear understanding of sequencing are a prominent component of SCAC curricular materials (Pavlus, 2012; Thompson, 2010). The emerging field of information architecture and design has informed the creation of materials that explain complex biological interactions occurring over space and time. Including different forms of media that address learning based on the theory of multiple intelligences (Gardner, 1983). These alternative learning materials provide entry points for students who might not initially engage with biology or textual material but connect more readily to visual and socially relevant material (Frankel, 2012). They also encourage students to create visual narratives that reveal their understanding (Ainsworth, 2011; Picturing to Learn).

Infographic thinking utilizes a narrative language that encourages critical thought about relationships, connections, pushes and pulls, and promotes nonlinear thinking, encouraging students to break disciplinary boundaries (Pavlus, 2012). Information designs are intentionally immersive and interactive offering multiple paths for discovering stories, and place agency and choice in the hands of the learner (Thompson, 2010). As John Gilbert describes, educators and students must develop “metavisual capability,” to successfully navigate within and between modes of representation in biology (Gilbert, 2005). He and others argue that the ability to visualize entities, relationships, causes, and effects is a vital process of theorizing models that form the basis of knowledge construction (Quillin & Thomas, 2015).

The visual aspects of our curriculum are varied and layered and include: 1) *The Sources of Stem Cells Radial Infographic* is a downloadable interactive pdf with 55 hyperlinks that allows learners to compare embryonic, fetal, and adult sources, with respect to their therapeutic and scientific potentials given their unique and varied associated ethical issues; 2) *The ZoomGraphics* provide a deeper look into human development, nuclear reprogramming, and each of fifteen different stem cell sources using graphics and text that clarify the detailed biotechnological manipulations necessary to create stem cell lines; 3) *Powerpoint Slide Sets* employ animations to highlight the dynamic nature of cell biological processes; 4) *Artworks* include video, theater, sculpture, fashion, painting, and comics, and 5) *Video Guides* include films that narrate and animate the human dimensions of SCR. Our inclusion of dynamic and real-world images of biological techniques is informed by research on visualization and learning, which demonstrates improved understanding when schematic images highlighting salient points are juxtaposed with real-life images from scientific research, because the latter cater to students who learn differently and provide different levels of detail (Spanjers, 2010; Tversky, 2002; Lu et al., 2007; Huk et al., 2010).

We encourage users to view the Video Guide for *The Sources of Stem Cells Radial Infographic* to acquire a deeper understanding if the rationale behind the radial design and understand the interactive nature of the graphic. This interactive pdf is designed for customized learning, allowing students to choose their entry point, and to navigate from places of natural interest to new areas of learning. As an example, the ethical issues may draw a student in to question why “eugenics” appears next to the spoke describing the use of Preimplantation Genetic Diagnosis (PGD) as a source of embryonic stem cells. Though the student may be familiar with the term eugenics, they may not readily see the connection in this SCR context. Furthermore, the location of the term may encourage the student to move quickly to other words associated with this technique, such as “savior siblings” where they would be able to learn more via a video clip from *Religion and Ethics Weekly.* Our intent in juxtaposing the Extranumerary and Research Embryo spokes next to one another to signify that these embryonic stem cell lines require eggs and sperm, and that both Extranumerary Embryos and PGD Embryos require potential parents to make choices as to whether embryos will be used in reproduction, research, or both, as in the case of egg sharing schemes in the UK, Israel, or South Korea. By expanding from this resource to the case studies mapped to the radial infographic, students would learn of the International Society for Stem Cell Research's position on compensation for egg provision and procurement for SCR.

Science Education for New Civic Engagements and Responsibilities (SENCER)

Stem Cells & Social Justice, a semester-length course using SCAC materials has emerged as a model course for SENCER because it promotes civic engagement through a deep understanding of basic science (SENCER, 2013). SCAC educational materials have been piloted on multiple campuses and with different student populations, ranging from high schools to professional schools, with excellent effect. They offer instructors and learners multiple avenues of entry and are found to have a transformative effect on students and their learning. These resources will be used on campuses that are vested in civic engagement and social justice, such as high schools that participate in the Facing Our History and Ourselves Project, colleges that are members of Project Pericles (and participate in the D4D (democracy- shaping exercises), and members of science departments who attend the SENCER DC Symposium every spring. To learn more about how this curriculum has been adapted and implemented, visit the *Presentations* page and view the sample syllabi posted under *Curriculum & Cases.*

Assessment of Student Learning

SCAC utilizes assessment and evaluation tools that specifically address interdisciplinary teaching and learning. Because the development of curricular content should be paired with the development of assessment instruments, our formative and summative assessment instruments were developed using a Backwards Design approach. We first outlined the learning outcomes, then developed the necessary educational components to meet those learning outcomes (Wiggins & McTighe, 2005).

