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DESIGN AND IMPLEMENTATION OF A TECHNOLOGY-SUPPORTED SOCIOSCIENTFIC INQUIRY UNIT IN HIGH SCHOOL BIOLOGY

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Socioscientific Inquiry (SSI) represents an instructional approach designed to target interest and knowledge in science. In this context, students consider scientific issues that have social implications and comprise a range of trade-offs, concepts, and considerations in order to arrive at informed conclusions (Sadler, 2004, 2011). Given the potential benefits to students on utilizing SSI within K-12 instruction, it is important to explore the challenges to implementing SSI in authentic classrooms settings. Doing so may provide additional insight into how to better partner with teachers to successfully implement SSI instruction. This design case describes an iterative inquiry curricular design process within the context of a 9th grade science classroom. Specifically, our case attempts to increase our understanding of the SSI design and implementation process as it applies to a high school classroom context, and enables us to understand what kind of instructional supports most benefit students.

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PROJECT OVERVIEW

The purpose of this design case is to share an iterative inquiry curriculum design project focusing on the collaborative design, development, and implementation of one specific socio-scientific inquiry (SSI) unit within a high school biology classroom. We will discuss the initial design and implementation of the unit, detail the lessons learned from our initial implementation of the unit, and outline the revisions made to overall design during the second implementation of the unit.

DESIGN CONTEXT

Students' lack of interest in science has become a major concern among science educators, researchers, and policy makers (Loukomies et al., 2013; National Research Council, 2012; Xu, Coats, & Davidson, 2012). A group of instructional designers in the Instructional Systems Technology (IST) department at Indiana University attempted to address this concern by employing the SSI framework into a high school biology classroom. As questions in SSI deal with scientific knowledge and issues relevant to students' lived experience, it is more likely to promote student interests in science studies (Sadler, 2011).

The design team collaborated with a secondary science teacher who had received an award for using technology-enhanced inquiry-based instruction in his classroom. The teacher had nine years of experience teaching science and math. The teacher normally used mini-lectures and individual work as his primary instructional strategies for delivering content. He had knowledge of various inquiry teaching strategies, but had not specifically taught using the SSI model previously. After being introduced to the SSI framework by members of the design team, the teacher believed that the SSI model could better support his instructional goals while engaging his students in more authentic inquiry practices.

The design team consisted of two professors and three of their doctoral students in the IST program. The design team had been focused on exploring how technology could support the implementation of inquiry-based learning for both teachers and students. The tools within Socio-Scientific Inquiry Network (SSINet) reflected the design team's efforts to assist teachers in designing disciplinary inquiry units and to facilitate the critical processes of SSI. Considering that technology tools could be utilized in a different ways depending on the particular subject area, the goal of the design team was to have a better understanding of how the teacher and students use SSINet in a natural and authentic way while working collaboratively with the teacher.

SSI Curriculum Model

The principles for planning and implementing SSI instruction focus on engaging learners with rich science content as they explore essential societal issues (Brush & Saye, 2014; Glazewski, Shuster, Brush, & Ellis, 2014; Saunders & Rennie, 2013; Saye & Brush, 2004). To establish relevance, instruction is built around a specific "driving" question that requires both science content knowledge as well as ethical decision-making in order to fully address the question itself. For example, a driving question may be something as simple as "Is our food safe?" In exploring this question within a specific science curricular area (microbiology for instance), the question helps make the content more relevant and engaging to learners. Once a framing question is established, teachers support inquiry by providing multiple ways of encountering content and supporting student thinking through hard and soft scaffolding (Saye & Brush, 2002). A critical component of this model is a well-designed culminating activity, through which students present and defend their position publicly (see Figure 1).

SSINet: A Web-Based Learning Environment

The unit discussed in this design case was developed within a web-based learning environment known as SSINet (http://education.indiana.edu/ssinet). The SSINet environment was developed with the goal of supporting teachers in their design and implementation of SSI curricula. Tools available in the SSINet environment enable teachers to create and manage activities and resources to support science inquiry learning (see Figure 2). The tools also assist teachers in the design of hard scaffolds that can be embedded into activities to support learners' performance, constrain the task, and help the teacher perform additional soft scaffolding (Brush & Saye, 2002).

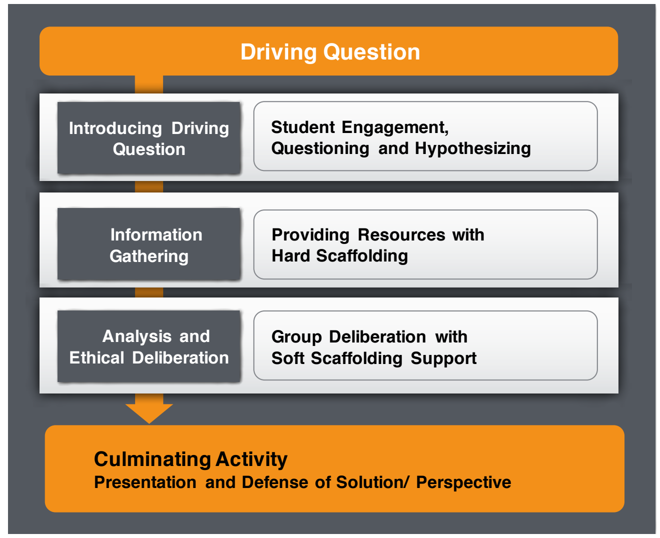

FIGURE 1. SSI curriculum structure (adapted from Saunders & Rennie, 2013).

