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Developing a Social Justice Biomedical Engineering Curriculum Unit

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The purpose of this WIP research paper is to outline the development of a K-12 curriculum unit intended to promote student learning about biomedical engineering through the lens of social justice concerns in organ transplantation. This work will be based on two primary domains relevant to science teaching and learning: socioscientific issues and the scaffolded knowledge integration framework.

Socioscientific issues

A growing segment of educational practitioners have amplified research focused on expanding learners' sociopolitical consciousness in relation to the material they are learning within their science classes [1], [2]. As a consequence, socioscientific issues have become a focal point for research attention by experts in argumentation, ethics, and science education more broadly; an unsurprising development given the area's potential to not only improve the conceptual understanding but also transform learners' normative beliefs about the nature of science as well [3].

Socioscientific issues instruction aims to contextualize science learning and teaching within an environment rich with ethical, controversial, and socially-impactful subject matter to motivate deliberative dialogue within and among learners [4]. Underlying these aims, however, is the ability for students to engage their critical thinking skills and construct arguments based upon evidence (as is illustrated by the inclusion of this practice within Next Generation Science Standards [5]).

Despite this, however, research notes that middle school science learners frequently struggle to develop more advanced argumentation skills without explicit consideration by curriculum or instruction [6]. Thus, educators and researchers alike have vested interest in incorporating argumentation-based learning activities in K-12 science classrooms which center social justice advocacy.

Scaffolded knowledge integration

The scaffolded knowledge integration framework aims to develop learning environments which make science accessible, illuminate learners' cognition, and promote a classroom culture of collaborative and lifelong learning [7]. Practical applications of the framework have sought out Web-based Science Inquiry Environments (WISE) which allow educators to design, host, and

share lesson plans with a broader audience of teachers and learners. Thus, the WISE platform has emerged as a platform which can facilitate scalable yet personalized unit plans for a diverse community of educators and science learners [8].

Present Study

The present work-in-progress research utilizes the WISE platform to advance an original social-justice oriented science curriculum which will be scalable to a diverse set of middle school science teachers and learners. The final product will improve students' argumentation skills, conceptual understanding, and scientific literacy by engaging learners in the following activities:

- Exploring the varied structures/functions of organs, organ systems, and scientific arguments;
- Learning about emergent solutions in biomedical engineering to prolong the storage of human organs;
- Constructing evidence-based arguments in the form of policy proposals designed to mitigate racial and/or socioeconomic disparities in organ transplantation (i.e. the 'Organ Gap');
- Engaging in structured argumentative discourse in support of/against policy proposals developed by students and their peers.

Method

The ongoing development and eventual practical application of this curriculum unit is guided by Design-Based Implementation Research (DBIR). DBIR is a methodological approach which seeks to (a) improve educational practice via collaborative, iterative design amongst multiple groups of stakeholders; (b) build theoretical and practical knowledge about teaching and learning, and; (c) and cultivate the institutional ability to sustain these changes [9]. The present work can be conceptually divided into a few distinct phases of research activities.

During the first phase, researchers consulted relevant literature in science education and argumentation theory to design the initial prototype of the curriculum unit. Researchers also sought guidance from subject matter experts in biomedical engineering during this phase of the project. These subject matter experts included multiple groups of postdoctoral fellows and tenured faculty members across several different research institutions in the United States. This first phase concluded in the Fall of 2023 after researchers had established a working prototype of the unit on the WISE platform.

The second phase of DBIR, which is currently ongoing, involves researchers seeking out feedback from multiple groups of essential stakeholders. While feedback will be tailored to the specific type of stakeholder group, it is generally intended to assist researchers in calibrating the content, structure, and sequence of lessons and activities contained within the existing prototype of the curriculum unit. The groups of stakeholders currently being recruited to assist in this process generally fall within three domains of expertise:

(1) Subject matter experts including key personnel within an NSF Engineering Research Center engaged in emergent research and development of organ/tissue preservation techniques such as machine perfusion, vitrification, etc. These individuals will support the revision process by confirming the accuracy of science content.

(2) Educational practitioners who ideally have some experience implementing novel curricular designs for inquiry-based science instruction. The type of input sought from this stakeholder group includes implementation concerns, such as feasibility, grade-level appropriateness of content, and standards-alignment.

(3) Industry partners consisting of professionals working within organ procurement and allocation organizations in the United States. These individuals will provide guidance regarding the culminating argumentation activities of the curriculum unit.

The nature of subsequent phases in the DBIR process depend on the insights gained as a result of these ongoing conversations with domain experts. These insights will be shared during our WIP research paper session.