Because the development of curricular content should be paired with the development of assessment instruments, our formative and summative assessment instruments were developed using a Backwards Design approach and are included in the teaching notes for each learning activity. After outlining the learning outcomes, we developed the necessary educational components to meet those learning outcomes (Wiggins & McTighe, 2005). To assess student learning of biological concepts we draw on existing methodologies and approaches generated by SENCER, The National Institute for Science Education/ Field-Tested Learning Assessment Guide (NISE), and portions of The Bioliteracy Project (Klymkowsky & Garvin-Doxas, 2008). Because SCAC seeks to address visual literacy and the scientific method, in-class exercises required drawing or visual narration of experimental techniques that are associated with stem cell research. To assess students' abilities to employ evidence-based reasoning and values in decision-making, grading rubrics for performative experiences such as role-play and written communications such as policy proposals accompany the Case Studies. Traditional exams include questions that require students to integrate ethical and social dimensions of SCR were employed but are not accessible on the website (Wilson & Sloane, 2000; Labov & Huddelston, 2008). Answer keys for restricted response answers to these exam questions, and a range of correct possible answers for free response questions or performative assessments are available by email (chamanyk@newschool.edu).

We welcome educators to use SCAC and adapt these resources for their unique learning environments, and welcome users to share their syllabi, adaptations, and experiences with us. We are particularly interested in the following questions: Who are the students? What course learning outcomes did the module address? Was the reading level and amount appropriate? Was the information in the module accurate and relevant? Was the module accessible to “all” students? Would other supplemental or ancillary teaching tools be useful? Were the infographics used, and what was the outcome for students? When/where in the course was the module implemented, and if multiple modules were used, in what sequence and based on what rationale? Are the modules sustainable, transportable, and flexible?

For more information, exams, and answer keys, please contact Katayoun Chamany at chamanyk@newschool.edu.

Bibliography

1. Anonymous. April 8, 2013. Fractious Problem-Solving Skills (FPSS) Online Ethics Center for Engineering. National Academy of Engineering. Link
2. AAAS. 2009. Vision and Change In Biology Undergraduate Education: A Call to ACTION. Link
3. AAC&U. 2007. College Learning for the New Global Century: A Report from the National Leadership Council for Liberal Education & America’s Promise. Washington DC. Link
4. Arao, B., & Clemens, K. 2013. From safe spaces to brave spaces: A new way to frame dialogue around diversity and social justice. In L. Landreman (Ed.), The art of effective facilitation: Reflections for social justice educators. (pp. 135-150). Sterling, Virginia: Stylus Publishing. Link
5. Ainsworth, S. et al. 2011. Drawing to learn. Science. 333 (6046):1096-1097. Call to action to science educators to teach students to draw for five reasons: Engagement, Representation, Reasoning, Learning, and Communication. Link
6. Allen, D, and Tanner, K. 2003. Approaches to cell biology teaching: Learning content in context- problem based learning. Cell Biology Education. 2: 73–81. Link
7. Baker, L. and Dunbar,K. 2000. Experimental design heuristics for scientific discovery: The use of “baseline” and “known standard” controls. International Journal of Human Computer Studies. 52: 335-349.
8. Barnes, L. et al. 2000. *Teaching and the Case Method: Text, Cases, and Readings*. Cambridge, MA: Harvard Business Press.
9. Barry, R. 2007. *The Ethics of Genetic Engineering*. New York, NY: Routledge Annals of Bioethics. 240.
10. Belenky, M. et al. 1996. *Women's Ways of Knowing: The Development of Self, Voice, and Mind*. New York: Basic Books.
11. Benjamin, R. 2013. *People’s Science: Bodies and Rights on the Stem Cell Frontier.* Palo Alto, CA: Stanford University Press. 272.
12. Bradt, S. 2009. Harvard University Press Release: Harvard to Offer Undergraduate Concentration in Human Developmental and Regenerative Biology. Link
13. Bruffee, K. 1993. *Collaborative Learning: Higher Education, Interdependence, and the Authority of Knowledge.* Baltimore, MD: John Hopkins University Press.
14. Chamany K. October 2006. Science and social Justice: Making the cases for case studies. Journal of College Science Teaching: 54-59.
15. Chamany K. et al. Fall 2008. Making biology learning relevant to students: Integrating people, history, and context into (college) biology teaching. CBE/Life Sciences Education. (7):267-278.Link
16. Christakis, N. July 19, 2013. Let’s Shake Up the Social Sciences. New York Times. Link
17. CIRM Approves $58 Million to Build California’s Future Stem Cell Research Workforce. CIRM Press Release. January 30, 2009. Link
18. DeHaan, R. 2011. Teaching creative science thinking. Science. 334(6062): 1499-1500. Link
19. Dori, Y., et al. 2003. Teaching biotechnology through case studies: Can we improve higher order thinking skills of nonscience majors. Science Education. 87(6): 767-793.
20. Eisenkraft, A. Expanding the 5E Model. The Science Teacher.70(6): 56-59. Link
21. Fink. R. 2002. Cloning stem cells, and the current national debate: Incorporating ethics into a large introductory biology course. CBE/Life Sciences Education. 1(14):132-144.
22. Fink. R. 2004. A shelf of stem cells. CBE/Life Sciences Education. 3(1):20-21. Link
23. Fox-Keller, E. 1985. *Reflections on Gender and Science.* New Haven and London: Yale University Press.
24. Frankel, F. and Depace, A. 2012. *Visual Strategies. A Practical Guide to Graphics for Scientists and Engineers*. Yale University Press. 153. There is also a blog Link