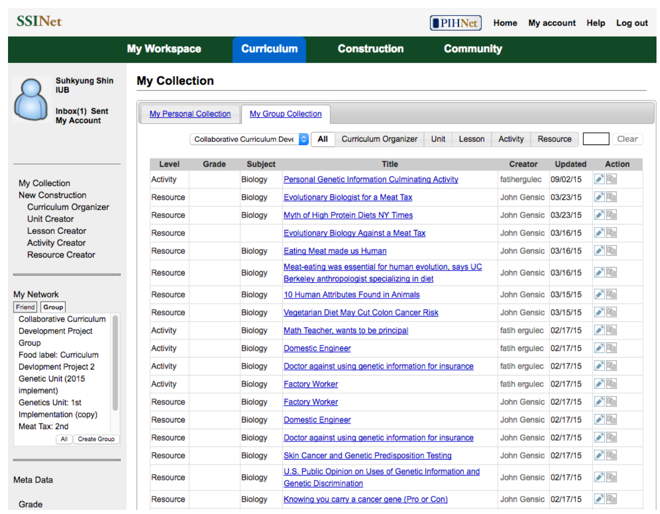

FIGURE 2. Socio-Scientific Inquiry Network (SSINet).

DESIGN PROCESS

The design process was a collaborative effort between the teacher and the design team. Below is a timeline of the overall design process (see Figure 3).

Initial Analysis

The first iteration of the unit design, development, and implementation took place between November 2012 and March 2013.To begin the process, the teacher and the design team had an initial meeting to conduct an analysis of the learners, context, and curriculum. The outcomes of the meeting were as follows:

Potential topic and teaching approach

Since the instructional time was limited and the topic needed to align with national and state science standards, the potential topics of a SSI unit had to be chosen from the teacher's normal curriculum. At this point, the teacher suggested that "Genetics and the Molecular Basis of Heredity" would be an appropriate topic for the unit. We discussed a number of different instructional strategies and activities that could be applied to SSI design. The design team also provided the teacher with video examples of inquiry-based units that had been implemented by other teachers, to help him have a better idea about how he could apply this model to his class and existing curricular content. The initial plan was that the teacher would draft a driving question, culminating activity, and an outline of SSI activities within two weeks of our initial meeting.

Science content within an ethical context

In the SSI framework, selected science content is embedded within a unit (or driving) question that requires students to engage in discussion and debate within a social and ethical context. One of the critical aspects the design team had to decide upon was the social/ethical context that would be the focus of the unit and would also motivate students to engage in the unit question. The teacher shared his concern that students might have a difficult time connecting specific SSI activities designed to address an ethical dilemma with the science content knowledge integrated into the unit. In other words, he was concerned that students would be unable to gain enough science content knowledge to fully explore the ethical aspects of the question that was the focus of the unit.

Introduction to the SSINet tools

During the initial meeting, the design team provided a brief explanation on how to use SSINet tools and delivered an SSINet manual to the teacher. It was essential to learn this feature because the teacher and the design team worked in different geographical locations and the SSINet tools allowed us to work collaboratively on the unit design.

Initial SSI Unit Design

Information about the class related to the learners and the environment was shared via email. The first implementation took place in mixed ability, 9th grade biology classes at a rural, though highly varied SES high school. Based on the mutual understanding of the teaching situation, activity ideas for the "Genetic Information" unit were proposed and discussed over a period of four months in preparation for the first implementation. These informal interactions took place through Skype, emails and online chats.

Brainstorming the topic and unit design

CLASSROOM ENVIRONMENT AND AVAILABLE RESOURCES: The teacher decided he would like to develop the unit using the SSINet tools and deliver it to the students via the Internet. The teacher's classroom had access to 15 MacBooks and 15 iPads, which could be used by his students to access the unit via the SSINet "activity viewer" tool.

CREATING A DRAFT OF THE UNIT USING SSINET: Although the design team collaborated with the teacher to develop the SSI unit, activities and resources, the teacher made all final decisions regarding the content, length of the unit, sequence of activities, and the various assessments that students would complete throughout the unit. After our initial face-to-face meeting, the teacher began to draft SSI activities. In subsequent brainstorming sessions with the design team, the teacher shared his ideas and the design team provided feedback and suggestions for better integrating components of the SSI curricular model into his design.

