Getting on the Same Page Using Scenario-Based Learning:

An Alignment of Education and Industry Goals for Technician Education

Foothill-De Anza Community College District

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Principal investigator

Submitted by SRI International

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Executive Summary

Aligning curricula with industry skills standards is a key element of educating technicians for high technology fields. Such alignments help industry partners collaborate effectively with community college educators, creating a common language and a set of shared goals. The products of alignment sessions provide guidance and focus to instructors who train technicians according to the needs of the industries that will hire their graduates.

The current report examines the alignment of a set of scenario-based learning materials with two sets of relevant industry standards. This review deepens knowledge about the range and types of knowledge and skills that scenario-based materials have the potential to address. In this case, the materials relate to the specific field of bioinformatics.

The bioinformatics SBL materials include four distinct tasks. Task 1 introduces students to the range of bioinformatics databases. Task 2 engages students in searching, downloading, and manipulating data. Task 3 gives students an initial experience analyzing data using spreadsheet software and interpreting data for a general audience. Task 4 combines all the phases of searching and data reporting in bioinformatics. As a set, the bioinformatics tasks effectively cover the range of technical problem solving skills, social teamwork skills, and social-technical communication skills that SBL tasks give students the opportunity to learn.

The key findings of the alignment study are the following:

Overall Alignment of SBL Instructional Materials with Industry Skills Standards: Industry and education experts tended to agree on the extent to which the four instructional activities included content that covered most of the social, social-technical and technical standards (see Table 4 below).

- On average, both the industry and education experts scored the instructional activities' coverage of these dimensions between 3 (Somewhat) and 4 (To a Great Extent), with industry experts consistently scoring the coverage as more extensive than education experts.
- One exception was the extent to which the content in Task 3 (Influenza Incidence and Analysis) covered the social-technical standards. Education and industry experts tended to significantly disagree, with industry experts scoring it higher than the education experts.

Overall Alignment of SBL Assessment Materials with Industry Skills Standards: With some exceptions, both the industry and education experts scored the assessment tasks' alignment with the technical and social-technical standards between 3 (Somewhat) and 4 (To a Great Extent).

- Industry experts consistently scored the coverage as more extensive than education experts.
- Industry and education experts disagreed on the extent to which Tasks 1 and 3 assessments

- measured the social standard, with industry experts scoring them higher.
- Industry and education experts disagreed on the extent to which the Task 2 assessment measured social-technical standards, with industry experts scoring it higher.

Usability of SBL Instructional Materials in the Classroom: The data indicated that faculty experts found Task 2 to be the most usable for the classroom, followed by Task 3, Task 4, and Task 1. The primary reason for these rankings related to the "step-by-step" directions in Tasks 2 and 3 and the relative complexity of Tasks 4 and 1.

Authenticity of SBL Instructional Materials to Industry Contexts: The industry experts found Tasks 2 and 4 to be the most authentic, followed by Tasks 1 and 3. They favored tasks that involved students in direct use of the NCBI database and the full cycle of data search, manipulation, representation, and interpretation. They disfavored tasks that emphasized the use of web tools without students understanding why they were using them (e.g., narrow focus on technical tool usage) or that did not involve typical NCBI data.

Authenticity of the SBL Assessments: The industry experts and education experts differed in their ratings of the authenticity of the assessments. The industry experts rated the assessments of Tasks 2 and 4 as the most authentic, whereas, educators rated the Task 1 and 2 assessments as the most authentic.

- Industry experts wanted to assess students' capacity to understand and engage in the wide range of interpretive activities used in the bioinformatics workplace, and they generally pushed for harder rubrics. The only assessment framework that industry experts preferred more than the education experts was for Task 4—the most comprehensive of the tasks and the associated assessments.
- Education experts wanted to assess students on knowledge and skills that seemed most appropriate considering the other courses students would be taking, and they indicated higher ratings for the overall assessment framework.

Opportunity for Students to Learn Industry Skills and Receive Targeted Feedback/Assessment: Industry experts viewed Task 4 as the most likely to offer an opportunity to learn the knowledge and skills needed in the bioinformatics industry, followed by Tasks 1 and 2. They rated Task 3 as the least likely to offer the opportunity to learn such industry-relevant skills. The assessment results mirrored these reviews. The industry experts rated Tasks 4 and 2's assessments as most focused on measuring high-level skills, followed by Task 1 and Task 3. They rated Task 2 assessments as most focused on measuring content knowledge, followed by the assessments of Tasks 1 and 4. They saw the Task 3 assessment as least related to bioinformatics content knowledge.

Opportunity for Students to Learn Curriculum-Relevant Knowledge and Skills and Receive Targeted Feedback/Assessment: Education experts viewed Task 4 as most likely to offer an opportunity to learn the knowledge and skills relevant to their curriculum, followed by Tasks 2, 3, and 1. But their review of the assessments differed. The education experts rated Task 1's assessment as most focused on measuring high-level curriculum-relevant skills, followed by Tasks 4, 2, and 3. They saw Task 1's assessment as most focused on measuring content knowledge relevant to their curriculum, followed by Tasks 4, 2, and 3.

This report indicates the central tension between the two cultures. Educators emphasize the need for structured developmental opportunities to learn or measure knowledge or a skill in instructional and assessment materials. By contrast, industry representatives emphasize the need for complex challenging opportunities to learn or measure knowledge and skill in instructional and assessment materials. The tensions around this dialogue were evident in this alignment task. Educators were most outspoken when they perceived the materials as failing to offer clear guidance or too much complexity. Industry representatives were most outspoken when materials appeared too easy and "low-level." When these types of professionals work together, this basic difference in perspective may threaten mutual understanding.

This study points to a promising direction for future collaboration between educators and industry. As was clear in a review of the ratings, both educators and industry experts tend to agree on the essential technical, social-technical, and social knowledge and skills required in the field. Using such industry-specific standards may serve as a potentially powerful tool for negotiating disagreements around instructional program design between these two communities. Further, this detailed, standards-specific procedure contrasts from popular efforts to simplify the alignment and validation processes around instructional materials by focusing mostly education-based experts on presumably "easier to rate" general skills such as "critical thinking," "problem solving," or "brainstorming." This research indicates that domain-specific standards may present the shortest and easiest path for developing agreement around workforce instructional and assessment materials.

Introduction & Background

Aligning curricula with industry skills standards is a key element of educating technicians for high-technology fields. Such alignments help industry partners collaborate effectively with community college educators, creating a common language and a set of shared goals. The products of alignment sessions provide guidance to instructors on what to cover in their classes and how to sequence courses in a program for training technicians for industry..

The current report examines the alignment of a set of scenario-based learning materials with two sets of relevant industry standards. Scenario-based, problem-based, or contextualized instructional materials are viewed as potentially effective tools for teaching not just basic content knowledge, but also skills that help students apply such knowledge in the real world. The focus on applied learning outcomes represents a shift in expectations for many postsecondary educators (Lumina Foundation, 2011), but one that is believed to be relatively familiar to career and technical educators (CTE). However, those who have studied CTE instruction have raised questions about whether the instructional approaches employed in these classes adequately prepare students to apply their knowledge in the workplace (Lynch, 2000).

In technician education, there are a few common ways to engage in standards alignment. The process can occur before the design of instructional materials in the form of a DACUM (Develop a Curriculum), a process that usually involves a series of meetings in which industry and sometimes education experts rate the importance of specific skills used in the workforce. A job task analysis represents another process of defining the knowledge, skills, and procedures most frequently used in the workplace—as well as the details of the context of their use. This approach is particularly useful in fields with newer work processes and procedures. Both a DACUM and job task analysis are useful primarily to set high-level goals for the content to be included in instructional materials.

Standards alignment also may occur after specific instructional tasks have been designed. This type of post-hoc alignment ensures that the specific features of an instructional activity reflect both the required job knowledge and sound pedagogical principles for learning (Keiser, Lawrenz, & Appleton, 2004). This form of alignment involves experts from both industry and education in reviewing the actual designed instructional activities. They rate the materials according to their judgments of required job knowledge or skills, and the degree to which the materials provide the student an opportunity to learn—or to be assessed on—such knowledge and skills.