25. Freire, P. 1970. *The Pedagogy of the Oppressed*. New York, NY:Bloomsbury Academic.183. Link
26. GAO. March 26, 2009. Human Subjects Research. Undercover Tests Show the Institutional Review Board System is Vulnerable to Unethical Manipulation. Government Accountability Office.Link
27. Gardner, H. 1983. *Frames of Mind: The Theory of Multiple Intelligences*. New York: Basic Books. Tenth Anniversary Edition with new introduction, New York, NY: Basic Books.
28. Gilbert, J. 2005. Visualization: A metacognitive skill in science and science education. In J. Gilbert (Ed.), Visualization in science education (pp. 9-27). Dordrecht, The Netherlands: Springer.
29. Gilbert, S. and Fausto-Sterling, A. 2003. Educating for social responsibility: changing the syllabus of developmental biology. International Journal of Developmental Biology. 47: 237-244.
30. Halverson, K. et al. 2009. Lenses for framing decisions: Undergraduates' decision making about stem cell research. 31(9): 1249-1268.
31. Halverson, K. et al. 2010. What undergraduates misunderstand about stem cell research. International Journal of Science Education. 32(17): 2253-2272.
32. Harding, S. 1998. Is *Science Multicultural? Postcolonialism, Feminism & Epistemologies*. Bloomington, IN: Indiana University Press.
33. Herreid, C. 2006. *Start with a Story: The Case Study Method of Teaching College Science*. A
34. Horton, M., & Freire, P. 1990. Ideas: "Is it possible to just teach biology?" In B. Bell, J. Gaventa & J. M. Peters (Eds.), We make the road by walking: Conversations on education and social change (pp. 102--109). Philadelphia: Temple University Pressrlington, VA: NSTA Press.
35. Huk, T. et al. 2010.The educational values of visual cues and 3D-representational format in computer animation under restricted and realistic conditions. Instructional Science. 38(5):455-469.
36. Klymkowsky, M. Garvin-Doxas. 2008. Recognizing student misconceptions through Ed's Tool and the Biology Concept Inventory. PLoS Biology, 6(e3):1-14.
37. Knight, J., Fulop, R., Marquez-Magana, L., and Tanner, K. 2008. Investigative cases and student learning outcomes in an upper-division cell and molecular biology laboratory course at a minority – serving institution. CBE/ Life Sciences Education. 7:382-393.
38. Labov, J. and Huddleston, N. 2008. Integrating policy and decision making into undergraduate science education. CBE/Life Sciences Education. 7(4):347-352
39. Landecker, H. 1999. Between beneficence and chattel: The human biological in law and science. Science in Context. 12 (1):203-225.
40. Landecker, H. 2010. *Culturing Life: How Cells Became Technologies.* Cambridge, MA: Harvard University Press.
41. Lu et al. 2007. BioClips of symmetric and asymmetric cell division. Biology of the Cell. 99(5): 289-295.
42. Moriarty, M. A. 2007. Inclusive pedagogy: Teaching methodologies to reach diverse learners in science instruction. Equity & Excellence in Education. 40(3):252-265.
43. Nagda, B., et al. 2009 Winter. Evaluating intergroup dialogue: Engaging diversity for personal and social responsibility. Diversity and Democracy. 12(1): 4. Link
44. Nieswandt, M. 2005. "Attitudes Toward Science: A Review of the Field." *In Beyond Cartesian Dualism: Encountering Affect in the Teaching and Learning of Science*. Ed. Aslop, S. New York, NY: Springer.
45. NIH.2006. *Regenerative Medicine.* Department of Health and Human Services. Link
46. NIH. 2001.*Stem Cells: Scientific Progress and Future Research Directions*. Department of Health and Human Services. Link
47. Obama, B. 2010. Barack Obama Speaks at Notre Dame, Calls for 'fair-minded Words.' Politico.Link
48. Pavlus, J. 2012.Why Infographic Thinking is the Future not a Fad. Francesco Franchi on Visual Storytelling and New Languages in Journalism. Fast Company Design. Link
49. Perry, W. 1981. "Cognitive and Ethical Growth: The Making of Meaning", in Arthur W. Chickering and Associates, *The Modern American College*. San Francisco: Jossey-Bass: 76-116.
50. Picturing to Learn Project. An NSF funded project designed to reveal student misconceptions about science. Link
51. Popper, K. R. 1963. *Conjectures and Refutations: The Growth of Scientific Knowledge*. New York, NY: Routledge.
52. Quillin, K., & Thomas, S. 2015. Drawing-to-learn: A framework for using drawings to promote model-based reasoning in biology. CBE Life Sciences Education. 14(1):es2. Link
53. Rapaport, W. 2011. William Perry's Scheme of Intellectual and Ethical Development. Link