ESTABLISHING A DRIVING QUESTION AND SEQUENCE OF SSI ACTIVITIES: The design team suggested to the teacher that he begin by determining the driving question for the unit. We discussed the key features of a good driving question; the question needed to address an important societal issue with ethical implications and needed to require knowledge of specific science content in order to fully address the question. To better assist the teacher's development of a driving question, the design team provided additional examples of driving questions from SSI units that had been previously developed by other teachers.

Using this information as a starting point, the teacher generated several potential driving questions that he thought would be engaging to students and allow for integration of key science content. The teacher was concerned that the question needed to allow him to integrate content that would be included on the end of course assessments that

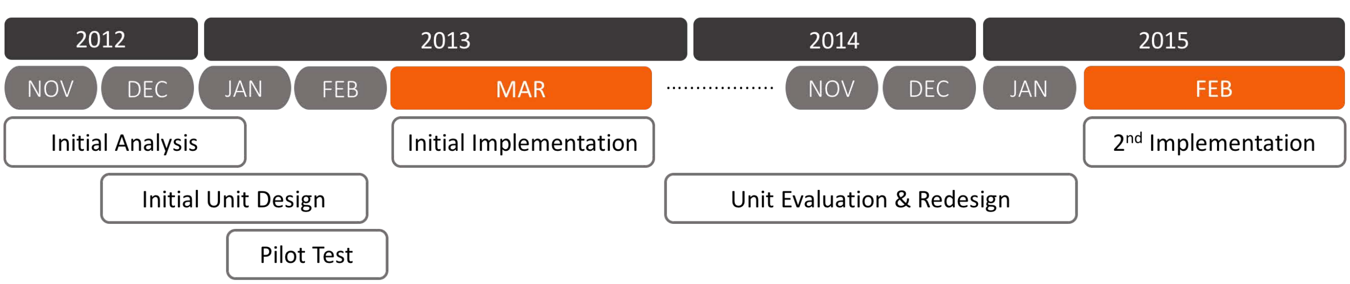

FIGURE 3. Timeline of design process.

students would complete at the end of the school year. The teacher worked with the design team on several drafts of the driving question, focusing on the requirements that the question should be engaging to students, incorporate ethical implications, and encompass the science content standards he wanted to cover in the unit.

After generating the driving question for the unit, the teacher then produced a series of activities that incorporated a variety of primary- and secondary-source articles and readings accompanied by detailed guidance for students. As the design team reviewed the materials, we identified additional scaffolding that could be embedded within various activities and resources to assist students' comprehension of the content. The design team suggested to the teacher that he could embed color-coded annotations into the reading materials to assist students with better understanding difficult content. We also discussed a class assessment plan and suggested to the teacher that he embed the evaluation rubric into the unit.

Pilot testing the SSINet student "viewer"

The design team conducted a pilot test of the unit activities within the SSINet student "viewer" (the web-based tool that students would use to view the actual activities the teacher developed) in which we asked a number of current doctoral students with K-12 teaching experience to test the unit with iPads and Macs. During the pilot test, the design team identified some technology issues that needed to be resolved. One issue was that the SSINet "viewer" worked well with laptop computers, but some web 2.0 resources incorporated into the unit activities did not perform well on iPads. While the teacher continued the final development of the unit activities, the design team worked with the lead programmer to address a majority of the technical problems. However, we were not able to successfully resolve some issues involved with using Web 2.0 tools and Google Docs on iPads. In these cases, we made the decision to use alternative delivery strategies for some student activities (e.g., providing the activities to students via paper-based resources). This allowed for the design focus to remain on the SSI unit itself instead of troubleshooting Web 2.0 tools.

Initial Unit Outline

Based on feedback from the design team, the teacher determined that the goal of the unit should focus on laws to determine appropriate use of genetic information.

SSI Model	Genetics Unit
Introducing Driving Question *Student Engagement, Questioning and Hypothesizing*	**Grabber: Knowing Your Genes** *Introduce question for unit and whole-class discussion based on preliminary information*
Information Gathering *Providing Resources with Hard Scaffolding*	**Jigsaw Activity** *Genetic traits* **Whiteboard Activity** *Components of genes*
Analysis and Ethical Deliberation *Group Deliberation with Soft Scaffolding Support*	**Culminating Activity** *Examine assigned role and deliberate perspective*
Culminating Presentation *Presentation and Defense of Solution/Perspective*	**Culminating Presentation** *Present perspective; support and defend perspective to other members of class*

FIGURE 4. Overview of the genetic information unit.

He generated the driving question for the unit, which was *"What laws should we have to govern the use of genetic information in health insurance, employment, life insurance, and long term care insurance?"* He then developed a sequence of activities to facilitate students' exploration of the ethical issues associated with the driving question while being introduced to the content for the unit. This sequence included four major activities: Entry event, Jigsaw, Whiteboarding, and Culminating activity. Figure 4 provides an overview of the unit design. The initial unit design can also be accessed via the SSINet viewer (http://156.56.1.74/pbltec/construction/activity/2601?pop).

