**Summary Report for the Development and Validation of the Biotechnology Problem-Solving Skills Assessment**

**Conducted as Part of the Evaluation of the Advanced Technological Education Program**

**Bethann Lavoie**

## Executive Summary

As the biotechnology industry grows rapidly, it requires increasing numbers of biotechnicians with problem-solving skills and technical knowledge, yet a college-level, work-related and completely validated assessment measuring biotechnology problem-solving skills does not exist in test banks or the problem-based learning literature. The purpose of this study was to develop and validate two parallel forms of an instrument that measures the biotechnology problem-solving skills of students enrolled in community college biotechnology programs.

The Biotechnology Problem-Solving Skills Assessment is a 17-item, written, short-answer test containing work-related biotechnology problems in five short problem analysis cases and one integrated performance memo. The assessment validation process answered research questions about the reliability of scores on the assessment, its usefulness and authenticity, and the extent to which scores on the assessment support inferences about students' biotechnology problem-solving skills on the job.

The assessment evolved through three testing phases: preliminary, pilot, and field testing. In each round of testing the assessment was administered, and students and experts were interviewed. Additionally during the field test with 115 students and 11 experts, three raters scored 10 student assessments, and two expert biotechnicians rated 10 student assessments.

The assessment scores were reliable (alpha = 0.81 for form A and 0.69 for form B). The assessment was viewed as authentic and useful for giving students feedback, as an instructional tool, and as a possible interviewing tool. Student scores on the

assessment correlated positively with a proxy measure of on the job problem-solving performance, employer ratings of student assessment answers ($\rho = 0.746$, $p = 0.013$). Experts validated the biotechnology and problem-solving content on the assessment. Intra- and inter-rater reliabilities were reasonable (intrarater, $\rho = 0.94$, 0.91, and 0.73; interrater, $\rho = 0.67$ for form A and $\rho = 0.54$ for form B). Subtotal and total scores on the two forms of the assessment correlated postitively, significantly and moderately. The assessment distinguished between experts and students (Mann-Whitney U test, $p = 0.004$ for form A and $p < 0.001$ for form B).

**Introduction**

As the biotechnology industry grows and helps fuel the U.S. economy, it requires increasing numbers of quality biotechnicians (Ernst & Young, 2000). Employers in the biotechnology industry, like other employers in the U.S., want their employees to utilize content knowledge, interpersonal skills, and thinking skills in the workplace (Carnevale & Desrochers, 2001; Clagett, 1997; Education Development Center [EDC], 1995; EDC and Future Farmers of America [FFA], 1998; Imel, 1999; McNabb 1997; Murnane & Levy, 1996; Oliver et al., 1997; Overtoom, 2000; Secretary's Commission on Achieving Necessary Skills [SCANS], 1992) The biotechnology industry, like many industries, expects community colleges to prepare students for the workplace by teaching these skills and content knowledge. In order to determine whether they are successfully teaching students these skills and knowledge, community colleges need appropriate assessments.

Both employers and educators define one frequently mentioned thinking skill, problem solving, in similar ways (ACT, 1976; Barrows & Tamblyn, 1980; Bransford, Sherwood, Vye, & Rieser, 1986; Custer 2001; DeLuca 1991; ETS, 1989; Gabel & Bunce, 1994; Hayes, 1989; Hill 1998; MacPherson 1998; Maudsley, 1999; Martinez, 1998; Mioduser 1998; Savage & Sterry, 1990; SCANS, 1992; Waetjen, 1989). Research shows that students' problem-solving performance depends on the context of a problem (Adams et al., 1988; Linn, 1981; Perkins & Salomon, 1989; Williams, 1993). Existing problem-solving assessments, however, do not situate problems in workplace biotechnology contexts or utilize the employers' definition of *problem solving*. Furthermore, reports of the existing assessments do not include appropriate validation information (see

Bibliography for a complete listing of assessments reviewed). To meet these requirements, I developed the Biotechnology Problem-Solving Skills Assessment and validated it using an assessment validation framework synthesized from the assessment literature. This new validation framework addresses four measurement issues: validity, authenticity, reliability, and usefulness (Table 1).

**Table 1. Definitions of Measurement Terms Used in Assessment Validation Framework: Reliability, Authenticity, Usefulness, and Messick's Six Aspects of Construct Validity Evidence**

| | Measurement Term | Definition |
|---|---|---|
| | Reliability | Consistency of scores |
| Wiggins | Authenticity | The extent to which assessments contain realistic problems, options, constraints, criteria, and standards, a realistic audience, and a genuine purpose |
| | Usefulness | The extent to which assessments can be used to improve the teaching and student learning of real-world skills and to fulfill the purposes of the assessment |
| Messick's Six Aspects of Construct Validity | Content-relevance aspect of construct validity | The extent to which a domain is adequately described, how well items measure the domain, how well the domain is over- or underrepresented by the items, administrative conditions affecting test performance, and the extent to which the domain is relevant, representative and socially desirable |
| | Structural aspect of construct validity | An evaluation of the scoring criteria |
| | Generalizability aspect of construct validity | The extent to which score properties and interpretations generalize across the construct domain |
| | Substantive aspect of construct validity | Theoretical rationales for the observed consistencies in test responses along with empirical evidence that the theoretical processes are actually engaged in by respondents |
| | External aspect of construct validity | The extent to which test scores measure other expected test-score relationships and fail to correlate with unexpected relationships |
| | Consequential aspect of construct validity | An assessment of the values of score interpretations as they relate to bias, fairness and social consequences |

The purpose of this study was to develop and validate an instrument that measures the biotechnology problem-solving skills of students enrolled in community college biotechnology programs. The study contributes to theory and practice in four ways. The Biotechnology Problem-Solving Skills Assessment addresses the lack of community college-level, biotechnology, work-related, problem-solving assessments in the literature. The assessment measures a problem-solving construct (Figure 1) grounded in both employer and education literature definitions of problem solving. The study also combines authentic performance and problem analysis items within one assessment and then validates this new format. The assessment validation framework used to validate the assessment is new and is tested during the study.

**Figure 1. Problem-Solving Construct Measured with the Biotechnology Problem-Solving Skills Assessment**

Problem solving: A worker who can solve problems

1. recognizes that a problem exists
    a. identifies the problem
    b. examines the context of the problem
2. identifies possible reasons for the discrepancy
    a. identifies and gathers pertinent information
    b. identifies possible causes of the problem
3. devises and implements a plan of action to resolve it
    a. identifies and evaluates problem constraints
    b. develops criteria for satisfactory solutions (including economic and social feasibility)
    c. generates possible solutions
    d. selects a solution by evaluating alternatives against criteria
    e. implements solution
4. monitors and evaluates progress
    a. gathers data systematically during implementation
    b. applies evaluation criteria to implemented solution
    c. identifies positive and negative consequences associated with the solution
5. revises the plan as indicated by findings
    a. refines solution to resolve deficiencies, if possible
    b. seeks alternative solutions if goals are not achieved

**Research Questions**

1. How reliable are scores on a 30-minute biotechnology problem-solving skills assessment designed to be useful and authentic?
2. To what extent do the scores on the biotechnology problem-solving skills assessment support inferences about students' biotechnology problem-solving skills on the job? (validity)
3. How authentic are the assessment's goals, roles, tasks, situations, ambiguities, constraints and scoring guides with respect to real-world biotechnology contexts?
4. How is the assessment useful for the biotechnology students, instructors, and industry?

5. What is the nature of problem-solving in Advanced Technological Education programs?

**The Biotechnology Problem-Solving Skills Assessment**

Both final forms of the assessment, the Biotechnology Problem-Solving Skills Assessment, consist of 5 short problem analysis cases and a performance memo (Appendices A and B). Each short problem analysis case describes a problem frequently encountered by entry-level biotechnicians. Up to three items follow each case and address various components of the problem-solving process. The performance memo describes a problem as well but requires an integrated response, a memo written to a supervisor. The memo addresses all of the components of the problem-solving process and is a common workplace response to problems and their implemented solutions. The Biotechnology Problem-Solving Skills Assessment Blueprints (Appendices E and F) show how items correspond to specific biotechnology content and problem-solving components.

**Methodology**

The Biotechnology Problem-Solving Skills Assessment evolved through three phases: drafting the assessment, preliminary testing, and pilot testing. The outline in Figure 2 shows the methodology of the study. It illustrates that the same three methods, with slight variations, occurred during the preliminary, pilot and field testing. Each round of testing included assessments, student interviews or focus groups, and expert interviews.