The analysis in this report is of the second type, and the work described serves two key purposes. At the most basic level, the alignment process provides objective verification that both educators and industry representatives consider a particular set of scenario-based instructional materials to address a defined set of relevant knowledge and skills. This is called "content validity." Materials that have undergone a favorable content validity review may be disseminated with confidence that they address valued content.

On a deeper level, this alignment reveals differences in how educators and industry experts perceive the content of the materials. Understanding these differences better supports the partnership between industry and educators.

Project Context

As part of a project funded by the National Science Foundation's (NSF) Advanced Technological Education (ATE) program, researchers from SRI International conducted face-to-face and online reviews of a set of instructional and assessment materials produced by the Scenario-Based Learning (SBL) project. The instructional and assessment materials focused on the topic of bioinformatics. SRI recruited a group of 26 experts for review panels. Each panel included industry and academic experts in biology, biotechnology, and bioinformatics. In the reviews, SRI researchers collected feedback from experts on the extent to which the SBL materials were consistent with industry needs, as well as the teaching goals of biotechnology and biology educators.

This report begins by describing the Destination SBL project, the SBL instructional and assessment materials that were reviewed, and the primary research questions guiding the alignment methodology. Next, the report presents the methodology for reviewing the SBL materials: The characteristics of the expert panel sample, the industry standards used for alignment purposes, the alignment instrumentation, and the procedures used to conduct the face-to-face and online panels. Finally, the report presents the panel findings and closes with a summary and discussion of the results.

Destination SBL Project

Changing realities of the global workforce have created a need for American community colleges to adopt instructional approaches that prepare knowledge workers for high skill, high technology workplaces. In problem-based learning models, such as scenario-based learning, learning activities are situated around problems that resemble those students would encounter in the real world, thus providing opportunities for students to improve their flexible problem solving skills. This logic has led to increased interest in using the approach in community colleges. Yet integrating scenario-based learning into the community college context requires change and an understanding of the ways that this pedagogical approach can be adapted to meet the needs of the faculty practitioner.

NSF awarded a grant to the Foothill-De Anza Community College District with a subcontract to SRI International to conduct research on SBL instructional and assessment materials for bioinformatics. The project uses faculty action research and expert panels to understand the most effective ways to adapt and disseminate SBL instructional materials and modules on a national level and applies those insights in a community of faculty who design and implement SBL tasks in their classrooms.

SBL-Bioinformatics Instructional and Assessment Materials

The SBL-Bioinformatics instructional and assessment materials are organized around a common scenario that situates students as interns in the National Institutes of Health's Bioinformatics Internship Program (BIP), which trains selected university-based Health Center interns. The tasks are summarized below:

- Task 1, *Databases and Tools,* familiarizes intern teams with important databases at the National Center for Biotechnology Information (NCBI) while they investigate research questions associated with the COMT gene.
- Task 2, *Influenza*—Building a Data Set, introduces intern teams to diverse strategies for searching the NCBI databases. Through this work, students find and compare molecular sequences and organize the sequences into a phylogenetic tree to gain insights into their evolutionary relationship. This work will serve as a foundation for more complex work carried out in a subsequent task.
- Task 3, *Influenza Incidence and Analysis,* requires intern teams to obtain data from the Center for Disease Control (CDC) website about the incidence of different subtypes of influenza in the U.S. human population and use graphical analysis to identify the types of influenza that have been most prevalent during several past seasons. The interns use the results of their analyses to identify patterns and uncover challenges in predicting and developing new vaccines.
- Task 4, *Avian Influenza,* requires intern teams to use phylogenetic analysis to investigate a possible Avian Influenza pandemic. The final assignment is conducted following the suspected transmission of influenza A from birds to humans. Interns present their findings and recommendations.

(See Appendix A for the Student Learning and Performance Objectives for each instructional task, as well as the Focal Knowledge, Skills and Abilities targeted by each assessment task, respectively.)

Research Questions

The expert panel was designed to build an evidentiary basis for addressing the following questions:

Usability and Authenticity of Materials

1. To what extent are the SBL-Bioinformatics instructional materials usable for instruction?
2. To what extent do the SBL-Bioinformatics instructional and assessment materials provide a context that seems consistent with real workplaces in the bioinformatics industry?

Opportunity to Learn Relevant Knowledge and Skills

3. To what extent do the SBL-Bioinformatics instructional and assessment materials provide students with an opportunity to learn the knowledge and skills needed in the bioinformatics industry?
4. To what extent do the SBL-Bioinformatics instructional and assessment materials provide students with an opportunity to learn the knowledge and skills in a standard bioinformatics or biology curriculum?

Alignment with Industry Skills Standards

5. To what extent do the SBL-Bioinformatics instructional and assessment materials align with industry skill standards?
6. To what extent do alignment ratings for the SBL-Bioinformatics instructional and assessment materials differ between industry and education experts?
7. To what extent do alignment ratings for the SBL-Bioinformatics instructional and assessment materials differ between education experts in biology and biotechnology, and between industry experts in these two subgroups?

Methodology

Sample

SRI recruited a total of 26 experts from a wide variety of academic and industry contexts (see Table 1): 13 experts from education (7 biology, 6 biotechnology) and 13 experts from industry (6 biology, 7 biotechnology). Of those 26, 7 participated in two face-to-face review sessions of the SBL bioinformatics instructional materials and assessments in November 2010, and 19 participated in an online review in February 2011 (see Table 2)

Table 1. Participating Education and Industry, SBL-Bioinformatics Expert Panel

Education Participants	Industry Participants
Austin Community College	StemCells, Inc. Palo Alto, CA
Mount Wachusett Community College	Mendel Biotechnology Inc.
Truckee Meadows Community College	Operational Technologies Corp., San Antonio, TX
Contra Costa College	SRI International
California State University, Sacramento	Stem Cell Research Laboratories
American River College	Chief Scientific Officer/Founder, Nano Science Diagnostics, Inc.
Gwinnett Technical College	SAIC-Frederick Inc. within the Advanced Biomedical Computing Center (ABCC) in Frederick, MD.
Florida State College at Jacksonville	Center for Cancer Research, National Cancer Institute (NCI), National Institutes of Health (NIH).
Pasadena City College	The Institute for Bioanalytics
San Jose State University	NASA Astrobiology
South Mountain Community College	Illumina, Inc.
Nevada Department of Education	

Table 2. Sample, Face-to-Face and Online Expert Panels

		FTF	Online	Total
Industry	Biology	1	5	6
	Biotechnology	3	4	7
Education	Biology	1	6	7
	Biotechnology	2	4	6
Total		7	19	26

Standards

In order to better understand the extent to which the bioinformatics SBL instructional and assessment materials aligned with both general education (biology, microbiology) and career technician education (biotechnology, bioinformatics), SRI reviewed industry skills standards from the U.S. Department of Labor's CareerOneStop Competency Model Clearinghouse, and Shoreline and Bellevue Community Colleges. SRI researchers with experience in community college education and SBL task content selected subsets of standards that were potentially aligned with SBL knowledge, skills, and abilities that are technical, social, and social-technical (see Table 4) and that are represented in each of the SBL instructional activities and assessment tasks. These subsets were then used in the alignment questions for the online survey (described below).

Instrumentation

We developed two instruments for collecting feedback from experts on the extent to which the SBL materials are consistent with industry needs, as well as biotechnology and biology teaching goals and standards: (1) an online survey to be completed by all panelists, and, (2) a semi-structured interview protocol for panelists participating in the face-to-face meeting. These instruments are described in more detail below.

Online Survey. Two versions of the survey were developed (i.e., one for each type of expert: education and industry). The survey was administered through SurveyMonkey, a popular web-based tool for developing and administering surveys on the Internet (see Appendix B). Each survey contained four primary sections, including instructions, background, and two materials review sections: instructional materials review, and assessment materials review.