Entry Event

An entry event (or "grabber") was designed to introduce the driving question for the unit by engaging students in a discussion regarding a recent event in which the question was addressed in an authentic context. In this case, students were presented with an NPR radio segment which discussed the advantages and disadvantages of having access to your personal genome sequence, and a second primary resource from *The New York Times* in which an individual described her struggles with the knowledge that she has a very high predisposition to contracting cancer based on possessing a specific gene mutation (see Figure 5).

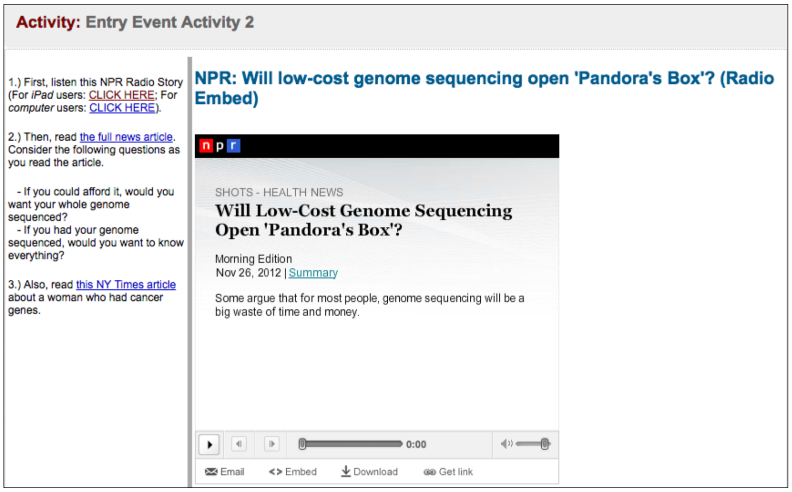

FIGURE 5. Entry event activity.

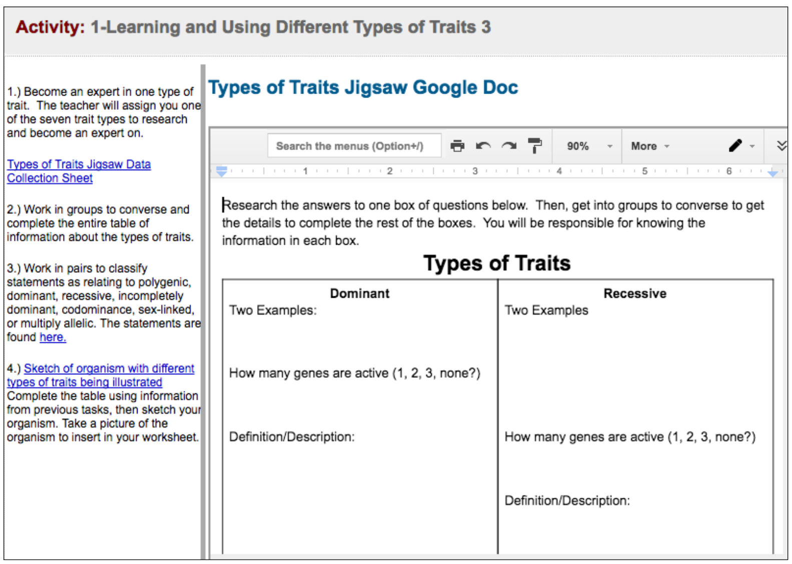

FIGURE 6. Jigsaw activity.

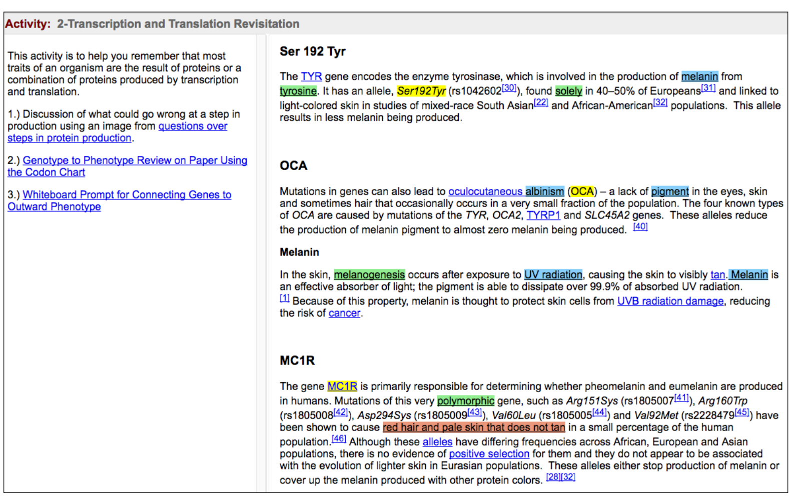

FIGURE 7. Whiteboard activity.