**Figure 2. Outline of Methodology**

***Drafting the Assessment***

- Determining the purposes and uses of the assessment
- Defining the problem-solving construct and biotechnology content domain
- Writing the assessment and scoring guide

***Preliminary Testing***

- Student Talk-Alouds (students take assessment)
- Student Focus Groups (students critique assessment)
- Expert Interviews (experts take and critique assessment)

***Pilot Testing***

- Student Assessments
- Expert Interviews (experts take and critique assessment)
- Student Interviews (students critique assessment)

***Field Testing***

- Administration of Assessment
  - Students take assessment
  - Experts take assessment
- Scoring by Multiple Scorers (10 assessments scored twice by multiple scorers)
- Employer Rating
- Expert Interviews (experts critique assessment)
- Student Interviews (students critique assessment)

The study's research questions and assessment validation framework (see Table 1) determined the types of evidence needed to revise and validate the assessment. The four types of evidence addressed the reliability of assessment scores, the validity of inferences made from the scores, the authenticity of the assessment, and its usefulness for instructors and students. Table 2 shows how each data source addressed the research questions and provided evidence for the validation of the assessment. The unshaded cells (intersection of source of data and category & research question) show the kinds of information collected by each source of data. The parentheses in the validity column refer to Messick's aspects of validation (see Table 1).

**Table 2. Data Sources Linked to Research Questions and Assessment Validation Framework**

<table>
<tr><th></th><th></th><th colspan="4">Assessment Validation Framework Category & Research Question</th></tr>
<tr><th>Part of Study</th><th>Source of data</th><th>Validity – To what extent do the scores on the assessment support inferences about students' biotechnology problem-problem solving skills on-the-job?</th><th>Reliability – How reliable are scores on a 30-minute biotechnology problem-solving skills assessment designed to be useful and authentic?</th><th>Authenticity – How authentic are the assessment's goals, roles, tasks, situations, ambiguities, constraints and scoring guides with respect to real-world biotechnology contexts?</th><th>Usefulness – How is the assessment useful for the biotechnology students, instructors, and industry?</th></tr>
<tr><td rowspan="3">Drafting the Assessment</td><td>Literature review</td><td>Alignment of assessment with problem-solving definitions and biotechnology content domains (content- relevance)</td><td></td><td>Match between literature and industry standards</td><td></td></tr>
<tr><td>Bioscience skill standards</td><td>Alignment of assessment with biotechnology content in standards developed through job analysis (content-relevance)</td><td></td><td>Match between assessment and industry standards</td><td></td></tr>
<tr><td>Test blueprints</td><td>Check for alignment of assessment & problem-solving/biotechnology content (content-relevance)</td><td></td><td></td><td></td></tr>
<tr><td rowspan="3">Preliminary Testing</td><td>Student talk-alouds</td><td>Students' words showing they are engaging in problem solving (substantive)<br>Comments on clarity (content-relevance)</td><td></td><td></td><td></td></tr>
<tr><td>Student focus groups</td><td>Comments on importance of topics, difficulty, clarity and how well their assessment answers reflect their perceived problem-solving ability (content-relevance)<br>Comments on bias, fairness, appropriate uses for and purposes of assessment (consequential)</td><td></td><td>Comments on authenticity of tasks, constraints, ambiguities</td><td>Comments on use of assessment</td></tr>
<tr><td>Expert interviews</td><td>Comments on importance of topics, ambiguity, difficulty, how well their assessment answers reflect their perceived problem-solving ability (content-relevance)<br>Comments on fairness, bias, appropriate uses for and purposes of assessment (consequential)<br>Review of scoring guides (structural)</td><td></td><td>Comments on authenticity of tasks, constraints, ambiguities; authenticity of criteria on scoring guide</td><td>Comments on use of assessment</td></tr>
</table>

**Table 2 (continued). Data Sources Linked to Research Questions and Assessment Validation Framework**

| | | *Assessment Validation Framework Category & Research Question* | | | |
|---|---|---|---|---|---|
| **Part of Study** | **Source of data** | **Validity** – To what extent do the scores on the assessment support inferences about students' biotechnology problem-problem solving skills on-the-job? | **Reliability** – How reliable are scores on a 30-minute biotechnology problem-solving skills assessment designed to be useful and authentic? | **Authenticity** – How authentic are the assessment's goals, roles, tasks, situations, ambiguities, constraints and scoring guides with respect to real-world biotechnology contexts? | **Usefulness** – How is the assessment useful for the biotechnology students, instructors, and industry? |
| **Pilot Testing** | Student assessments | Internal consistency, equivalence of forms and sections (content-relevance)<br>Intrarater reliabilities (structural)<br>Description of sample, representative sample (generalizability) | Internal consistency, item analyses, use of varied contexts and response formats, intrarater reliabilities | Real-world characteristics of administration conditions | |
| | Student interviews | Comments on clarity, difficulty, importance of topics, how well their assessment answers reflect their perceived problem-solving ability (content-relevance)<br>Comments on fairness, bias, appropriate uses for and purposes of assessment (consequential) | | Comments on authenticity of tasks, constraints, ambiguities | Comments on use of assessment |
| | Expert interviews | Comments on how well their assessment answers reflect their perceived problem-solving ability (content-relevance)<br>Comments on fairness, bias, appropriate uses for and purposes of assessment (consequential)<br>Review of scoring guides (structural) | | Comments on authenticity of tasks, constraints, ambiguities; authenticity of criteria on scoring guide | Comments on use of assessment |

**Table 2 (continued). Data Sources Linked to Research Questions and Assessment Validation Framework**

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| **Field Testing** | Student assessments | Internal consistency, factor analysis, equivalence of forms and sections (content-relevance)<br>Intra- and interrater reliabilities (structural)<br>Description of sample, representative sample, comparison of pilot and field test students (generalizability) | Internal consistency, item analyses, use of varied contexts and response formats, intrarater reliabilities | Real-world characteristics of administration conditions | |
| | Expert assessments | Comparison with student scores (content-relevance)<br>Assessment answers verify scoring guide criteria (structural) | | | |
| | Employer ratings | Correlation of ratings of student answers with student assessment scores (external) | | | |
| | Student interviews | Comments on clarity, difficulty, importance of topics, how well their assessment answers reflect their perceived problem-solving ability (content-relevance)<br>Comments on fairness, bias, appropriate uses for and purposes of assessment (consequential) | | Comments on authenticity of tasks, constraints, ambiguities | Comments on use of assessment |
| | Expert interviews | Comments on how well their assessment answers reflect their perceived problem-solving ability (content-relevance)<br>Comments on fairness, bias, appropriate uses for and purposes of assessment (consequential)<br>Review of scoring guides (structural) | | Comments on authenticity of tasks, constraints, ambiguities; authenticity of criteria on scoring guide | Comments on use of assessment |

*Preliminary Testing*

The purpose of the preliminary testing was to gather data that would inform the decisions made while revising the assessment and scoring guide. After using literature on problem-solving and the Skills Standards for the Bioscience Industry (1995) to develop the initial draft of the assessment, I used preliminary test data from student talk-alouds, student focus groups, and instructor and experienced biotechnician interviews to revise the assessment. The preliminary testing included student talk-alouds, student focus groups, and expert interviews about the assessment and scoring guide. Six second-year biotechnology students, 2 biotechnology instructors, and 4 experienced biotechnicians affiliated with a North Central region community college completed and critiqued the assessment during two days in January 2003. Their scored answers to the assessment and oral responses during the interviews and focus groups guided revisions of the assessment and scoring guide. The data provided evidence about the assessment's authenticity and usefulness and the validity of inferences made from its scores.

*Pilot Testing*

The pilot test of the assessment and scoring guide, which had been revised during the preliminary test, involved three data collection methods: student assessments, expert interviews, and student interviews. Twenty-three students from 4 community college biotechnology programs across the U.S. took both forms of the assessment in different sequences. Analyses of the students' answers including item score distributions, item analyses, internal consistency, intrarater reliabilities, equivalence of the two forms, and reasons students missed points demonstrated reliability and validity. Interviews with 2 experts in the biotechnology field and 3 students who took the assessment provided evidence of usefulness, authenticity, and validity. As I revised each assessment item and its scoring guidelines, I considered all of these data to balance validity, authenticity, and usefulness with reliability.