Each of the two review sections contained four main subsections, one for each task: Task 1—Databases and Tools; Task 2—Building an Influenza Data Set; Task 3—Influenza Incidence and Analysis; and Task 4—Avian Influenza. Each of the review sections contained three to four closed-response questions (e.g., multiple choice, Likert scale; see Table 3). Each question contained an option for providing a constructed response further describing or explaining their closed-response selection.

Focus Group Interview Protocol. The face-to-face panel included a focus group interview with participants approximately halfway through completion of the survey (see below for additional details about each type of panel). The interview protocol questions closely followed the survey questions, but as open-ended versions of each question. For example, the faculty follow-up questions focused on usability of the materials, and the industry follow-up questions requested general feedback.

Table 3. Materials Review Questions, Industry and Education Surveys

Industry Survey	Education Survey
Instructional Materials	
Please rate the extent to which you think these SBL instructional materials provide an opportunity for students to learn the knowledge and skills needed in your industry. *(To a Great Extent, Somewhat, Very Little, Not at All)* Please rate the extent to which you believe the materials provide a context that seems consistent with real workplaces where you have worked. *(Very Consistent, Consistent, Inconsistent, Very Inconsistent)* Please rate the extent to which these SBL instructional materials include content that covers the following bioinformatics knowledge and skills. *(To a Great Extent, Somewhat, Very Little, Not at All)**	Please rate the extent to which you think these SBL instructional materials provide an opportunity for students to learn the knowledge and skills included in your standard bioinformatics or biology curriculum. *(To a Great Extent, Somewhat, Very Little, Not at All)* Please rate the extent to which you think the materials are usable for instruction. *(To a Great Extent, Somewhat, Very Little, Not at All)* Please rate the extent to which these SBL instructional materials include content that covers the following bioinformatics knowledge and skills. *(To a Great Extent, Somewhat, Very Little, Not at All)*
Assessment Materials	
Please review the information in the Knowledge and Skills section of the assessment task. To what extent do the specific skills listed for the task accurately reflect the work that people in the field do? *(To a Great Extent, Somewhat, Very Little, Not at All)* Please review the Question section of the assessment task. When you are finished please rate the extent to which the question: • gives students a chance to develop higher-level thinking skills important for future study or work in bioinformatics. • poses a problem that students would encounter in outside of an academic setting (i.e., in the "real world"). • gives students a chance to develop content knowledge important for future study or work in bioinformatics. *(To a Great Extent, Somewhat, Very Little, Not at All)* Please review the Rubric/Scoring Key section of the task. When you are finished, please rate the extent to which the scoring key consists of knowledge and skills that are arranged on a scale relevant to measuring performance outside of an academic setting (i.e., in the "real world"): *(To a Great Extent, Somewhat, Very Little, Not at All)* Please rate the extent to which this assessment task elicits knowledge, skills and abilities that are consistent with the following bioinformatics standards: *(To a Great Extent, Somewhat, Very Little, Not at All)**	

* Note. Please see Appendix B for complete list of standards used in these rating questions.

Face-to-Face Panel

Two all-day, face-to-face panel sessions were conducted at SRI International in Menlo Park, CA. The first panel was attended by three, primarily education, experts and the other panel was attended by four, primarily industry, experts. Each expert was outfitted with a laptop with Internet connectivity and scratch paper for writing notes. Experts were given a brief introduction to the purpose of the review activities, the online survey, and the overall agenda and timing for the panel. Following the introductory remarks, panelists were given approximately three hours to get started on the survey. The focus group interview was conducted following the first review session and then lunch was served. Following lunch, panelists participated in another three-hour session to complete the survey.

Online Panel

The online panel sessions were conducted using a combination of email, SurveyMonkey and WebEx, a popular online meeting tool. Two weeklong sessions were scheduled to accommodate experts' schedules. Panelists were sent an email with a secure link to the online survey and given a 5-day window to complete the survey questions at their convenience. Two voluntary call-in times, complete with WebEx support (if needed) were scheduled for each session. Panelists were informed of the voluntary call-in times and asked to use them if they had any questions about the survey format or content, or their participation in the expert panel. A few participants made use of the call-in number.

Analysis

We use a combination of descriptive statistics supplemented, when relevant, by open-ended responses to build an evidentiary basis for addressing all research questions. Additionally, for questions six and seven, the analysis of the survey data will provide experts' views of the alignment of SBL tasks to education and industry needs, as represented by industry and academic standards. The categorization approach developed by Yarnall in previous SBL research (Yarnall & Ostrander, in press) was used to classify industry and academic skill standards along three dimensions: technical content knowledge and skills, social skills, and social-technical skills (see Table 4).[1] We use *t*-tests to compare average ratings of industry and education experts across items in each standard dimension. *T*-test results were used to draw inferences about the extent to which alignment ratings differ, beyond what we would expect by chance, for different expert groups.

1 Further research is needed to determine the extent to which the proposed dimensional structure is empirically verified (i.e., using factor analytic methods).

Table 4. Example Academic and Industry Standards Classified into Technical, Social-Technical and Social Dimensions

Standard Dimension	Dimension Description	Example Standards in Dimension
Technical	• Using tools, languages, and principles of domain. • Generating a product that meets specific technical criteria. • Interpreting problem using principles of domain.	• Knowledge of NCBI (National Center for Biotechnology Information (NIH)) and other similar sites. • Working with complex and multi-dimensional databases. • Knowledge of basics of bioinformatics (generating and managing data, analyzing data and making models of systems based on data).
Social-Technical	• Translating client needs into technical specifications. • Researching technical information to meet client needs. • Justifying or defending technical approach to client.	• Knowledge of the goals and components of the study being analyzed. • Critical thinking and decision-making skills. • Participate in the preparation of reports or scientific publications.
Social	• Reaching consensus on work team • Polling work team to determine ideas	• Collaborative and teaming skills, in person and virtual.

Findings

Below, relevant expert panel findings are presented for each research question. For each question, summary statistics (i.e., n, mean, standard deviation) from the Likert rating items are presented first, followed by relevant, open-ended responses to supplement, and when possible, the summary statistics.

Research Question 1 Findings

To what extent are the SBL-Bioinformatics instructional materials usable for instruction?

Only the education experts *(N* = 13) rated the instructional materials (http://elc.fhda.edu/bioinfo/index.html) to address the question of usability (see Table 5) and provided follow-up comments. Both educators and industry experts provided general feedback on usability partly through the face-to-face follow-up interview.

As shown in Table 5, faculty experts found Task 2 to be the most usable for the classroom, followed by Task 3, Task 4, and Task 1. As the face-to-face follow-up responses revealed, the primary reason for these rankings related to the "step-by-step" directions in Tasks 2 and 3 and the relative complexity of Tasks 4 and 1.

Table 5. Summary Statistics, Usability of Materials

Please rate the extent to which you think the materials are usable for instruction.	
	Education (M)
Instructional Task 1: Databases and Tools	3.15 (n=13, sd=0.69)
Instructional Task 2: Influenza- Building a Dataset	3.50 (n=12, sd=0.80)
Instructional Task 3: Influenza Incidence and Analysis	3.38 (n=13, sd=0.65)
Instructional Task 4: Avian Influenza	3.17 (n=12, sd=0.72)

In open-ended responses, the education experts provided these additional comments regarding the reasons for their ratings:

Task 1: Six educators agreed that using the curriculum assumes a certain level of prior knowledge, and it's not appropriate for non-majors, but would work with biology majors. They would include more orientation for the students to the materials and give more information on NCBI.

Task 2: Two educators said some of the materials need to be updated (e.g., Blast for beginners, and the step-by-step procedures). A third educator commented that the "memo" did not seem credible, but the deliverable section was good.

Task 3: Four educators agreed that the background information was outdated and that students might have a difficult time using Excel.

Task 4: Two educators agreed the task was good, but well beyond the abilities and training of most community college students. A third educator commented that it's a "tedious task" and that he would want to require the students to prepare 40% of the sequences, and he'd do 60%.