The teacher then engaged students in a whole-class discussion in which they debated the pros and cons of having knowledge of personal genetic information, and then discussed how knowledge of genetic predispositions might impact other health-related issues.

Jigsaw

To assist them with developing foundational genetics content knowledge, students then completed a jigsaw activity in which student groups were assigned one of seven trait types (polygenic, dominant, recessive, incompletely dominant, codominance, sex-linked, or multiply allelic), and asked to research the specific trait and share an overview of the trait to their classmates. While exploring the content, students were using a Google Doc activity sheet that was embedded into the SSINet student viewer (See Figure 6).

Whiteboarding Activity

Students then completed a whiteboard activity to assist them with understanding additional genetics content (namely, that most traits of an organism are the result of proteins or a combination of proteins produced by transcription and translation).

After exploring the content with their peers, each group presented how their gene works when it is activated and deactivated at the molecular level. While reading the articles, students were provided with scaffolding such as thinking questions and background information that were embedded in the reading materials (see Figure 7).

Culminating Activity

Finally, student groups engaged in a culminating activity in which they were to draft laws to guide how personal genetic information could be used by employers. Student groups were "countries" that settled upon their genetic information laws and then presented their laws and rationale to the rest of the class. Each group then gave final presentations in which they defended the scientific, ethical, and moral implications of the laws they developed (see Figure 8).

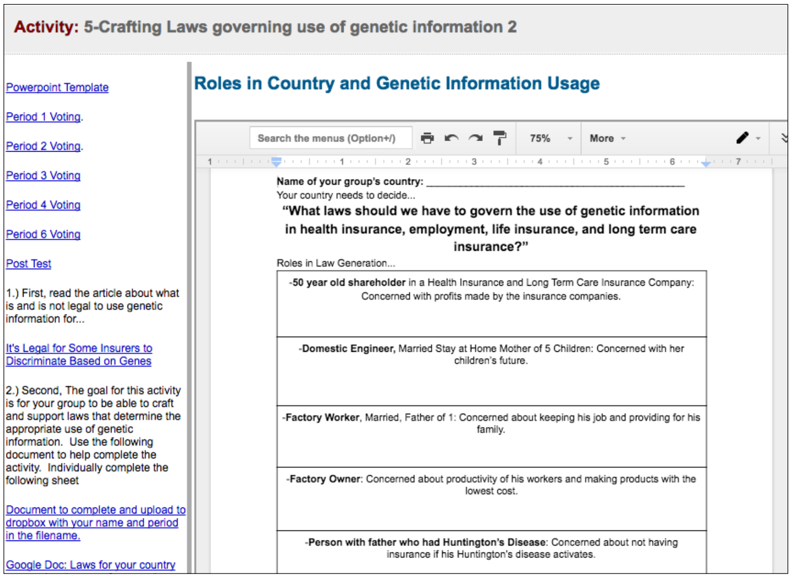

FIGURE 8. Culminating activity.

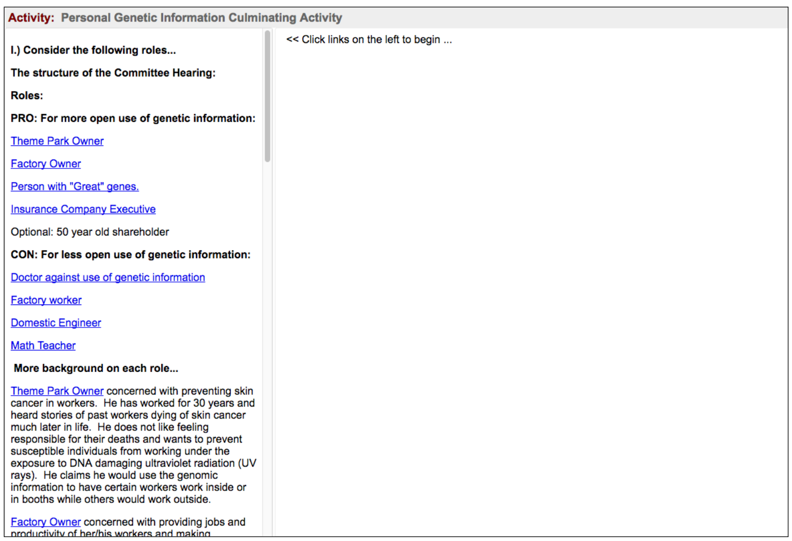

FIGURE 9. Culminating activity of the unit displaying all stakeholder positions.

DESIGN ISSUES AND REVISION OF SSI UNIT: LESSONS LEARNED FROM THE FIRST IMPLEMENTATION

The initial implementation took place within the context of the teacher's 9th-grade biology course; students engaged in the 11-day unit in which classes met daily for 50 minutes. During the initial unit implementation, the design team observed each class session and had informal conversations and a daily debriefing session with the teacher. The design team also conducted post-unit interviews with the teacher and students in order to evaluate the design, development, and implementation process.