*Field Testing*

The purpose of the field test was to collect the data needed to validate the Biotechnology Problem-Solving Skills Assessment. Student and expert assessments scored by multiple raters, employer ratings of student assessment answers, and expert and student interviews provided these data. Instructors at 7 community colleges across the U.S. administered both forms of the assessment in different sequences with 115 biotechnology students. These 7 instructors and 4 experienced biotechnicians also completed the assessment. Three science education graduate students scored 10 of the assessments twice to provide inter- and intrarater reliabilities and structural validity evidence. Other analyses of the answers, which addressed reliability and validity issues, included item score distributions, item analyses, internal consistencies, the correlations between the two forms, factor analysis, and comparisons of expert and student scores. Two experts from the biotechnology industry used anonymous student answers and the Holistic Rating Scale to rate students' on-the-job, biotechnology problem-solving skills. The field test also addressed validity, authenticity, and usefulness by combining relevant data from the preliminary and pilot tests with data from 2 expert and 3 student interviews. The quantitative data inform the reliability and validity aspects of the assessment validation framework while the qualitative data contribute to the validity, authenticity, and usefulness aspects.

## Results and Discussion

*How reliable are scores on a 30-minute biotechnology problem-solving skills assessment designed to be useful and authentic?*

The reliability of scores on the assessment was good. The coefficient alpha was 0.81 for form A and 0.69 for form B, showing that students score consistently on most items on the assessment. I used internal consistency as a measure of reliability because the problem-solving construct contains many different components, which work together to form the entire problem-solving construct. These components may correlate with one another to different degrees but still form an integrated construct when taken together. Average intrarater reliabilities were 0.94, 0.91, and 0.73 for three different scorers. Positive discrimination indices indicate that the top half of students received full credit more often than the bottom half of students on all items on both forms. This shows that all items consistently, but sometimes weakly, discriminate between top- and bottom-half students. The difficulty indices ranged from 0.000 to 0.865 for form A and from 0.000 to 0.462 for form B. For items with difficulty indices of 0.000, no students received full credit. These items were retained in order to keep the problem solving construct intact and because experts did receive full credit on them. Students may not have been taught the appropriate skills to answers these items completely, but these skills still need to be measured to completely understand students' problem-solving abilities.

*To what extent do the scores on the biotechnology problem-solving skills assessment support inferences about students' biotechnology problem-solving skills on the job? (validity)*

Overall, the evidence relating to the six aspects of construct validity indicates that some valid inferences can be made about students' workplace biotechnology problem-solving skills from their assessment scores. The employer ratings of student assessment answers correlated highly and significantly with the students' scores on the assessment ($\rho = 0.746$, $p = 0.013$). This correlation indicates that students' total scores can be used to infer how students would solve biotechnology problems in the workplace. The inferences made about students' workplace biotechnology problem-solving skills from the assessment scores apply only to community college biotechnology students taking the assessment in classroom settings without resources and to the biotechnology content on the assessment.

The assessment contains appropriate content because it is aligned to the literature and employer definitions of workplace problem solving and because students and experts reported that the assessment included the appropriate biotechnology and problem-solving content. The significant difference between expert and student total scores indicates that the problem-solving content on the assessment is appropriate since experts outscored students (form A students 13.2 $\pm$ 0.5, experts 21.7 $\pm$ 1.4, $p = 0.004$; form B students 11.0 $\pm$ 0.4, experts 19.9 $\pm$ 1.4, $p < 0.001$). During preliminary test interviews students made comments which showed that they were cognitively engaging in problem solving while taking the assessment. The scoring guides were adequate because intrarater correlations averaged across items were high ($\rho = 0.94$, 0.91, and 0.73) but may require revisions as indicated by interrater correlations of $\rho = 0.54$ for form B and $\rho = 0.67$ for form A. Expert answers also met the scoring criteria, demonstrating their appropriateness. The assessment was fair for assessing students' biotechnology problem-solving skills as long as students had enough time to complete it. Students did not report any biases on the assessment but said that it should be used only if classes teach the type of problem solving on the assessment.

The two forms of the assessment are moderately equivalent (total form A vs. total form B, Spearman's $\rho = 0.495$, $p = 0.013$). Correlations indicate comparable relative ordering of results but not absolute equivalence of the level of the scores. Therefore, the scores cannot be interpreted using the same cut off score. For these reasons, the two forms should not be used as equivalent forms.

While the internal consistencies for the assessment were 0.81 for form A and 0.69 for form B, both forms loaded onto 6 factors. This suggests that problem solving can be broken down into pieces, but that there is a holistic aspect of problem solving as well. The factors differed for the two forms. The factors may have differed because the biotechnology content in the corresponding items on the two forms differed (customer service vs. ordering supplies) although the biotechnology content overall on each form was very similar (i.e., all biotechnology content areas were on both forms).

*How authentic are the assessment's goals, roles, tasks, situations, ambiguities, constraints and scoring guides with respect to real-world biotechnology contexts?*

The assessment contains highly realistic tasks, constraints, ambiguities, and scoring guides. Biotechnicians reported that they had encountered the problems on the assessment but that biotechnicians in the workplace would involve the supervisor in most of these problems immediately. The format of the assessment is reasonably authentic according to Wiggins' criteria for assessing contextual realism and authenticity (1998) because it involves students in contextualized, messy problems that simulate actual client problems. These same criteria indicate that the assessment is administered less authentically because it does not allow students to use resources, receive feedback during the assessment, or contain intrinsic or extrinsic incentives of any kind.

*How is the assessment useful for the biotechnology students, instructors, and industry?*

The interview responses about the usefulness of the Biotechnology Problem-Solving Skills Assessment indicate that it is useful in its current form, even with the occasional authenticity and validity issues raised earlier. Experts felt the assessment could be useful in several ways: (1) students could receive feedback about their biotechnology problem-solving abilities, (2) instructors could discuss how to address problems in the workplace and how to approach supervisors, and (3) employers could use the assessment as an interviewing tool. Some students were not sure whether the assessment was useful to them since they believed their biotechnology programs did not test or teach them the types of concepts found on the assessment. The students with biotechnology industry work experience believed the assessment was useful for showing them what to expect when they entered biotechnology jobs.

*What is the nature of problem-solving in Advanced Technological Education programs?*

In 1992 Congress passed a law that led to the creation of the ATE program (Mahoney & Barnett, 2000). The program goals are to (1) increase the number and quality of science, technology, engineering and mathematics (STEM) technicians in the workforce and (2) improve the technical skills and the general STEM preparation of these technicians and the educators who prepare them (NSF, 2002). In order to meet these goals, many ATE programs, including biotechnology programs, included problem solving in their curricula (Reed, 2001).

In order to determine how ATE programs portrayed problem solving, I conducted an email survey and analyzed curricular materials. I emailed a survey to the 66 programs that reported they had developed curricular materials on a 2001 web-based survey of all active ATE programs. The email survey asked programs if they used problems in their courses, how they defined problem solving, and for examples of one simple and one complex problem used in their courses. These same programs submitted an example of the best curriculum material they had developed as part of the ATE program. Of the 66 programs, 30 reported that they had created instructional materials, while others developed recruiting materials and skills standards. Of these 30, 29 provided accessible materials, and 13 completed the email survey. Because so few completed the survey and many of those answered survey questions by referencing the submitted materials, I compiled data using the materials but not the email survey responses. I analyzed the materials with a materials analysis checklist based on this study's problem-solving construct and definition of a problem.

The results of the checklist allowed me to briefly describe the ATE programs that developed the materials and to report how the programs portrayed problem solving in their materials. The ATE programs that submitted the curricular materials they developed included 19 sets of materials targeted to the community college level, 6 for high school, and 3 for both levels. The programs addressed the following technical areas: 14% information technology, 24% physics, electronics, or engineering, 10% environmental technology, 14% manufacturing, 7% chemistry, 7% biotechnology, and 3% each for telecommunications, marine technology, and automotive technology. Of the 29 sets of materials, 24 contained problems of some type. The materials utilized the problems different ways throughout the materials. Table 3 shows the percentage of submitted materials that used problems in each way. The problem use categories are ranked with the highest level of use (i.e., problem situations drive all learning units) at the top of the table. If a set of materials used problems in more than one way, only the highest level of use was recorded. The largest percentage of materials (34%) emphasized problem-solving activities, and the rest of the materials used problems almost equally at all levels except that only 3% utilized repeated "plug and chug" problems.