In the follow-up discussion during the face-to-face rating sessions, faculty experts liked the step-by-step instructions, but they had many questions. They noted that there was a lot of information in the instructional materials about working on teams, but little information for the students about why working on a team was important for either students' grades in the class or their work in the real world. They expressed concern that students will "pass right over" this material. Faculty also wanted to know if the final presentation would be used instead of a final examination. Faculty members also wanted to know what pre-requisite knowledge students should have for these tasks, and specifically, how to link the kinds of biology content knowledge that is critical in their courses to interpreting the data in the NCBI databases. With respect to the technical task, the faculty said that across all tasks there needed to be stronger reflection prompts to help students understand what they look for in each database and, most importantly, why: "The prompts weren't helpful. Who cares if you make 60 combos? The real question is why?" and "The task is good at showing the hammer, but why are they using the tools?" They expressed several concerns about keeping these materials current, based on the dates of the scholarly articles to the NCBI web resources and screenshots in the instructions.

In the follow-up discussion during the face-to-face rating sessions, the industry experts said they liked the nice "story" developed for students because it might allow students to take ownership of the work and have something less "cookbook-ish." They described the tasks overall as good for a "low-level employee," but they were not sure if students were developing, or required to use, critical thinking skills. They said Task 1 seemed longer and not as well linked to the other tasks. They suggested a "review of terminology" at the beginning so the student could determine his or her level of knowledge. They said there should be more background information on the NCBI tools.

Research Question 2 Findings

To what extent do the SBL-Bioinformatics instructional and assessment materials provide a context that seems consistent with real workplaces in the bioinformatics industry

Only industry experts (*N* = 12-13) reviewed instructional materials for their consistency with "real-world" industry contexts, but both education and industry experts reviewed the assessments to address this research question. The summary statistics for the assessment materials appear in Tables 7, 8, 9, and 10. After providing ratings, the experts described the reasons for their responses, summarized below each table.

As shown in Table 6, industry experts found Tasks 2 and 4 to be the most authentic, followed by Tasks 1 and 3. They favored tasks that involved students in direct use of the NCBI database and full cycle of data search, manipulation, representation, and interpretation. They disfavored tasks that emphasized the use of web tools without students understanding why they were using them (e.g., narrow focus on technical tool usage) or that did not involve typical NCBI data.

Table 6. Summary Statistics, Bioinformatics Industry Context for Instructional Materials

Please rate the extent to which you think the materials provide a context that seems consistent with real workplaces in the bioinformatics industry.	
	Industry (M)
Instructional Task 1: Databases and Tools	3.23 (n=13, sd=0.60)
Instructional Task 2: Influenza- Building a Dataset	3.46 (n=13, sd=0.52)
Instructional Task 3: Influenza Incidence and Analysis	3.08 (n=12, sd=0.79)
Instructional Task 4: Avian Influenza	3.33 (n=12, sd=0.65)

In open-ended responses, the industry experts provided these additional comments regarding the reasons for their ratings of the instructional materials:

Task 1: Six industry experts agreed that the materials were good, but many of the resources were dated or obsolete: "Perlegen is a main focus of a big chuck of the slide set, and they no longer exist."

Task 2: Three industry experts said the activity would be "appropriate and easy to implement in a class." Another expert wrote that students would not be able to explain how the tools work.

Task 3, One industry expert wrote that "manually copying and pasting from tabular data on a website" is not a typical task in bioinformatics. However, four other experts commented that it was relevant for work in epidemiology and a "true data mining" project for health sciences.

Task 4: Two industry experts wrote the task provided a good framework for a final project. A third thought the topic was a bit narrow and recommended, "selecting topics that provide knowledge of bioinformatics basics." A fourth suggested including as a resource the URL flu.gov.

Both education and industry experts reviewed three aspects of the assessments (these may be obtained by contacting the principal investigator) and discussed how relevant to real world work these aspects of the assessment were: (1) The knowledge, skills, and abilities targeted for measurement (KSAs); (2) the test question to elicit evidence of those knowledge and skills, and, (3) the rubric used to rate student performance. In open-ended responses, experts provided further comments on their ratings.

As shown in Tables 7 through 10, industry experts and education experts had somewhat different perspectives. The industry experts saw the assessments of Tasks 2 and 4 as the most authentic. Educators saw the Task 1 and 2 assessments as the most realistic. Industry experts wanted to assess students' capacity to understand and engage in the wide range of interpretive activities used in the bioinformatics workplace, and they generally pushed for harder rubrics. Education experts wanted to assess students on knowledge and skills that seemed most appropriate, considering the other courses students would be taking, and they indicated higher ratings for the overall assessment framework. The only assessment framework that industry experts preferred more than the education experts was for Task 4—the most comprehensive of the tasks and the associated assessments.

Table 7. Summary Statistics, Bioinformatics Industry Context for Assessments, Task 1

Assessment of Familiarity with Databases and Search Query Procedures

Please rate the extent to which you think the materials provide a context that seems consistent with real workplaces in the bioinformatics industry.		
	Education (M)	Industry (M)
Assessment Task 1: Databases and Tools		
KSA	3.77 (n=13, sd=0.44)	3.38 (n=13, sd=0.65)
Questions	3.69 (n=13 , sd=0.48)	3.38 (n=13 , sd=0.65)
Rubrics	3.62 (n=13 , sd=0.51)	3.31 (n=13 , sd=0.63)
Mean	3.69	3.36

Below is a summary of the open-ended responses regarding assessments.

KSAs: Of the 26 experts who rated this item, seven responded that they felt strongly that some of the knowledge and skills that are important to real world work were not identified. One bioinformatics educator said the knowledge and skills should have encompassed other contexts for using the NCBI database tools, including "genetic modification strategies, identifying isolates, and selecting commercial enzymes." One bioinformatics industry professional said the KSA would be better aligned with the assessment scenario if it focused on "assessing genotype testing for pharmacogenomics." The five other respondents did not look at the KSA section specifically, but commented on other sections, such as the test question, which they thought effectively reflected a real world task, but perhaps narrowly focused on the area of pharmaceutical or drug research. They also focused on the students' "possible responses," which they thought were too focused on assessing students' familiarity with databases and searching techniques and not sufficiently focused on inferential skills bioinformatics experts use.

Question: Of the 26 experts who rated this item, four responded with some additional comments. Three industry experts seemed to vary on just how difficult the question was, with one saying it provided "the right challenge to a student in various areas related to bioinformatics," another saying the scope of the problem was "quite large" and more appropriate for a "Ph.D.-level scientist," and another saying the task was "not very difficult and does not require critical thinking." The fourth, an educator, simply noted there was only one question.

Rubric: Of the 26 who rated this item, four offered further comments on the rubrics. One educator would have added a fourth level to the rubric to acknowledge "exemplary responses" and one discussed the question rather than the rubric. The two industry respondents wanted to see more difficulty and higher expectations in the rubric, which focused mainly on students' familiarity with different databases and capacity to form search terms. These industry respondents wanted more focus on interpretation of the data that were found.

Table 8. Summary Statistics, Bioinformatics Industry Context for Assessments, Task 2

Assessment of Ability to Review Research and Use Tools for Manipulating NCBI Data

Please rate the extent to which you think the materials provide a context that seems consistent with real workplaces in the bioinformatics industry.		
	Education (M)	Industry (M)
Assessment Task 2: Influenza- Building a Dataset		
KSA	3.83 (n=12, sd=0.39)	3.62 (n=13, sd=0.51)
Questions	3.58 (n=12, sd=0.51)	3.62 (n=13, sd=0.51)
Rubrics	3.75 (n=12 , sd=0.45)	3.36 (n=11, sd=0.67)
Mean	3.72	3.53

Below is a summary of the open-ended responses regarding assessments.

KSAs: Of the 26 experts who rated this item, six responded with additional comments about how much the skills identified represented real work in bioinformatics. Both the industry and education respondents described the skills identified as highly relevant and "very good" and "excellent." As one industry representative put it: "The task of analyzing the data used in a recent publication and understand its context/ significance to one own's research is a critical element of bioinformatics research. I think this paper and associated bioinformatics question does reflect what we do."