After the initial implementation of the unit, the teacher and design team reviewed the observation and interview data, and used these data to redesign the unit based on issues identified during the first implementation. We redesigned the genetics unit between November 2014 and March 2015.

The major design change we initiated between the first and second implementation focused on the culminating activity. The decision to redesign the culminating activity was based on our observations that, despite the importance of the culminating activity with regard to the SSI curricular model (see Figure 1), the way in which the culminating activity was implemented in the unit did not generate the desired learning outcomes from students. In fact, students were unclear regarding the importance of the culminating activity and the actual processes they needed to perform in order to complete the activity.

As a result, the design of the culminating activity for the second implementation included additional hard scaffolding to assist students with understanding the specific steps involved in developing their final presentations, and with understating their roles and responsibilities with regard to the activity itself. These design changes are described below. The revised unit design can also be accessed via the SSINet viewer (http://156.56.1.74/pbltec/pad/activity.html?2969).

REDESIGN OF THE CULMINATING ACTIVITY

After carefully reviewing data collected via classroom observations and students' post-unit interviews, and engaging in discussions with the teacher, the design team identified several challenges faced by students while completing the unit activities and, in particular, the culminating activity/student presentations. Specifically, there were three main areas in which students struggled: (a) understanding different roles, (b) building arguments with evidence, and (c) monitoring and evaluating their arguments. Thus, we decided to redesign the culminating activity to address these issues.

Assigning Specific Roles

After observing group presentations, the teacher and design team concluded that students felt overwhelmed while preparing their group presentations.

In our initial design, students were asked to present all stakeholder positions (see Figure 9), but many of the groups failed to provide evidence to support their position regarding the use of personal genetic information.