**Table 3. Use of Problems in ATE Program Instructional Materials**

| Level of Problem Use | Percentage of Materials |
|---|---|
| Problem situations drive all learning units. | 17% |
| Materials emphasize problem-solving activities that require students to develop their own method for solving the problem. Problems do not drive all learning units however. Problems are sprinkled throughout the materials or are found in capstone problem projects. | 34% |
| Materials use some problem-solving activities that require students to develop their own method for solving the problems but only in a few places in the materials. | 14% |
| Materials require students to solve complex problems according to a prescribed procedure. | 14% |
| Materials require students to solve repeated "plug and chug," simple problems on paper. | 3% |
| There are no problems in the materials. | 17% |

The types of problems used in the materials varied greatly, with many materials using several types of problems. Three percent of materials fell into each of the following problem categories: mathematics problems with a career or life context, developing an environmental proposal, designing a multimedia project, creating a business plan, or analyzing a biological procedure. The remaining materials contained problems utilizing the scientific method (10%), traditional physics or chemistry problems (21%), troubleshooting problems (17%), design problems (10%).

Tables 4 and 5 show how the materials portrayed problems and problem solving, using the definitions from this study. Table 4 reports the percentage of materials containing each problem characteristic, and Table 5 lists the percentage of materials that specifically taught or required students to perform each problem-solving component. Categories on each table are not mutually exclusive. Many problems (69%) were relevant to students if they were to complete their degrees and seek employment as technicians in the specified field. While over half of the materials contained ill-structured or multiple solution problems, only 28% contained messy and

38% contained complex problems. All materials asked students to identify problems and implement solutions, although many of the solutions were implemented in the sense that students simply wrote down or presented their answers. Actual implementation and all of the components following implementation occurred infrequently. Because so many problems were design problems, they did not require students to identify causes of the problem. In the design problems, human needs were given as the problem and causes were irrelevant.

**Table 4. Percentage of Materials Containing Each Problem Characteristic**

| Problem Characteristic Found in Materials | Percentage of Materials |
|---|---|
| Ill structured (not all information needed to solve the problem is present) | 55% |
| Messy (problem contains extraneous information) | 28% |
| Complex (problem requires analysis of pros/cons, constraints, risks, or context) | 38% |
| Has more than one possible right answer | 52% |
| Students likely to encounter in lives or careers | 69% |
| Could change with the addition of new information | 41% |

**Table 5. Percentage of Materials Addressing Each Problem-Solving Component**

| Problem-Solving Component Contained in Materials | Percentage of Materials |
|---|---|
| Identify the problem | 100% |
| Examine the context of the problem | 34% |
| Identify and gather pertinent information | 55% |
| Identify possible causes of the problem | 14% |
| Identify and evaluate problem constraints | 20% |
| Develop criteria for satisfactory solutions | 31% |
| Generate possible solutions | 45% |
| Select a solution by evaluating alternatives against criteria | 28% |
| Implement solution (includes presenting a solution and recording answers to problems on paper) | 100% |
| Gather data systematically during implementation | 31% |
| Apply evaluation criteria to implemented solution | 17% |
| Identify positive and negative consequences associated with the solution | 10% |
| Refine solution to resolve deficiencies if possible | 17% |
| Seek alternative solutions if goals are not achieved | 0% |

*Limitations and Notes about Using the Assessment*

- The sample of field test students who completed the assessment did not complete it conscientiously, and if they had, the validation results might be different.
- Students need one hour to complete one form of the assessment.
- The two forms of the assessment should not be used as equivalent forms. Form A is appropriate for any biotechnology students; form B is more appropriate for advanced students finishing their biotechnology programs.

- The assessment has been validated with community college biotechnicians in the U.S. only.
- Like any relatively short, specific assessment, this assessment should not be used alone to guide decisions about students or programs because it measures only one aspect of what biotechnology programs teach, work-related problem-solving skills.
- The correlation between assessment scores and employer ratings of student answers used small sample sizes, limiting confidence in the finding that scores and employer ratings correlated highly, positively, and significantly.

*Recommendations for Similar Evaluation Studies*

Lessons learned during this study could guide other assessment validation studies. First, the assessment cases could be developed more fully in the preliminary testing phase. The cases were quite realistic; the biotechnicians said that they had experienced the very problems on the assessment during their careers. I could have asked them to describe these events in detail instead of relying on the limited details in the cases adapted from the Skill Standards for the Bioscience Industry. Using the details from real events described directly to me could have made the realistic context of the cases on the assessment even better.

Second, recruitment of participants should be a streamlined process that occurs about two to three weeks into the semester for testing beginning about one month after recruitment. A phone call alerting potential subjects that an email with more information was coming in a few days was very effective at generating initial responses to the email. Emails should summarize key information briefly and then include attachments with complete details for potential subjects to read if they wish. About half of eligible programs were willing to participate, and then half of the students in those programs completed the assessment. Initial recruitment numbers should account for this.

Third, all communication with the sites should be streamlined and sites should be given about two weeks to administer the assessment plus one week on each side for mail delivery. More than two weeks for administering the assessment results in participants dropping out. Sites should be able to complete all research activities at once rather than dividing the activities over time or different phases of the study.

Last, experts are extremely valuable sources of information during the preliminary testing phase. One-hour interviews were not sufficient. Interviews should last longer or more experts should be interviewed, perhaps each one about a different instrument (the assessment itself, the scoring guide, the Holistic Rating Scale). Increasing the number of experts and limiting their time commitment could reveal more ideas about the instruments by increasing the amount of data and sampling a wider range of the population.

### *Findings about Problem Solving*

The theoretical definition of problem solving needs to be adapted slightly when it is applied to written tests. Two problem-solving components were difficult to capture on the written assessment, implements solution and examines problem context. Three problem-solving components address the criteria for successful problem solutions, so I asked for these criteria specifically only once. Problem constraints should be defined clearly enough to distinguish it from solution criteria or should be subsumed within solution criteria.

The distribution of student scores on the assessment shows that the following problem-solving components were difficult for all students: select solution and justify it, monitor solution, and evaluate solution using criteria. In addition, students scoring in the bottom-half on the assessment had difficulty with gather information to determine the cause and revise solution. Instruction must address these problem-solving components.

Increasing the complexity of a problem's context seems to decrease students' problem-solving performance, especially for students with little content knowledge. Students generally scored lower on the form B memo than on the form A memo, possibly due to the complexity of the form B memo. This difference was more pronounced for field test students who had taken fewer biotechnology courses.

Student content knowledge may also affect students' abilities to handle a problem in the integrated manner of the performance memo. Many students who scored in the bottom half on the assessment as a whole performed better on the problem analysis cases than they did on the performance memo. This suggests that problem solving can be broken down into pieces, but that there is a holistic aspect of problem solving as well.

Additionally, the number of biotechnology courses a student had taken correlated significantly, positively, and weakly with problem analysis subtotals and totals on both forms. All of these findings about problem solving complexity and student content knowledge suggest that instructors should gradually increase the complexity of problems they present to students as the students' content knowledge increases.  Instruction should also address problem-solving components both individually and in an integrated manner.

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## Appendix A - Biotechnology Problem-Solving Skills Assessment Form A (Field Test/Final Version)

Dear Student,

This activity is designed to reveal your thinking as you solve problems that occur in workplace situations. It is not intended to reveal your biotechnology knowledge. There are many possible answers for each question, so it is important to explain the reasoning for all of your answers. Many of the questions will seem similar because repeated questions are required for this type of activity. Your answers will be used to help me revise the activity items and create an activity that biotechnology programs across the nation can use. Supervisors of entry-level biotechnicians have told me that this test contains good job interview questions. Use this opportunity to practice for interviews by giving thoughtful answers. You will have 60 minutes to complete the test. It has four sections.

Before you begin the activity, please answer the questions on this page. I will use this information to describe the types of students completing this activity. Your instructor will tell you when to begin the rest of the activity.

Thank you!

**Answer the following questions in the space provided:**

1. List ALL of the biotechnology courses you have taken.

2. List ALL the degrees you have earned and your major for each.

3. This is my (check one)
   ____ first year in the biotechnology program
   ____ second year in the biotechnology program
   ____ third year in the biotechnology program
   ____ other (please specify) ___________________________________

4. How many years of full time work experience do you have? _______

5. What is the first language you learned as a child? (check one)
   ____ English
   ____ other

# Biotechnology Problem-solving Skills Assessment (Form A)

College Name: ___________________________ Date: ___________

Course Name: ___________________________

**Section 1**

**Directions**: Read each case below and then answer the question(s) that follow it in the space given. You do not have to use complete sentences if you can make your reasoning clear using phrases.

| |
|---|
| Case A: The president of a large yogurt processing company has promised to supply food stores with $500,000 of a new yogurt product this week. The company has already spent money advertising for the new product. As the company biotechnician, you test whether or not the batches of yogurt have spoiled. You will run out of a chemical reagent used in this test by tomorrow. Although you ordered more of the reagent several days ago, the vendor just called to tell you the reagent will not be available for another week. No other vendors make the reagent. |

1. What are <u>four</u> possible ways to solve this problem?

2. a. Which solution for the problem would you use?

   b. Why is this solution better than the others?

| |
|---|
| Case B: You work in a laboratory certifying a manufactured product. As you weigh each sample, you find that each of the last 5 samples have weighed 5.00g, 5.03g, 5.01g, 4.90g, and 4.93g. Yesterday's samples weighed 6.10g, 6.15g, 5.95g, 6.02g, and 6.08g. |

3. a. Is there a problem in this case? Yes No (circle one) Why or why not?

   b. If there is a problem, what is it?