One industry respondent wanted to see a performance assessment of how students created a phylogenetic tree. Three industry respondents expressed preferences for including special areas of interest in the assessment: One did not like the narrow focus on health care, another did not like the choice of genes, and another would have preferred more "high throughput sequencing examples."

Question: Of the 26 experts who rated this item, two responded with some additional comments. One industry representative wrote: "I think this question does reflect a real-life bioinformatics research question as it encompasses several elements: a) Literature review and critique, b) Data collection, downloading and storage, c) Bioinformatics analyses and d) Biological inference." One educator who gave the question a lower rating than others described this assessment's question set as the kind students would "be expected to know already before going into the real world."

Rubric: Of the 26 who rated this item, four of the industry experts offered further comments on the rubrics. The one industry expert giving the rubric a lower rating than others wrote that the expectations fell short of the full range of skills required in bioinformatics. Two others noted that the rubric's rating of a proficient performance reflected real world expectations around using BLAST to expand on finding sequences. One industry expert wrote that the expectations of knowing "precise procedures used" during data manipulation might be too high since even professionals might not be able to recite all their exact steps unless they use the tools every day.

Table 9. Summary Statistics, Bioinformatics Industry Context for Assessments, Task 3

Assessment of Ability to Use Excel to Compare and Analyze NCBI Data

Please rate the extent to which you think the materials provide a context that seems consistent with real workplaces in the bioinformatics industry.		
	Education (M)	Industry (M)
Assessment Task 3: Influenza Incidence and Analysis		
KSA	3.64 (n=11, sd=0.67)	3.23 (n=13, sd=0.60)
Questions	3.27 (n=11 , sd=0.79)	3.23 (n=13, sd=0.60)
Rubrics	3.36 (n=11 , sd=0.81)	3.18 (n=11, sd=0.75)
Mean	3.42	3.21

Below is a summary of the open-ended responses regarding assessments.

KSAs: Of the 26 experts who rated this item, eight responded with additional comments on how much the skills measured reflected real world expectations. Three of the industry and education experts noted that the task was very consistent with the work of epidemiologists more than bioinformatics specialists. One called the assessment "great," and noted that: "We do these kinds of things all the time. In fact sometimes we do this during a (job) interview." Two industry experts noted that the skills, particularly those focused on Excel, seemed elementary.

Question: Of the 26 experts who rated this item, five responded with some additional comments. The two industry and three education experts characterized the question as too simplistic and the topic of the flu as not sufficiently focused on typical bioinformatics content. It seemed more akin to an "educational" test question than a real world test question.

Rubric: Of the 26 who rated this item, four offered further comments on the rubrics, and all four were expanding on their reservations about the "simplicity" of the test question. They also wanted to see in the "possible responses" some room for argumentation. Two industry respondents emphasized that there were multiple expectations for real world professionals, from knowing what data to download to knowing what comparisons to make within the data results. The focus on the rubric was on Excel skills and graphing data, but they wanted more.

Table 10. Summary Statistics, Bioinformatics Industry Context for Assessments, Task 4

Assessment of Ability to Design NCBI Search, Conduct It, and Represent the Data

Please rate the extent to which you think the materials provide a context that seems consistent with real workplaces in the bioinformatics industry.		
	Education (M)	Industry (M)
Assessment Task 4: Avian Influenza		
KSA	3.70 (n=10, sd=0.48)	3.69 (n=13, sd=0.48))
Questions	3.30 (n=10 , sd=0.82)	3.62 (n=13 , sd=0.51)
Rubrics	3.40 (n=10 , sd=0.70)	3.62 (n=13 , sd=0.65)
Mean	3.47	3.64

Below is a summary of the open-ended responses regarding assessments.

KSAs: Of the 26 experts who rated this item, five responded that the knowledge and skills targeted for measurement were critical, and nearly all were commenting on how they liked the question.

Question: Of the 26 experts who rated this item, six responded with some additional comments. All responded positively to the question and the task very positively. As one expert put it: "This question really tests a student's bioinformatics acumen and skills." The one quibble was setting it up as a "friend" posing the bioinformatics question. Two respondents thought it was more realistic to have a community group or fellow professional posing the question.

Rubric: Of the 26 who rated this item, four offered further comments on the rubrics. Two industry experts thought the rubric reflected real world judgments of quality, but one industry expert cautioned it might exceed normal expectations for an "entry level bioinformaticist." One thought asking students to think about a "contingency plan" in the assessment was highly consistent with professionals who "always put together a second approach" in case the original does not work out. One industry expert described the rubric as "perfectly" capturing the expectations of the assessment question, but one education expert who gave the rubric a lower rating thought the detail in the rubric could not be anticipated by looking at the original test question.

Research Question 3 Findings

To what extent do the SBL-Bioinformatics instructional and assessment materials provide students with an opportunity to learn the knowledge and skills needed in the bioinformatics industry?

Only industry experts (*N* = 12-13) reviewed instructional materials to address this question. Their responses to address this question for the assessment question were also analyzed in terms of how much the test question measured two kinds of knowledge and skills: higher-level thinking and content knowledge. Higher-level thinking skills focus on problem-solving skills, such as framing a bioinformatics research problem, planning research, and making inferences from data. Content knowledge focuses on understanding specific representations and databases. Both sets of summary statistics appear in Table 11. After providing ratings, the industry experts described the reasons for their responses to the instructional materials, summarized below the table. The industry experts' comments regarding the ratings of the assessments were captured in the summary in the above section regarding research question 2.

To summarize for the instructional materials, industry experts viewed Task 4 as the most likely to offer an opportunity to learn the knowledge and skills needed in the bioinformatics industry, followed by Tasks 1 and 2. They rated Task 3 as the least likely to offer the opportunity to learn such industry-relevant skills. To summarize for the assessments, industry experts rated Tasks 4 and 2's assessments as most focused on measuring high-level skills, followed by Task 1 and Task 3. They rated Task 2 assessments as most focused on measuring content knowledge, followed by the assessments of Tasks 1 and 4. They saw the Task 3 assessment as least related to bioinformatics content knowledge.

In open-ended responses, the industry experts provided these additional comments regarding the reasons for their ratings of the alignment of the instructional materials with the knowledge and skills needed in the bioinformatics industry:

Table 11. Summary Statistics, Opportunity to Learn Industry-Relevant Knowledge and Skills

Please rate the extent to which you think the materials provide a context that seems consistent with real workplaces in the bioinformatics industry.	
	Industry (M)
Instructional Task 1: Databases and Tools	3.38 (n=13 ,sd=0.65)
Instructional Task 2: Influenza- Building a Dataset	3.38 (n=13 ,sd=0.77)
Instructional Task 3: Influenza Incidence and Analysis	3.17 (n=12 ,sd=1.03)
Instructional Task 4: Avian Influenza	3.50 (n=12 ,sd=0.67)
Assessment Task 1: Databases and Tools	
Questions. Higher-level thinking	3.54 (n=13 ,sd=0.66)
Questions. Content knowledge	3.77 (n=13 ,sd=0.44)
Mean	3.65
Assessment Task 2: Influenza- Building a Dataset	
Questions. Higher-level thinking	3.85 (n=13 ,sd=0.38)
Questions. Content knowledge	3.85 (n=13 ,sd=0.38)
Mean	3.85
Assessment Task 3: Influenza Incidence and Analysis	
Questions. Higher-level thinking	3.23 (n=13 ,sd=0.83)
Questions. Content knowledge	3.08 (n=13 ,sd=0.76)
Mean	3.15
Assessment Task 4: Avian Influenza	
Questions. Higher-level thinking	3.85 (n=13 ,sd=0.38)
Questions. Content knowledge	3.77 (n=13 ,sd=0.44)
Mean	3.81

Task 1: One industry expert stated the material present a somewhat idealized view of meetings and team communication.