54. Scott, C. 2015. Backward by design: Building ELSI into a stem cell science curriculum. Hastings Center Report. 45(2): 26-32.
55. SENCER: Science Education for New Civic Engagements and Responsibilities. A rich site with model course curricula, workshop and institute announcements, and white papers. Link
56. SENCER/Student Assessment of Learning Gains. Link
57. Skloot, R. 2010. *The Immortal Life of Henrietta Lacks*. New York, NY: Broadway Books/Crown Publishing.
58. Spanjers, I. 2010. A theoretical analysis of how segmentation of dynamic visualizations optimizes students' learning. Education Psychology Review 22: 411-423.
59. Tanner, K. 2009. Learning to see equity in science. CBE/Life Sciences Education. 8(4): 265-270. Link
60. Tanner, K. and Allen, D. 2004. Approaches to biology teaching and learning: learning styles and the problem of instructional selection—engaging all students in science courses. CBE/Life Sciences Education. 3:197–201
61. Tanner, K. and Allen, D. 2007. Cultural competence in the college biology classroom. CBE/Life Sciences Education. 6:251-58. Link
62. The Perry Network. A center for the study of intellectual development using William Perry's model of ethical development http://www.perrynetwork.org/ and UC Berkeley has an abbreviated overview Link;Youtube Overview Link
63. Thompson, C. Visual Thinking. October 2010. Wired Magazine. One page op-ed that highlights the ways in which RSAnimate, Googlemaps mashups and other tools are allowing new ways of learning and teaching. Link
64. Tobias, S. 1990. *They're Not Dumb, They're Different: Stalking the Second Tier*. Tucson, AZ: Research Corporation.
65. Tversky, B. 2002. Animation: can it facilitate? International Journal of Human Computer Studies 57:247-262.
66. Wiggins and McTighe. 2005. *Understanding by Design, 2nd Ed*. ACSD.
67. Wilson, M. and Sloane, K. 2000. From principles to practice: An Embedded Assessment System. Applied Measurement in Education 13 (2):181-208. Description of the BEAR assessment instrument to assess students' understanding of how to consider evidence, benefits and trade offs in decision making.
68. Weasel, Lisa H. 2004. Feminist intersections in science: Race, gender and sexuality through the microscope. Hypatia. 19(1) Winter:183-193.
69. Workforce Development in Stem Cell Research. 2011. Link