Case C: Your job is to assist with cleaning, preparing, sterilizing and inoculating a bioreactor. A bioreactor is a vessel for growing cells and contains a pH meter, openings for air to enter and exit the vessel, and filters. Two hours after inoculation, a coworker points out that the bioreactor's entrance air filter cartridge is not installed. This means that there is no filter between the recombinant cells in the bioreactor and the outside environment. The stock eukaryotic cells you put into the bioreactor took 6 months to produce and sell for $700/mL. After 2 days of growth in the bioreactor, you will have enough cells for shipment. Your customer expects her shipment to arrive in 3 days, and your supervisor is on vacation. To solve this problem you decide to immediately insert the filter into the machine. You then continue running the machine.

4. a. What are the <u>two</u> most significant advantages of your solution?

b. What are the <u>two</u> most significant disadvantages of your solution?

5. a. Explain your plan to monitor your solution. In other words, what information will you gather and how will you gather it to find out if your solution is working?

b. How will you determine whether this solution is successful? In other words, what standards, criteria, constraints, or limitations will you use to determine whether this solution is successful?

Case D: As a biotechnician in a laboratory, you routinely pack and ship biological samples to customers. A customer reports that the samples you sent are leaking from their containers.

6. What are <u>four</u> possible causes of the problem?

7. Explain how you would gather <u>two</u> pieces of information that would help you determine the actual cause of the problem.

Case E: At your supervisor's request, you have updated the quality control testing procedure for your company's product. You evaluate your updated quality control test in two ways. First, you retest 20 samples of product that passed the old quality control tests yesterday. All 20 samples pass your new test. Second, you test 50 samples of product made today. Two of the 50 samples fail your new test. You can test 10 samples per hour, and you are not allowed to work overtime.

8. a. What will you do next?

b. Why?

**Section 2**

**Directions**: Read the following case and write a memo or letter that contains your answers in the space below. You may use the back of the page as well, if needed.

9. In the research laboratory where you work as a biotechnician, the viability of many of the cell lines you maintain has decreased to 70% in the past 24 hours. For the past 6 months, the cells had been growing well with 97% viability. If you don't fix the problem in 36 hours, all of the lines could die.

Draft a memo or letter to your supervisor to notify her about the situation. Explain the following in it:

- a the problem(s)
- b & c possible causes & how you will know which one is the real cause
- d possible solutions
- e the solution you recommend & why it is best
- f & g your plan to monitor the solution (In other words, what information will you gather and how will you gather it to find out if this solution is working? What standards or criteria will you use to determine whether this solution is successful?)
- h what you will do if the solution doesn't work

Your supervisor will judge your memo and solution to the problem on its accuracy, cost-effectiveness, efficiency, and ability to convey the information she needs to know.

## Appendix B - Biotechnology Problem-Solving Skills Assessment Form B (Field Test/Final Version)

Dear Student,

This activity is designed to reveal your thinking as you solve problems that occur in workplace situations. It is not intended to reveal your biotechnology knowledge. There are many possible answers for each question, so it is important to explain the reasoning for all of your answers. Many of the questions will seem similar because repeated questions are required for this type of activity. Your answers will be used to help me revise the activity items and create an activity that biotechnology programs across the nation can use. Supervisors of entry-level biotechnicians have told me that this test contains good job interview questions. Use this opportunity to practice for interviews by giving thoughtful answers. You will have 60 minutes to complete the test. It has four sections.

Before you begin the activity, please answer the questions on this page. I will use this information to describe the types of students completing this activity. Your instructor will tell you when to begin the rest of the activity.

Thank you!

**Answer the following questions in the space provided**:

1. List ALL of the biotechnology courses you have taken.

2. List ALL the degrees you have earned and your major for each.

3. This is my (check one)
   ____ first year in the biotechnology program
   ____ second year in the biotechnology program
   ____ third year in the biotechnology program
   ____ other (please specify) ___________________________________

4. How many years of full time work experience do you have? _______

5. What is the first language you learned as a child? (check one)
   ____ English
   ____ other

# Biotechnology Problem-solving Skills Assessment (Form B)

College Name: ______________________________ Date: ___________

Course Name: _______________________________

**Section 1**

**Directions**: Read each case below and then answer the question(s) that follow it in the space given. You do not have to use complete sentences if you can make your reasoning clear using phrases.

| |
|---|
| Case A: You work as a biotechnician at a company that supplies its customers with genetically-modified organisms made to order. The president of the company has promised a new client that you will fill an order in one week. The new client could double your company's income. It will take you at least two weeks to fill the order because the specific vendor kit needed will not be available for two weeks. No other vendors make the kit. |

1. What are <u>four</u> possible ways to solve this problem?

2. a. Which solution for the problem would you use?

   b. Why is this solution better than the others?

| |
|---|
| Case B: You work in inventory control for an animal feed processing plant. You receive an order from the animal center at a medical research laboratory for mouse feed, fill the order, and ship it to the customer. Customer service informs you that the customer is very upset. She believes that the feed you sent her is making the genetically-engineered mice in her colony ill. |

3. a. Is there a problem in this case? Yes or No (circle one) Why or why not?

   b. If there is a problem, what is it?

| |
|---|
| Case C: Your lab uses radioactive compounds, and the environmental health and safety department will be inspecting it tomorrow morning. As you assist with checking the lab using a Geiger counter to measure levels of radiation, you find radioactive equipment on a lab bench. Because the level of contamination is so high, you decide to solve this problem by calling in the hazardous waste division of your company. They will clean up the contamination today, and charge your lab $300/hour. |

4. a. What are the <u>two</u> most significant advantages of your solution?

b. What are the <u>two</u> most significant disadvantages of your solution?

5. Assume you decide to solve the problem by cleaning up the contamination yourself because you are trained to clean up radioactive waste.

a. Explain your plan to monitor this solution. In other words, what information will you gather and how will you gather it to find out if this solution is working?

b. How will you determine whether this solution is successful? In other words, what standards, criteria, constraints, or limitations will you use to determine whether this solution is successful?

Case D: You work in a quality control laboratory certifying your company's product. You test for impurities in the product by running it through a column. You calculate that 2.0 L of the pure product has a yield of 10.0 ± 0.5 g/L. You run 2.0 L of product through the column and obtain 16.1 g of product. This is a lower yield than you expected.

6. What are <u>four</u> possible causes of the problem?

7. Explain how you would gather <u>two</u> pieces of information that would help you determine the actual cause of the problem.

Case E: Your lab recently received a new model of bioreactor. Your supervisor has asked you to update the old bioreactor's procedure manual for use with the new bioreactor. You inoculate the new reactor with cells from a frozen stock of batch 3 and follow your updated procedure. You end up with contaminated product. To solve this problem, you throw out the culture media you used. You then sterilize all the equipment used during the procedure and run diagnostic checks on the reactor. The reactor is working properly and tests negative for contamination. Using cells from batch 3, you and a coworker separately follow the procedure with a sterile bottle of culture media from a new lot. Both of you end up with contaminated product five times in a row.

8. a. What will you do next?

b. Why?

**<u>Section 2</u>**

**Directions**: Read the following case and write a memo or letter that contains your answers in the space below. You may use the back of the page as well, if needed.

9. Greasy Oil Company just had an oil tanker crash off the coast of Alaska near an open-sea fish hatchery. They need oil-eating bacteria shipped from your genetic engineering company, and as a biotechnician you are responsible for testing them before they are shipped. You find the bacteria are 80% viable, consume 0.5 g oil/g bacteria/hour and can survive when there is no oil left to consume. To be within specifications, the cells must be at least 90% viable, consume 0.8±0.2 g oil/g bacteria/hour, and die when there is no oil left to consume.