Task 2: Three general comments from industry experts were presented, such as "use googledocs to share data." Four additional experts agreed that "the topic is too basic," and students need to know how to use the tools but also be able to explain how they work."

Task 3: Two industry experts wrote that they don't do work as presented in Task 3, and didn't find it relevant to bioinformatics skills. However, three other industry experts commented that it was a relevant task, particularly because the student learned data extraction, analysis, interpretation, and reporting.

Task 4: The three industry experts who responded agreed that the task was well presented and "ideal in my research."

Research Question 4 Findings

To what extent do the SBL-Bioinformatics instructional and assessment materials provide students with an opportunity to learn the knowledge and skills in a standard bioinformatics or biology curriculum?

Only education experts (*N* = 13) reviewed instructional materials to address this question. Their responses to address this question for the assessment question were also analyzed. Both sets of summary statistics appear in Table 12. After providing ratings, the education experts described the reasons for their responses for the instructional materials, summarized below the table. The education experts' comments regarding the ratings of the assessments were captured in the summary in the above section regarding research question 2.

To summarize, education experts viewed Task 4 as most likely to offer an opportunity to learn the knowledge and skills relevant to their curriculum, followed by Tasks 2, 3, and 1. But their review of the assessments differed. The education experts rated Task 1's assessment as most focused on measuring high-level curriculum-relevant skills, followed by Task 4, 2, and 3. They saw Task 1's assessment as most focused on measuring content knowledge relevant to their curriculum, followed by Task 4, 2, and 3.

Table 12. Summary Statistics, Opportunity to Learn Curriculum-Relevant Knowledge and Skills

Please rate the extent to which you think the materials provide students with an opportunity to learn the knowledge and skills needed in a standard bioinformatics or biology curriculum.	
	Education (M)
Instructional Task 1: Databases and Tools	3.38 (n=13 ,sd=0.51)
Instructional Task 2: Influenza- Building a Dataset	3.62 (n=13 ,sd=3.62)
Instructional Task 3: Influenza Incidence and Analysis	3.54 (n=13 ,sd=0.78)
Instructional Task 4: Avian Influenza	3.75 (n=12, sd=0.62)
Assessment Task 1: Databases and Tools	
Questions. Higher-level thinking	3.92 (n=13, sd=0.28)
Questions. Content knowledge	3.85 (n=13, sd=0.38)
Mean	3.88
Assessment Task 2: Influenza- Building a Dataset	
Questions. Higher-level thinking	3.67 (n=12, sd=0.49)
Questions. Content knowledge	3.50 (n=12, sd=0.67)
Mean	3.58
Assessment Task 3: Influenza Incidence and Analysis	
Questions. Higher-level thinking	3.36 (n=11, sd=0.50)
Questions. Content knowledge	3.55 (n=11, sd=0.69)
Mean	3.45
Assessment Task 4: Avian Influenza	
Questions. Higher-level thinking	3.80 (n=10, sd=0.42)
Questions. Content knowledge	3.60 (n=10, sd=0.52)
Mean	3.70

In open-ended responses, the education experts provided these additional comments regarding the reasons for their ratings of the alignment of instructional materials with biology and bioinformatics academic standards:

Task 1: Three general comments were submitted, including this example: "I clicked somewhat but want to comment, are the students expected to learn to use NCBI on their own?" Two more specific comments were also submitted, including: one educator commented that the list of tools and skills was good, but "it's too much." A second educator commented that the material was very advanced for introductory students.

Task 2: Two general comments from educators were presented. One example was "a background section in the introduction would be excellent."

Task 3: Two educators commented that the instructions on how to create a graph were confusing. Three additional educators stated that the task would be limited in use, one believed it was good for microbiology, another thought "all classes," and a third thought only epidemiology.

Task 4: Two educators agreed that the students would need a great deal of background knowledge to do the task.

Research Questions 5 and 6 Findings

To what extent do the SBL-Bioinformatics instructional and assessment materials align with industry skill standards?

To what extent do alignment ratings for the SBL-Bioinformatics instructional and assessment materials differ between industry and education experts?

The survey data supports a general trend for industry experts to rate all tasks, both instructional and assessment, as more strongly aligned than the education experts (see Tables 13 and 14).

Industry and education experts tended to agree on the extent to which the four instructional activities included content that covered most of the social, social-technical and technical standards. On average, both the industry and education experts scored the instructional activities' coverage of these dimensions between 3 (Somewhat) and 4 (To a Great Extent), with industry experts consistently scoring the coverage as more extensive than education experts (see Table 13). One exception was the extent to which the content in the third instructional activity (Influenza Incidence and Analysis) covered the social-technical standards. Education and industry experts tended to significantly disagree on the extent to which Influenza Incidence and Analysis included content that covered the social-technical standards ($t(24)=2.357, p < 0.05$). On average, the industry experts scored Influenza Incidence's coverage of these standards 3.6 (between Somewhat and To a Great Extent), whereas the education experts scored the standards coverage at 3.0 (Somewhat).

Table 13. Summary Statistics, Instructional Materials Ratings

Instructional Materials				
	Background	**N**	**Mean**	**Std. Deviation**
Task 1: Databases and Tools				
Technical Skills (n = 21 items)	Education	13	3.11	0.53
	Industry	13	3.26	0.56
Social-Tech Skills (n = 9 items)	Education	13	3.09	0.68
	Industry	13	3.40	0.56
Social Skills (n = 1 item)	Education	13	3.38	0.51
	Industry	13	3.38	0.77
Task 2: Influenza- Building a Dataset				
Technical Skills (n = 23 items)	Education	13	3.24	0.55
	Industry	13	3.38	0.55
Social-Tech Skills (n = 2 items)	Education	13	3.08	0.73
	Industry	13	3.35	0.59
Task 3: Influenza Incidence and Analysis				
Technical Skills (n = 27 items)	Education	13	3.26	0.48
	Industry	13	3.43	0.54
Social-Tech Skills (n = 5 items)	Education	13	3.05	0.58
	Industry	13	3.57	0.55
Social Skills (n = 1 item)	Education	13	3.31	0.85
	Industry	13	3.46	0.52
Task 4: Avian Influenza				
Technical Skills (n = 16 items)	Education	12	3.44	0.49
	Industry	13	3.53	0.48
Social-Tech Skills (n = 3 items)	Education	12	3.17	0.64
	Industry	13	3.54	0.42
Social Skills (n = 1 item)	Education	12	3.58	0.67
	Industry	13	3.62	0.51

In open-ended responses, the education and industry experts provided these additional comments regarding the reasons for their ratings of alignment of the instructional materials with industry standards:

Task 1: Four educators agreed that the task would only be effective for the most knowledgeable and motivated student, more background materials should be included to help guide the student to use NCBI, and the instructor would need to provide significant input. Four other educators gave individualized comments, such as "students are not questioning accuracy of information/data, students are not introduced to archival procedures, there is no opportunity to practice or recognize out-of-range results, students will need to learn the skill of how to approach an assignment, and the soft-skills would not be specifically taught in this course."

There were 2 general comments from industry experts, and 2 who agreed there wasn't an opportunity for "database query design and testing," because the language implies "the ability to run command-line queries against an underlying database to mine for information (e.g., SQL queries)." There were 3 specific comments, including: the opinion that students do not use information to draw logical conclusions, there was no need to analyze data; and, conducting searches on regulatory agency databases includes the FDA and EPA.

Task 2: There were two general comments from two separate educators: "I'm not convinced students could apply these skills to a future project." In agreement, another stated that students will be "visiting the expert" many times to complete the assignment. Three additional educators all agreed that there was no opportunity for the student to identify "out-of-range" results. In addition, there were individual comments that students are not asked to evaluate for accuracy, to document procedures, and to use data analysis tools.

Three industry experts commented, as did three educators, that there was no opportunity for the student to identify "out-of-range" results. Four agreed there was no opportunity for data analysis and no conclusions could be drawn, rather students "select and input data into templates for preprogrammed analysis." Two industry experts also commented that it would be helpful to provide more background material on the theory of phylogenetic analysis.