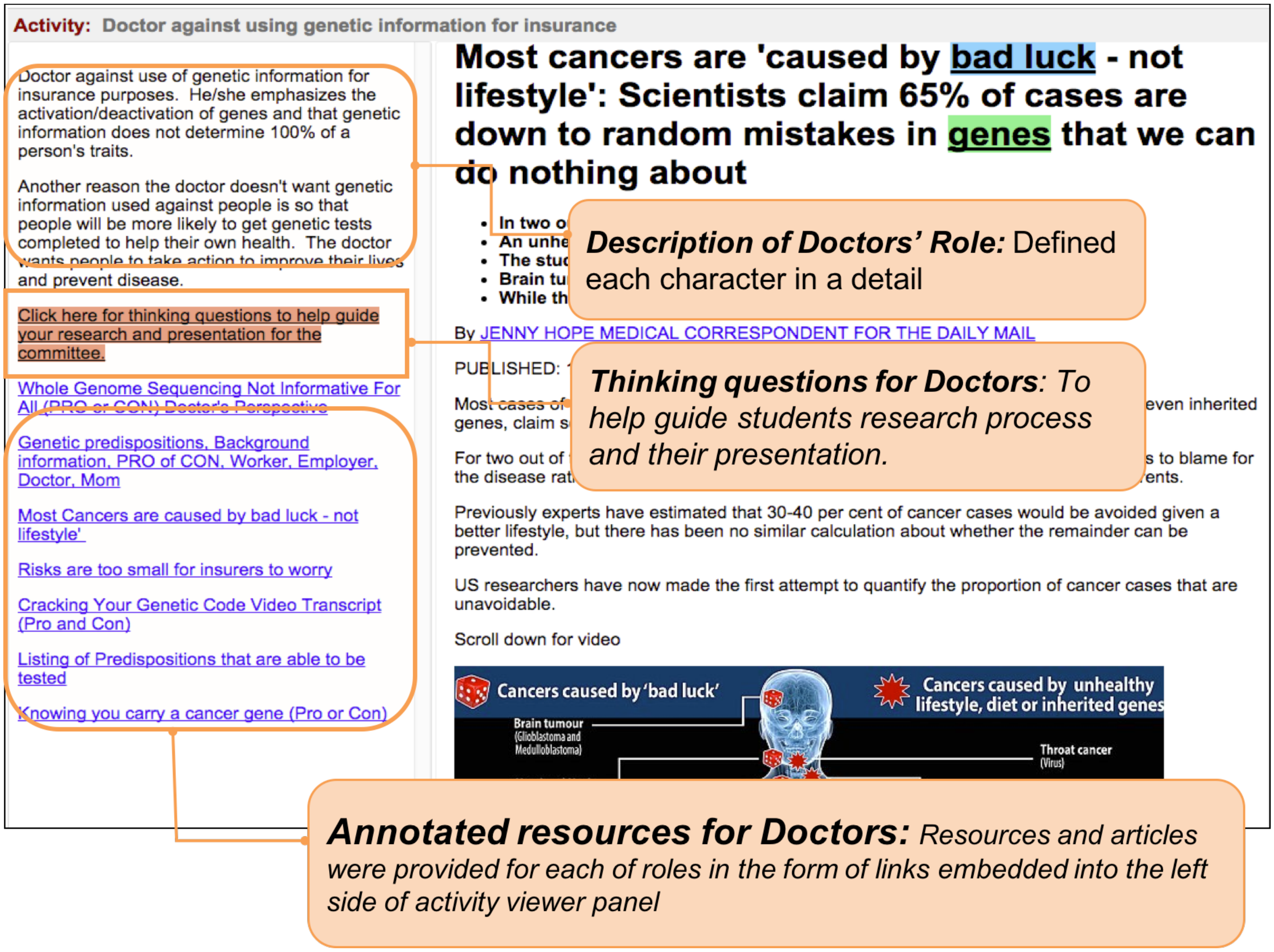

FIGURE 10. Culminating activity of the unit displaying 'Doctors' group page.

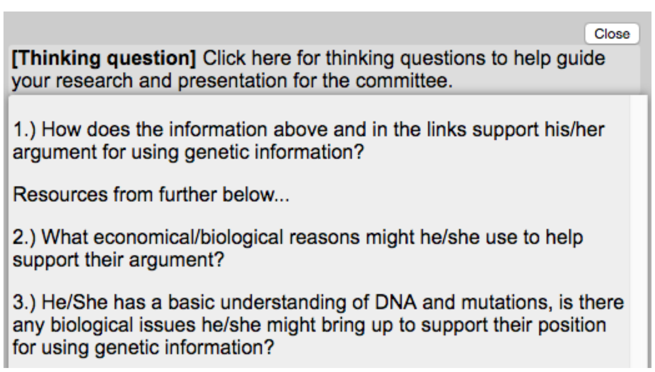

FIGURE 11. Thinking questions for each role.

FIGURE 12. Question-asker meeting.

The design team examined the process by which students prepared their final presentations and concluded that this issue might be due to the fact that students were not able to fully understand each possible position regarding the use of genetic information. Students were required to review each stakeholder position, develop their own personal position regarding the use of genetic information, and search for relevant resources to support their position. With limited time devoted to the culminating activity, most student groups were unable to develop robust presentations in which they provided evidence to support their positions.

The design team discussed this issue with the teacher and suggested that instead of asking students to review all of the various stakeholder positions he developed, he assign students to one specific stakeholder role and provide more detailed descriptions of each position. Based on our discussion, the teacher revised the culminating activity and refined the roles. He assigned student groups to one of eight specific stakeholder positions (theme park owner, factory owner, person with "great" genes, insurance company executive, doctor against use of genetic information, factory worker, domestic engineer, and math teacher) and had each group research their specific role and present the stakeholder's position regarding the use of genetic information to the rest of the class.

Providing Multiple Forms of Support During the SSI Activity

Based on the results of the first implementation, we also decided to provide additional forms of scaffoldings to clarify each role and assist students in constructing arguments and supporting those arguments with evidence. To help students understand each role, the teacher added descriptions of each character role and defined each character in detail. This assisted students with focusing on key aspects of the role they were assigned as it related to the driving question for the unit.

We also determined that students needed additional support while constructing their presentations and selecting evidence to support their claims. To assist students with building arguments with supporting evidence to include in their presentations, the teacher provided specific resources to each group. These resources were selected to help each group better understand their assigned character's position, as well as assist groups with building evidence to support that position. Four to eight annotated resources were provided for each stakeholder position. These resources were provided in the form of links embedded in the activity viewer panel (see Figure 10). While refining the design, the teacher began reviewing current news articles to provide authentic materials related to each of the roles. Once the teacher selected a resource, he used the SSINet tools to annotate the resource by embedding color-coded definitions, background information, and thinking questions to assist students with understanding specific information contained in the resource. In addition, the teacher generated a number of thinking questions for each role that helped guide students in developing their presentations (see Figure 11).

Supporting Peer Questioning

Based on the lack of student-student interaction during presentations that occurred during the first iteration, the design team and teacher were concerned that student groups would focus exclusively on developing evidence to support their assigned role, and fail to consider the perspectives presented by other groups in the class. We believed that this lack of interaction between student groups would allow students to maintain a very narrow view of the pros and cons of using genetic information to make decisions (namely, they would most likely only have a deep understanding of their assigned stakeholder view of the issue). Thus, we decided to include an additional responsibility for student groups as they completed their presentations. Groups were given the added responsibility of researching an opposing stakeholder position and preparing "challenge" questions for the group representing that position.

The teacher assigned one student in each of group to the role of "question-asker" and facilitated a question-asker meeting during group activities (see Figure 12). In the question-asker meeting, students shared tentative questions that they planned to ask other groups. After the meeting, each question-asker returned to their group and shared a summary of the meeting including other groups' perspectives and questions. This preparation enhanced the quality of responses to questions that came from other groups during group presentations, and facilitated a broader view of the various perspectives regarding the driving question among all students in the class.