Draft a memo or letter to your supervisor to notify her about the situation. Explain the following in it:

- a the problem(s)
- b & c possible causes & how you will know which one is the real cause
- d possible solutions
- e the solution you recommend & why it is best
- f & g your plan to monitor the solution (In other words, what information will you gather and how will you gather it to find out if this solution is working? What standards or criteria will you use to determine whether this solution is successful?)
- h what you will do if the solution doesn't work

Your supervisor will judge your memo and solution to the problem on its accuracy, cost-effectiveness, efficiency, and ability to convey the information she needs to know.

# Appendix C – Scoring Guide for Biotechnology Problem-Solving Skills Assessment Form A (Field Test/Final Version)

**Case A**

**1. What are four possible ways to solve this problem?**

2 pts total
½ pt per solution
BUT "do nothing", implausible solutions, and duplicate solutions do not count as a solutions.
The solution must solve the problem, firing someone does not solve the immediate problem.
Send it out without testing=do nothing.
Watch for solutions that are equivalent to doing nothing.
Run test without the reagent = implausible.
Order from another vendor = implausible since no other vendors make it.
Get reagent from another company and a local hospital are duplicates ½ pt for both combined.
Solutions must be significantly different from each other to get credit for each one.
no other criteria for solutions – they will be evaluated in later question
*examples of answers*

- *Get the vendor to obtain reagent for you*
- *Develop another test to detect spoiled yogurt*
- *Stop the yogurt line until you have the reagent*
- *Use less reagent and test smaller samples of yogurt until you get the reagent*

**2. a. Which solution for the problem would you use?**
**b. Why is this solution better than the others?**

3 pts total based on the following scale
Grade a & b together, as one answer
Statements in answer must use words that clearly indicate time, cost, accuracy, safety, integrity, or satisfaction. Don't assume one of these is implied without reading a word/phrase in the answer that clearly indicates it. "Fill the order" indicates that the order will be filled on time.

| | |
|---|---|
| 3 pts | Solution is feasible. Its justification balances accuracy, efficiency and cost within the constraints of the problem. |
| 2 pts | Solution is feasible. Its justification balances two of the three categories (accuracy, efficiency, or cost) within the constraints of the problem. |
| 1 pt | Solution is feasible. Its justification addresses one of three categories (accuracy, efficiency, or cost). |
| 0 pts | Solution is not feasible. Solution is not justified at all, or justification is inaccurate (doesn't make sense) or isn't very convincing. |

Definitions
Feasible – resources are available in the biotech workplace for the biotechnician to implement the solution
Justifications for solutions should balance three categories: accuracy, efficiency, and cost.
Accuracy – the solution is justified because it could potentially solve the problem. Or it is justified because it could safely solve the problem, maintain company or employee integrity, prevent the problem in the future, satisfy the customer, involves all stakeholders, or involves the appropriate authority person.
Efficiency – the solution is justified because it could solve the problem under the time constraint in the case
Cost – the solution is justified because it could solve the problem within the cost constraints of the case

**Case B**

**3. a. Is there a problem in this case? Yes or No (circle one) Why or why not?**
**b. If there is a problem, what is it?**

2 pts total, grading a & b together
1 pt if answer "yes" OR if answer "no" or "maybe" with a logically supported reason.
1 pt if problem or cause listed is plausible – could occur given the data in the case
must list a problem or cause: if says there could be a problem if the environment changed but doesn't list what that problem is – 0 pts for problem or cause listed is plausible

*Examples of good answers for "What is problem?"*

- *Sample might weigh too little for certification since yesterday's certified samples weighed around 6g*
- *Could also list the cause of problem such as balance is malfunctioning or assembly line is filling samples inaccurately, quality control overfill problem*

**Case C**

**4. a. What are the two most significant advantages of your solution?**
**b. What are the two most significant disadvantages of your solution?**

3 pts total, grading a & b together
1/2 pt per first 2 advantages and first 2 disadvantages only if each is plausible and makes sense – could actually be a positive or negative consequence of the solution
don't give credit for duplicate answers. Watch carefully for this.
prevent contamination = cells still useable ½ pt only
contamination and customer satisfaction are different 1 pt
changing environment will affect the speed and temperment of cells = 0 (doesn't make sense)
must throw out because violated regulations = plausible ½ pt
1 pt if advantages and disadvantages, taken together, address all of the following: efficiency, cost and accuracy of the solution
½ pt if advantages and disadvantages, taken together, address 2 of 3: efficiency, cost, accuracy of solution

**5. a. Explain your plan to monitor this solution. In other words, what information will you gather and how will you gather it to find out if this solution is working?**

2 pts total
Information is collected systematically as the solution to the problem is implemented.
½ pt. Feasible – resources are available in the biotech workplace for the biotechnician to gather the information listed
½ pt. Accurate - the information gathered could potentially show that the solution is not working. Must list specific tests used to gather the info (plating, culture, cell growth, oxygen, pH). Don't need to mention what to look for in test, though, that is in 5b. Test for contamination is not specific enough – test how? Test for contamination = feasible.
Ask customer how solution worked = feasible.
½ pt. Info is collected at regular intervals. "monitor" or "keep watching" = regular intervals
½ pt. Info is collected from all necessary locations so that plan can show the problem was solved completely. Must mention sampling or testing cells in bioreactor.

**5. b. How will you determine whether this solution is successful? In other words, what standards, criteria, constraints or limitations will you use to determine whether this solution is successful?**

**If answers to 5b are in 5a or vice versa, still give credit.**
2 pts total
1 pt if criteria are useful – specific enough to definitively expose solutions that are not working
useful = no or 0% contamination, pH or oxygen levels remain as they should be for this type of cell, cell growth is at a normal rate, compared to a standard product, meets criteria in SOP.
Customer doesn't complain = .5 pts
1 pt if criteria address the time and money constraints mentioned in the case (customer gets shipment on time, save as much of the cells as possible to keep costs of mistake down)

**Case D**

**6. What are four possible causes of the problem?**

2 pts total
1/2 pt per cause that is
plausible – could be the actual cause
do not count duplicate answers more than once
*examples of good answers*

- *improperly sealed containers*
- *container broke during shipping due to packing problem*
- *sample inside container decayed/reacted breaking container*

7. **Explain how you would gather two pieces of information that would help you determine the actual cause of the problem.**

2 pts total
1/2 pt per piece of information/gathering method that is useful – would help determine the cause and specifies symptoms/problems to look for or to help id cause
½ pt per piece of info/gathering method that is plausible – could be obtained via gathering method(s) suggested. This means the gathering method (how) is specified.
*Examples of good answers*

- *Call customer and ask to describe container - Appearance of leaking containers (seal, cracked, etc.)*
- *Call customer and ask to describe condition of package (location of packing material, condition of packing material)*

**Case E**

8. **What will you do next? Why?**

1 pt total
½ pt actions suggested revise the solution or develop a new one based on (related to) the evidence in the case
½ pt actions propose a control or comparison group test to identify the source of the problem
repeat the test without comparison group total=.5

**9. write memo or letter.**

**a. Problem(s)**

1 pt if problem listed is plausible – could occur given the data in the case

- *Cell lines have decreased to 70% viability*

**b. Possible causes**

1 pt Lists at least two possible causes of problem. ½ pt per cause (max 2 causes) that is

- plausible – could be the actual cause

*examples of good answers*

- *During a transfer of cells, cells were contaminated*
- *Cell growth media contaminated*

**c. How you will know which one is the real cause**

1 pt
1/2 pt information/gathering method that is useful – would help determine the cause and specific enough to let you know if it is or is not a cause
½ pt info/gathering method that is plausible – could be obtained via gathering method(s) suggested. This means the gathering method (how) is specified.
Check pH and see if pH changed = 1 because tells how get info (check pH) and what to look for to know if pH is a cause
Test cells for contamination = 1.
Check pH = .5 since don't know what to look for (not useful, specific enough)
Things counted here may also be counted under monitoring/standards question. They may also be counted under possible solutions if appropriate.

**d. Possible solutions**

2 pts total
1 pt per solution listed (max 2 solutions)
solutions must be plausible
if listed environmental factors as causes and the answer specifies that all these causes should be changed, checked, or tested may assume that altering these environmental factors in some way is a list of possible solutions.