Task 3: One educator wrote a general comment that the task seemed appropriate for biology majors who've completed several background courses. Another commented that the task was a mix of advanced and elementary material (interpret CDC data, and prepare an Excel chart). Three educators wrote that the Excel version was dated (2003 vs. 2007). Two additional educators agreed that "knowledge of NCBI and other sites is not required," the CDC was not considered another similar website by these respondents. Two more educators agreed that students were not asked to evaluate the accuracy of the data. Two other educators lamented the lack of opportunity for students to recognize out of range data, and no statistical analyses were required.

There were four general comments from industry experts, such as "nice module, show students how to use R or other packages, need a discussion of statistics, and scripted nature of task removes need for critical thinking." Two industry experts provided some specific comments, including the lack of opportunities for students to match the data sets to the type of analysis performed, and not to question the validity of data. One educator commended that "only an informal report is given to the group."

Task 4: Three educators wrote general comments, for example, "not sure all these learning outcomes could be reached, good use of skills listed, and final task better blend of scenario learning." A fourth commented there wasn't an opportunity for students to check for relevance and accuracy of data. One education expert questioned whether the student would learn from the SBL task, writing, "The modules don't really help students learn about broad and more general applications for these tools," such as building trees and looking for motif differences.

Four industry experts wrote they liked this task and thought it was well presented. A fifth did not see an opportunity for students to discuss statistics. Two general comments were offered, including "the overall objective is poorly defined."

There was slightly wider variation in education and industry experts' opinions about the extent to which the assessment tasks included content that covered most of the social, social-technical and technical standards. However, with some exceptions (noted below), on average, both the industry and education experts scored the assessment tasks' coverage of the technical and social-technical standards between 3 (Somewhat) and 4 (To a Great Extent), with industry experts consistently scoring the coverage as more extensive than education experts (see Table 10). For example, education and industry experts tended to significantly disagree on the extent to which the first (Databases and Tools—$t(24)= 2.294, p < 0.05$) and third (Influenza Incidence—($t(22)= 2.842, p < 0.01$) assessment tasks included content that covered the social standard (social skills aggregates are composed of only one standard). On average, industry experts scored Databases and Tool's coverage of this standard stronger (3.1) than education experts (2.2). Likewise, on average, industry experts scored Influenza Incidence's coverage of this standard higher (3.15) than education experts (2.18). As another example, education and industry experts tended to significantly disagree on the extent to which the second assessment task (Building a Dataset) included content that covered social-technical standards ($t(24)= 2.149, p < 0.05$). On average, industry experts scored Building a Dataset's coverage of these standards stronger (3.5) than education experts (2.95). Education and industry experts also tended to disagree, although not in a statistically significant manner, on the extent to which the first and third assessment tasks included content that covered the social-technical standards.

Table 14. Summary Statistics, Assessment Materials Ratings

Instructional Materials				
	Background	**N**	**Mean**	**Std. Deviation**
Task 1: Databases and Tools				
Technical Skills	Education	13	3.42	0.39
	Industry	13	3.51	0.37
Social-Tech Skills	Education	13	3.03	0.61
	Industry	13	3.43	0.42
Social Skills	Education	13	2.23	1.01
	Industry	13	3.08	0.86
Task 2: Influenza- Building a Dataset				
Technical Skills	Education	12	3.29	0.45
	Industry	13	3.49	0.44
Social-Tech Skills	Education	12	2.96	0.81
	Industry	13	3.54	0.52
Task 3: Influenza Incidence and Analysis				
Technical Skills	Education	11	3.35	0.44
	Industry	13	3.50	0.53
Social-Tech Skills	Education	11	3.11	0.43
	Industry	13	3.54	0.59
Social Skills	Education	11	2.18	0.98
	Industry	13	3.15	0.69
Task 4: Avian Influenza				
Technical Skills	Education	10	3.53	0.52
	Industry	13	3.71	0.32
Social-Tech Skills	Education	10	3.23	0.50
	Industry	13	3.51	0.44
Social Skills	Education	10	2.40	1.17
	Industry	13	3.15	0.90

In open-ended responses, the education and industry experts provided these additional comments regarding the reasons for their ratings of alignment of the assessment materials with industry standards:

Task 1 Assessment of Familiarity with Databases and Search Query Procedures:

The experts noted that the assessment did not measure student skills of working on a team, the social-technical skills of communicating with a client, or the technical skills of identifying "out of range results." They confirmed that the assessment aligned with technical skills of knowing the resources and appropriate search tools. Three of the experts specifically praised the assessment as "great," "a great synthesis task," and "designed to make students critically think through challenging tasks." With respect to the disagreement between educators and industry experts on how the assessment measured team skills, more of the educator experts noted that the assessment did not address these skills even though they saw a possible opportunity to assess such skills within this scenario.

Task 2 Assessment of Ability to Review Research and Use Tools for Manipulating NCBI Data:

The experts noted that the assessment did not address students' skills to analyze outliers or to conduct data visualization or formal presentation of data in a final report, but did address students' capacity to use and understand tools. With respect to the disagreement between educators and industry experts on how the assessment measured communication skills, none of the experts offered comments that addressed this issue except to say that, if they scored something low, it was because the assessment did not appear to address that skill.

Task 3 Assessment of Ability to Use Excel to Compare and Analyze NCBI Data:

The experts noted that the assessment did not measure social team skills, social-technical communication skills except for talking to the journalist, technical critical analysis of data, or even much technical knowledge of NCBI—since the CDC website was given. The experts generally considered this to be a lower-level assessment that did not address bioinformatics skill standards: "The student who cannot prepare a chart in Excel is certainly not prepared to evaluate bioinformatic data." They wanted to see focus on other programs for analysis beyond Excel, such as R, Matlab, Perl, or Python. With respect to the disagreement between education and industry experts on how the assessment measured team skills, it appears again that educators in their comments expressed two points: That the data problem was so small, collaboration was not necessary, and that an individual assessment might not be able to assess team skills.

Task 4 Assessment of Ability to Design NCBI Search, Conduct It, and Interpret the Data:

The experts noted that the assessment did measure the technical skills of interpreting phylogenetic trees and knowledge of database reporting tools and practices, but that it did not measure social skills of teamwork or project management. "This seems to be an outline for a good final project," wrote one, but another thought that the burden of copying information from databases makes for a very challenging "paper and pencil" testing task."

Research Question 7 Findings

To what extent do alignment ratings for the SBL-Bioinformatics instructional and assessment materials differ between education experts in biology and biotechnology, and in these two subgroups and industry experts?

As reported above, the survey data support a general trend for industry experts to rate all tasks, both instructional and assessment, as more strongly aligned than the education experts. This trend holds true for both education-biology experts and education-biotechnology experts. However, the data also indicate that education-biology experts rate the materials as being more strongly aligned with the social and social-technical standard dimensions, while the education-biotechnology experts rate the materials as being more strongly aligned with the technical standard dimension. The data, however, does not support any of these differences as being statistically significant, or beyond what we would expect by chance.

Summary & Discussion

The alignment study shows that, overall, both the SBL instructional materials and assessments are well aligned with bioinformatics industry skills standards. Of the instructional tasks, both sets of experts gave Task 4 the overall highest rating for alignment with the technical skills of bioinformatics and the social skills of bioinformatics (e.g., teamwork). They disagreed on which task offered the most alignment with industry-specific social-technical skills (e.g., communication, presentation), with industry rating Task 3, the task that involves making a presentation to a journalist, the highest, and educators rating Task 4, the task that involves making a presentation on one's research to the class, the highest. Of the assessment tasks, both sets of experts gave Task 4's assessments the highest ratings for alignment with the technical skills of bioinformatics.

Both experts noted a general need for a greater opportunity for students to learn how to deal with "out of range" data and problems of interpretation. They wanted less focus on tools and more on the use of such technological tools for interpretive tasks.