IMPLICATIONS OF THE REDESIGN

In the second implementation of the unit, the redesign of the culminating activity resulted in more in-depth and detailed student presentations. Both the design team and the teacher believed that (a) more students were better able to apply specific content to support the assigned perspective they were given, (b) that the students were highly engaged in the activity, and (c) that the students had more sense of the purpose of the activity and what they needed to complete in order to prepare their presentations. Table 1 provides a summary of the design issues identified after the first implementation and the modifications made for the second implementation.

The redesign of the culminating activity for the second implementation resulted in several positive outcomes. First, assigning each group to a specific role allowed students to better engage in group

discussions that enhanced their understanding of their own positions. For example, most of groups were able to explicitly articulate their group role and the procedures they followed to prepare their group presentations. In the first implementation, many of the groups stated that they did not understand the procedures they needed to follow to complete their presentations, or even the overall purpose of the presentations themselves. Providing a specific stakeholder position to each student group allowed them to better understand their assigned task (developing a presentation to support their assigned position), and thus develop a procedure for completing the task. This also benefitted students in that

STUDENT SSI ACTIVITY	DESIGN ISSUES: LESSON LEARNED FROM THE 1ST IMPLEMENTATION	REDESIGN OF THE CULMINATING ACTIVITY
UNDERSTANDING STAKEHOLDER POSITIONS	*Initial design* • Students were asked to present all stakeholder positions. *Student difficulties* • With limited time and resources, students had to understand all stakeholder roles as well as search for relevant resources to build and support their position.	*Assigning specific roles* • Designed eight roles and assigned student groups to one specific role to help them focus more deeply on a specific perspective.
BUILDING ARGUMENTS WITH EVIDENCE	*Initial design* • Some possible roles that students might take were given, but students were not asked to take one specific role. • There were minimal descriptions of possible roles. *Student difficulties* • Students had difficulties in developing their arguments without specific contextual information.	*Providing multiple forms of support* • Designed additional forms of scaffoldings to clarify each role and assist students in constructing rigorous argumentations. *Hard scaffolds* • Authentic resources. • Color-coded annotations. *Soft scaffolds* • The teacher facilitated each groups' discussion via timely questioning and provided feedback on their presentation slides.
QUESTIONING AND UNDERSTANDING COMPETING PERSPECTIVES	*Initial design* • There was a lack of student-student interaction during group presentations. *Student difficulties* • Students did not consider the perspectives presented by other groups in the class. • Students completed the culminating presentations having a very narrow view of the pros and cons of using genetic information to make decisions.	*Supporting peer questioning* • Groups were given the added responsibility of researching an opposing role and preparing challenge questions for the group representing that role.

TABLE 1. A summary of the design issues identified after the first implementation and the modifications made for the second implementation.

they could engage in more meaningful group discussions during the presentations.

Second, our design decision to provide more structured hard scaffolds such as descriptions of each role and selective resources with color-coded annotations may have facilitated students' engagement in and success with the culminating activity. We believe that providing these types of scaffoldings may have assisted students' acquisition of content knowledge needed to develop arguments, and may have provided embedded guidance to help student groups remain on task while the teacher was working with other student groups.

Lastly, our design decision to incorporate "question-askers" as a role for a student in each group both better prepared students to present evidence to support their assigned positions, and forced students to investigate other groups' perspectives in order to gain a broader view of the overall issue. Specifically, the question-asker meeting provided an opportunity for students to listen to other positions and share progress, which may have assisted students with reflecting on their own views regarding the use of genetic information. In addition, the teacher's timely soft scaffolding such as guiding students towards specific resources and providing feedback during group work was also critical to the successful implementation of the unit.

CONCLUSION

This design case provides a more detailed view of the iterative processes involved in creating and sustaining an inquiry-based activity in a high school classroom. When we reflect on our design process, we believe that collaboration between the teacher and design team enhanced the development and implementation of actual inquiry unit. During both implementations of the unit, the design team and the teacher had daily conversations and reflection sessions to identify areas for improvement. We discussed what went well and what did not go well in terms of teaching and student performance during the daily debriefing sessions. From the teacher's perspective, he had the opportunity to reflect on his practice and share his experiences through the process of designing and implementing the genetics unit. During our debriefings, the teacher sometimes identified immediate areas for improvement and modified the design of the unit during the implementation. He was also able to modify activities or add additional resources based on his "on the fly" assessment of student needs. From the design team's perspective, having conversations with the teacher provided an opportunity to identify challenges and needs from the perspectives of the teacher and students. Thus, involving teachers in the design process is critical in bridging gaps between actual teaching practices and design and research activities, which is valuable to the design and development of curricular innovations in a wide array of K-12 instructional settings.

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