Results

Provided that this research is currently ongoing, the reported results are limited to the prototype of the curriculum unit. This unit is currently divided into four distinct lessons or thematic areas of subject matter. Each lesson contains a variable amount of individual 'steps', or activities, designed for students to complete. Table 1 provides an outline with summary descriptions of activities comprising the current unit prototype.

Table 1: WISE Curriculum Unit Outline

Lesson	**Step**	**Description ("Students will…")**
Introduction to Organs, Organ Systems, and Scientific Argument	What do you know?	Elicit prior knowledge regarding organ systems as well as argumentation.
	Doctor Diaries (3)	Read fictionalized medical case studies where a organ systems. Identify argument components within these texts.

Translating Knowledge into Real-World Applications: Organ Transplantation and Biopreservation	Transplant Testimony	Watch and reflect on a video testimony about an individual's organ transplantation journey.
	History of Organ Transplantation	Read and discuss the history of organ donation and transplantation. Identify the primary challenges facing the organ transplantation system.
	Lessons from Nature	Watch video(s) about animals which have evolved to regulate their internal temperatures to survive in extremely cold climates. Draw connections between these adaptations and human organ preservation.
	Biopreservation	Compare and contrast emerging organ preservation techniques with traditional cold storage.
Science, Technology, and Society (Jigsaw Activity)	Investigate	Explore resources covering historical examples of scientific discoveries with significant moral and social implications.
	Reflect	Individually respond to reflective questions about their respective historical case.
	Discuss	Discuss their responses to the reflective questions with peers who had reviewed the identical resources.
	Present	Share summaries and takeaways of their respective case in peer groups
Culminating Argumentative Activities	Policy Briefs	Examine evidence about the 'organ gap' in the U.S. organ transplantation system in the United States. Craft an argumentative essay advocating for a policy-based solution to this issue.
	Classroom Debate	Engage in argumentative discourse regarding the policy plans outlined by students in the previous activity.

The work presented in the above table is currently contained with all relevant materials under the WISE platform. During the Spring of 2024, we presented unit materials to NSF ERC faculty with expertise in convergent bio-engineering research and STEM workforce development (N = 17) and solicited their feedback/suggestions regarding (a) the accuracy of science content and (2) evidentiary resources for the culminating argumentative activities. This stakeholder input is currently being analyzed to facilitate the re-design of unit materials.

Based on consultation with the relevant research literature as well as preliminary feedback from project stakeholders, we outline at a set of key takeaways for researchers and educators seeking to integrate argumentation-based curricula from the perspective of socioscientific issues. Specifically, activities should:

(1) Orient the science content around a focal issue which lacks a well-defined solution. The present work does so by centering the issue of healthcare inequality, but other curricula might consider issues related to environmental justice, genetically modified organisms, artificial intelligence, etc.

(2) Scaffold students' understanding of the features which constitute a well-constructed argument. This scaffolding may include explicit instruction about argument structure (i.e., Toulmin's argument pattern), contrasting examples of high- and low-quality arguments, Students should also be provided with examples of how scientists/engineers employ arguments in their practice as well.

(3) Be carefully and intentionally designed to support student learning based on features of the classroom context, such as the prior knowledge of students and teachers, the particular science/engineering topic being discussed, and the cultural or social dynamics shaping the learning environment.

Discussion

Despite its current status as being a work-in-progress, the development and ultimate implementation of this curriculum unit is expected to benefit both the teaching practices and learning outcomes of students exploring concepts in the biological and engineering sciences. It expands upon previous work related to socioscientific issues and scaffolded knowledge integration through the collaborative, iterative refinement of scalable curriculum intended to engage learners in authentic science inquiry practices such as examining data, constructing explanations, and creating arguments from evidence. As a result, we anticipate the product of this endeavor will serve as a model for researchers, teachers, and curriculum design experts in establishing learning activities required for a diverse engineering workforce in the 21st century.

In the meantime, our paper session will engage the audience in critical conversations surrounding equity, diversity, and inclusion within engineering education. Specifically, we plan to facilitate discussion around the following topics/questions:

1. What challenges can teachers/researchers expect while covering complex social justice issues, like disparities in organ transplantation?

2. How might this curriculum design (or curriculum in general) more effectively leverage students' funds of knowledge and foster the development of engineering identity?

3. How might authentic engineering practices (e.g., developing models, analyzing data, using math/computational thinking) be further incorporated into learning about the social justice aspects of science topics?

We expect these topics to yield productive and engaging conversations among audience members, inspiring future refinements of our social justice engineering unit.

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