All experts gave relatively lower ratings to the assessments for measuring the social skills (teamwork) and social-technical skills (communication/presentation) of bioinformatics across all tasks—an acknowledgement that none of these assessments were intended to assess such skills. Yet, even though both sets of raters gave relatively lower ratings to the assessments for these social and social-technical skills, the industry experts' ratings were still significantly higher than the ratings educators gave to the assessments on these particular elements. Based on a review of the experts' comments, it may be that educators are simply more sensitive to such gaps in assessment materials and are closely monitoring the materials for providing concrete ways to measure (i.e., grade) such learning outcomes.

Another interesting point of disagreement emerged between educators and industry experts in their view of "step-by-step" instructions. Educators favored tasks, such as Task 3, for its use of these kinds of instructions. By contrast, industry experts expressed strong displeasure in the use of step-by-step instructions, particularly around Excel spreadsheet software. In their view, bioinformatics students needed to learn how to use more advanced, industry-specific forms of software (e.g., R was mentioned several times). They also expressed frank impatience with the notion that Excel was difficult to use, dismissing anyone who does not know how to use Excel as perhaps not capable of work in the bioinformatics field. By contrast, educators revealed concern that many of their students do not know how to use Excel software, and they saw Task 3 as an important context for teaching students this basic skill.

Task 3 emerged as perhaps the key point of disagreement between the educators and industry experts. Bioinformatics experts classified the content as not quite aligned with the knowledge and skills of their field, and likened it more to epidemiological work or analysis that involved little, if any, familiarity with bioinformatics databases or content. By contrast, the educators saw Task 3 as potentially quite useful for engaging their students in the full "arc of analysis"—from gathering data to manipulating it to interpreting it. This disagreement, and others, repeatedly underscored the very different contexts of work for educators and industry professionals. Educators viewed all materials through the lens of their students' prior preparation and the ease of using the materials with those students in a classroom. Industry experts tended to view all materials along a continuum of a hiring chart, rating it according to whether a "beginning" or "higher level" employee would conduct the work.

When taking these findings and applying them to the larger context of engaging industry with educators in developing workforce education materials, this report indicates the central tension between the two cultures. Educators emphasize the need for *structured developmental opportunities* to learn or measure knowledge or a skill in instructional and assessment materials. By contrast, industry representatives emphasize the need for *complex challenging opportunities* to learn or measure knowledge and skill in instructional and assessment materials. The tensions around this dialogue were evident in this alignment task. Educators were most outspoken when they perceived the materials as failing to offer clear guidance or too much complexity. Industry representatives were most outspoken when materials appeared too easy and "low-level." When these types of professionals work together, this basic difference in perspective may threaten mutual understanding.

This finding potentially raises questions that go to the heart of efforts to promote scenario-based or problem-based learning in the educational field, particularly in a high-stakes accountability environment: How much specification do educators need to "feel comfortable" using such instructional materials? Where is the appropriate dividing line between narrowly specifying what one should learn in an instructional task and making room for students to imagine and expand the potential learning goals of any given instructional task?

On a positive note, this study also pointed in a promising direction for future collaboration between educators and industry. As was clear in a review of the ratings, both educators and industry experts tend to agree on the essential technical, social-technical, and social knowledge and skills required in the field. Using such industry-specific standards may serve as a potentially powerful tool for negotiating disagreements around instructional program design between these two communities. Further, this detailed, standards-specific procedure contrasts from popular efforts to simplify the alignment and validation processes around instructional materials by focusing mostly education-based experts on presumably "easier to rate" general skills such as "critical thinking," "problem solving," or "brainstorming." This research indicates that domain-specific standards may present the shortest and easiest path for developing agreement around workforce instructional and assessment materials.

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Appendix A. Supplemental Information, SBL-Bioinformatics Instructional and Assessment Materials

Table A-1. Student Learning & Performance Objectives, SBL-Bioinformatics Instructional Materials

Instructional Task	Student Learning and Performance Objectives
Task 1: Databases and Tools	1. Become familiar, in general, with the contents of diverse NCBI databases and the kinds of information stored in each database. 2. Learn how to use interpret the gene diagram provided in the Gene database to obtain information for the multiple proteins that might be specified by a single gene. 3. Practice reading and finding information in the abstracts that accompany scientific papers. 4. Be able to define the following terms: SNP, allele, polymorphism, and pharmacogenomics. 5. Be able to describe how a SNP could change the amino acid sequence of a protein.
Task 2: Influenza- Building a Dataset	1. Become familiar, in general, with the contents of diverse NCBI databases. 2. Learn how to use the NCBI Taxonomy Browser to find a variety of information, organized by phylogeny. 3. Learn how to use four different methods for querying NCBI databases: using accession numbers, using information about an organism, using the name of a gene or protein, and using BLAST. 4. Learn how to perform a BLAST search, obtain sequences, and evaluate BLAST statistics (bit score, % identity, and E value). 5. Be able to evaluate and describe the advantages and disadvantages of using different types of search methods and different databases. 6. Learn how to prepare a multi-sequence FASTA formatted data set of molecular sequences for use in alignments and phylogeny studies. 7. Learn how to use JalView to access the ClustalW web service and align sequences with ClustalW. Learn how to use JalView to edit the alignments. 8. Learn how to make a neighbor-joining tree with JalView. 9. Learn how to assign an outgroup to a phylogenetic tree.
Task 3: Influenza Incidence and Analysis	1. How to use Excel to create histogram plots. 2. Interpret histogram plots. 3. How to find epidemiology information at the Centers for Disease Control (CDC) website. 4. Searching PubMed, LANL, CDC 5. Students will practice presentation, communication, and team coordination.

Table A-1. Student Learning & Performance Objectives, SBL-Bioinformatics Instructional Materials, (Continued)

Instructional Task	Student Learning and Performance Objectives
Task 4: Avian Influenza	1. Learn about the epidemiology and biology of influenza. 2. Research the current state of knowledge concerning transmission of influenza. 3. Be able to find information about sensitivity to anti-viral agents like Tamiflu. 4. Learn how to use the Influenza virus resource at the NCBI. 5. Be able to get specific protein sequences from strains at NCBI where complete genomes are available. 6. Be able to format protein sequences for use in multiple alignments. 7. Be able to interpret the results of sequence alignments and phylogenetic trees. 8. Make intuitive judgments about outbreaks of flu and antigenic drift and shift. 9. Be able to use phylogenetic trees to determine if a strain is of avian origin. 10. Prepare a plan to determine what animals (Influenza infections) should be followed for avian flu infection. 11. Be able to identify specific motifs in a set of viral sequences.

Table A-2. Focal Knowledge, Skills and Abilities, SBL-Bioinformatics Assessment Materials

Assessment Task	Focal Knowledge, Skills, Abilities
Task 1: Databases and Tools	Applying strategic knowledge of how to plan a research strategy. This includes knowledge of the relevant databases and search functions, basic knowledge of biology. It also includes knowledge of appropriate bioinformatics representations that aid in analyzing viral characteristics and evolutionary patterns.
Task 2: Influenza- Building a Dataset	How to set up and conduct searches for molecular sequences by accession number, taxonomy browser, sequence name, and the Basic Local Alignment Search Tool (BLAST).
Task 3: Influenza Incidence and Analysis	Knowing how to use Excel (or other spread-sheet and graphing programs) to produce tables, bar charts, and carry out calculations.
Task 4: Avian Influenza	Knowing how to (1) Read biomedical research materials and identifying information that can be used search the National Center for Biotechnology Information (NCBI) databases and that can help plan a research strategy based on basic knowledge of biology (including genetic evolution, virus characteristics, etc.); (2) Apply biological content knowledge to understand which specific databases in the NCBI to query, such as knowing the difference between nucleotide, protein, and genome sequences; knowing influenza viruses are classified by the type of proteins; and knowing that similar proteins can be found in multiple species; (3) Use appropriate bioinformatics representations that aid in analyzing viral characteristics and evolutionary patterns; and, (4) Interpret results from database searches.

Appendix B. Education and Industry Surveys

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