**e. The solution you recommend & why it is best**

3 pts total based on the following scale

Statements in answer must use words that clearly indicate time, cost, accuracy, safety, integrity, or satisfaction. Don't assume one of these is implied without reading a word/phrase in the answer that clearly indicates it. "immediate solution" and "fast" imply time.

| | |
|---|---|
| 3 pts | Solution is feasible. Its justification balances accuracy, efficiency and cost within the constraints of the problem. |
| 2 pts | Solution is feasible. Its justification balances two of the three categories (accuracy, efficiency, or cost) within the constraints of the problem. |
| 1 pt | Solution is feasible. Its justification addresses one of three categories (accuracy, efficiency, or cost). |
| 0 pts | Solution is not feasible. Solution is not justified at all, or justification is inaccurate (doesn't make sense). |

Definitions
Feasible – resources are available in the biotech workplace for the biotechnician to implement the solution
Justifications for solutions should balance three categories: accuracy, efficiency, and cost.
Accuracy – the solution is justified because it could potentially solve the problem. Or it is justified because it could safely solve the problem, maintain company or employee integrity, prevent the problem in the future, or satisfy the customer.
Efficiency – the solution is justified because it could solve the problem under the time constraint in the case
Cost – the solution is justified because it could solve the problem within the cost constraints of the case

**f. Your plan to monitor solution. In other words what information will you gather and how will you gather it to find out if this solution is working?**
2 pts total
Must state "monitor by…" or "check". It must be clear that something is checked after something is changed/solution is implemented. Original diagnosis of the problem, checking variables such as pH, without changing anything first does not count as monitoring a solution. Answers may duplicate how will you know it is the real cause question.
Information is collected systematically as the solution to the problem is implemented.
½ pt. Feasible – resources are available in the biotech workplace for the biotechnician to gather the information listed
½ pt. Accurate - the information gathered could potentially show that the solution is not working. Must list specific tests used to gather the info and these tests must be able to show if the solution is working. Don't need to mention what to look for in test, though.
½ pt. Info is collected at regular intervals. "keep checking" or "keep watching" = regular intervals
½ pt. Info is collected from all necessary locations so that plan can show the problem was solved completely. Must have multiple locations.

**g. What standards or criteria will you use to determine whether this solution is successful?**
1 pt total
½ pt if criteria are useful – specific enough to definitively expose solutions that are not working (increase in viability)
1/2 pt if criteria address the time and money constraints mentioned in the case (before line dies)

**h. What you will do if the solution doesn't work**
1 pt actions suggested revise the solution or develop a new one
do other tests = 0 – too vague; try it again = 0 – not new; get advice/tell supervisor = .5
try other tests when other causes are listed earlier in answer = 1 because assume the tests would be for the causes listed

# Appendix D – Scoring Guide for Biotechnology Problem-Solving Skills Assessment Form B (Field Test/Final Version)

**Case A**

**1. What are four possible ways to solve this problem?**

2 pts total
½ pt per solution
BUT "do nothing", implausible solutions, and duplicate solutions do not count as a solutions.
Watch for solutions that are equivalent to doing nothing.
Order from another vendor = implausible since no other vendors make it.
Extra worktime or manpower = implausible since you don't have the materials needed to do the work
Order 2 kits and double production once the kits are available = implausible since the customer still won't get the product on time.
Get kit from another company and a local hospital are duplicates ½ pt for both combined.
Solutions must be significantly different from each other to get credit for each one.
no other criteria for solutions – they will be evaluated in later question
*examples of answers*

- *Develop another way to do what the kit does*
- *Satisfy the customer in some other way – with service, a discount, etc.*
- *Explain the customer why he cannot have his order for 2 weeks*
- *Learn the customer's needs and try to find another product you make that could meet his needs and be ready in one week*

**2. a. Which solution for the problem would you use?**
**b. Why is this solution better than the others?**

3 pts total based on the following scale
Grade a & b together, as one answer
Statements in answer must use words that clearly indicate time, cost, accuracy, safety, integrity, or satisfaction.
Don't assume one of these is implied without reading a word/phrase in the answer that clearly indicates it.

| | |
|---|---|
| 3 pts | Solution is feasible. Its justification balances accuracy, efficiency and cost within the constraints of the problem. |
| 2 pts | Solution is feasible. Its justification balances two of the three categories (accuracy, efficiency, or cost) within the constraints of the problem. |
| 1 pt | Solution is feasible. Its justification addresses one of three categories (accuracy, efficiency, or cost). |
| 0 pts | Solution is not feasible. Solution is not justified at all, or justification is inaccurate (doesn't make sense). |

Definitions
Feasible – resources are available in the biotech workplace for the biotechnician to implement the solution
Justifications for solutions should balance three categories: accuracy, efficiency, and cost.
Accuracy – the solution is justified because it could potentially solve the problem. Or it is justified because it could safely solve the problem, maintain company or employee integrity, prevent the problem in the future, or satisfy the customer.
Efficiency – the solution is justified because it could solve the problem under the time constraint in the case
Cost – the solution is justified because it could solve the problem within the cost constraints of the case

**Case B**

**3. a. Is there a problem in this case? Yes or No (circle one) Why or why not?**
**b. If there is a problem, what is it?**

2 pts total, grading a & b together
1 pt if answer "yes" OR if answer "no" or "maybe" with a logically supported reason.
problems or causes listed must be plausible – could occur given the data in the case
½ pt related to the feed

½ pt related to customer being upset
implausible = product is contaminated or customer made mice ill (don't know for sure)
*Examples of good answers for "What is problem?"*

- *Your feed may have caused illness in mice*
- *Customer believes your feed caused illness in mice*
- *Customer is upset*

**Case C**
**4. a. What are the two most significant advantages of your solution?**
**b. What are the two most significant disadvantages of your solution?**
3 pts total, grading a & b together
1/2 pt per first 2 advantages and first 2 disadvantages only if each is plausible and makes sense – could actually be a positive or negative consequence of the solution
don't give credit for duplicate answers. Watch carefully for this.
cleaned up properly and pass inspection are different 1 pt
people will know you made a mistake, safety dept may discover something else, safety dept will see that you take contamination seriously = 0 for all (poor quality, filler type answers, not reasonable answers)
"passing inspection" and "getting it cleaned up" imply time since inspection is tomorrow
lab will be closed for a day implies time
1 pt if advantages and disadvantages, taken together, address all of the following: efficiency, cost and accuracy of the solution
½ pt if advantages and disadvantages, taken together, address 2 of 3: efficiency, cost, accuracy of solution
*Examples of good answers*

- *Pros: fast, likely to result in lab passing inspection since professionals will be doing clean up*
- *Cons: expensive*

**5. a. Explain your plan to monitor this solution. In other words, what information will you gather and how will you gather it to find out if this solution is working**
2 pts total
Information is collected systematically as the solution to the problem is implemented.
½ pt. Feasible – resources are available in the biotech workplace for the biotechnician to gather the information listed
½ pt. Accurate - the information gathered could potentially show that the solution is not working. Must list specific tests used to gather the info (Geiger counter, scintillation test, swipe test). Don't need to mention what to look for in test, though, that is in 5b. Follow safety book is not specific enough – test how? Follow safety book = feasible. Follow company procedures = feasible.
½ pt. Info is collected at regular intervals. "frequently" "multiple times" or "after each is cleaned" = regular intervals
½ pt. Info is collected from all necessary locations so that plan can show the problem was solved completely. Must mention sampling or all equipment or whole area.
*example of a good answer*
*Use the Geiger counter to test all equipment and sections of the counter for radioactive contamination after each is decontaminated*

**5. b. How will you determine whether this solution is successful? In other words, what standards, criteria, constraints, or limitations will you use to determine whether this solution is successful?**
**If answers to 5b are in 5a or vice versa, still give credit.**
2 pts total
1 pt if criteria are useful – specific enough to definitively expose solutions that are not working
useful = acceptable levels or standards in safety standards will be used 1 pt for either
clean, free of contamination = ½ pt for either because they don't specify how you will know it is clean/free of contamination
1 pt if criteria address the time and money constraints mentioned in the case (done before inspection, pass the safety inspection, no money constraints really mentioned)
*Examples of good answers*

- *Clean  up must be finished before inspectors arrive*
- *Each Geiger counter reading taken (every piece of equipment on the counter and across the entire counter) shows levels of radiation at or below the acceptable level*

**Case D**

**6.  What are four possible causes of the problem?**

2 pts total
½ pt per cause that is
plausible – could be the actual cause
do not count duplicate answers more than once
do not count implausible or inadequate answers.  Product concentration is not as high as expected = 0 because this just restates the problem, inadequate.  Some answers about density/concentration may be implausible, check carefully.
must mention that one possible cause is impure product.  If there are 4 plausible causes, but this is not one of them = 1.5 pts.
*examples of good answers*

- *error in calculating calculated yield or sample yield*
- *error weighing/measuring product*
- *something went wrong during the purification process, most likely product contains impurities*
- *the column is not functioning properly*

**7.  Explain how you would gather two pieces of information that would help you determine the actual cause of the problem.**

2 pts total
1/2 pt per piece of information/gathering method that is useful – would help determine the cause and specifies symptoms/problems to look for or to help id cause
½ pt per piece of info/gathering method that is plausible – could be obtained via gathering method(s) suggested. This means the gathering method (how) is specified.
*Run test again (1/2) and record results (1/2) because I assumed you look for the same or different result on the test. Run another sample (1/2) and record accuracy (1/2) because I assumed you would compare to what measurement should be for this sample.*

**Case E**

**8.  What will you do next?  Why?**

1 pt total
½ pt actions suggested revise the solution or develop a new one based on (related to) the evidence in the case and would help solve the documentation problem in the case
½ pt actions propose a control or comparison group test to identify the source of the problem
comparison test total=1
check for contamination in batch 3 total= .5 because no comparison/control group
throw out media = 0 because it was already done in the case
answers that assume batch 3 must be discarded total = 0 because based on the evidence, you shouldn't throw out batch 3 until you test it for contamination.  It may not be contaminated after all.

**<u>Section 2</u>**

**9. write memo or letter.**

**a. Problem(s)**

1 pt if problem listed is plausible – could occur given the data in the case
must list both problems here: ½ pt for cells not meeting specs, ½ pt for immediate need to clean up oil spill or bacteria not dying could cause environmental problem
*Examples of good answers*

- *Bacteria don't meet specifications but customer needs them immediately*
- *Bacteria won't eat as much oil as they should*
- *Bacteria will live on in ecosystem after eating all the oil*

**b. Possible causes**
1 pt Lists at least two possible causes of problem. ½ pt per cause (max 2 causes) that is
- plausible – could be the actual cause

*examples of good answers*
- *genetic recombination was not performed accurately*
- *tested samples incorrectly – maybe at wrong temp for test*
- *bacteria contaminated in some way as shown by lowered viability*

**c. How you will know which one is the real cause**
1 pt
1/2 pt information/gathering method that is useful – would help determine the cause and specific enough to let you know if it is or is not a cause
½ pt info/gathering method that is plausible – could be obtained via gathering method(s) suggested. This means the gathering method (how) is specified.
Change temp and see how specs affected = 1 because tells how get info (change temp) and what to look for to know if temp is a cause
Things counted here may also be counted under monitoring/standards question. They may also be counted under possible solutions if appropriate.

**Examples of good answers**
- *Can gather info to determine if testing was done improperly or where procedure for creating bacteria broke down, but really need to move on and deal with the customer's need and oil spill problem. Could identify protocol problems after customer problem is solved.*
- *Need info about fish hatchery, local wildlife to predict how bacteria might affect them if used*

**d. Possible solutions**
2 pts total
1 pt per solution listed (max 2 solutions)
solutions must be plausible and address the current problem
if listed environmental factors as causes and the answer specifies that all these causes should be changed, checked, or tested may assume that altering these environmental factors in some way is a list of possible solutions.
Run tests to make the bacteria stronger = implausible, doesn't make sense
Don't ship = 0 unless this statement is supported with logical reasoning
Make a new organism, make a new strain, or re-engineer the organism = 1
Bring bacteria to specifications = 0 too vague
Grow new batch = 0 because not changing anything will probably give the same result
Grow new batch under new conditions or environment = 1 since it potentially fixes a cause of the problem

**e. The solution you recommend & why it is best**
3 pts total based on the following scale
Statements in answer must use words that clearly indicate time, cost, accuracy, safety, integrity, or satisfaction. Don't assume one of these is implied without reading a word/phrase in the answer that clearly indicates it.
"immediate solution" and "fast" imply time.

| | |
|---|---|
| 3 pts | Solution is feasible. Its justification balances accuracy, efficiency and cost within the constraints of the problem. |
| 2 pts | Solution is feasible. Its justification balances two of the three categories (accuracy, efficiency, or cost) within the constraints of the problem. |
| 1 pt | Solution is feasible. Its justification addresses one of three categories (accuracy, efficiency, or cost). |
| 0 pts | Solution is not feasible. Solution is not justified at all, or justification is inaccurate (doesn't make sense). |

Definitions
Feasible – resources are available in the biotech workplace for the biotechnician to implement the solution
Justifications for solutions should balance three categories: accuracy, efficiency, and cost.

Accuracy – the solution is justified because it could potentially solve the problem. Or it is justified because it could safely solve the problem, maintain company or employee integrity, prevent the problem in the future, or satisfy the customer.
Efficiency – the solution is justified because it could solve the problem under the time constraint in the case
Cost – the solution is justified because it could solve the problem within the cost constraints of the case

**f. Your plan to monitor solution. In other words what information will you gather and how will you gather it to find out if this solution is working?**
2 pts total
Must state "monitor by…" or "check". It must be clear that something is checked after something is changed/solution is implemented. Original diagnosis of the problem, checking variables such as pH, without changing anything first does not count as monitoring a solution. Answers may duplicate how will you know it is the real cause question.
Information is collected systematically as the solution to the problem is implemented.
½ pt. Feasible – resources are available in the biotech workplace for the biotechnician to gather the information listed
½ pt. Accurate - the information gathered could potentially show that the solution is not working. Must list specific tests used to gather the info and these tests must be able to show if the solution is working. Don't need to mention what to look for in test, though.
½ pt. Info is collected at regular intervals. "keep checking" or "keep watching" = regular intervals
½ pt. Info is collected from all necessary locations so that plan can show the problem was solved completely. Must have multiple locations.

**g. What standards or criteria will you use to determine whether this solution is successful?**
1 pt total
½ pt if criteria are useful – specific enough to definitively expose solutions that are not working (improvement, reaches specs)
1/2 pt if criteria address the time and money constraints mentioned in the case (clean up oil fast before harms fishery, environment or fish and environment not harmed)

**h. What you will do if the solution doesn't work**
1 pt actions suggested revise the solution or develop a new one
try again, back to drawing board, or make new batch = 0
any evidence of multiple solutions =1
get supervisor's input = .5

## Appendix E - Pilot & Field Testing – Form A Test Blueprint

| Biotechnology Content → / Problem-Solving Content ↓ | Safety Case C | Lab skills/methods Memo | Equipment failure Memo | Quality control Case E | Communication Case D, Memo | Ordering supplies Case B | Documentation Case F | Customer service Case A |
|---|---|---|---|---|---|---|---|---|
| *1. recognizes that a problem exists* | | | | | | | | |
| 1a. identifies the problem | | 9a | 9a | 3a 3b | 9a | | | |
| 1b. examines the context of the problem | | | | | | | | |
| *2. identifies possible reasons for the discrepancy* | | | | | | | | |
| 2a. identifies and gathers pertinent information | | 9b | 9b | | 9b | | | 7 |
| 2b. identifies possible causes of the problem | | 9c | 9c | | 9c | | | 6 |
| *3. devises and implements a plan of action to resolve it* | | | | | | | | |
| 3a. identifies and evaluates problem constraints | | | | | | | | |
| 3b. develops criteria for satisfactory solutions (including social and economic feasibility) | | | | | | | | |
| 3c. generates possible solutions | | 9d | 9d | | 9d | 1 | | |
| 3d. selects a solution by evaluating alternatives against criteria | | 9e | 9e | | 9e | 2a 2b | | |
| 3e. implements solution | | | | | | | | |
| *4. monitors and evaluates progress* | | | | | | | | |
| 4a. gathers data systematically during implementation | 5a | 9f | 9f | | 9f | | | |
| 4b. applies evaluation criteria to implemented solution | 5b | 9g | 9g | | 9g | | | |
| 4c. identifies positive and negative consequences associated with the solution | 4a 4b | | | | | | | |
| *5. revises the plan as indicated by findings* | | | | | | | | |
| 5a. refines solution to resolve deficiencies, if possible | | 9h | 9h | | 9h | | 8 | |
| 5b. seeks alternative solutions if goals are not achieved | | 9h | 9h | | 9h | | 8 | |

## Appendix F - Pilot & Field Testing – Form B Test Blueprint

| **Biotechnology content →**<br><br>**Problem-Solving content ↓** | Safety Case D | Lab skills/methods Memo | Equipment failure Memo | Quality control Case A | Communication Case C, Memo | Ordering supplies Case B | Documentation Case F | Customer service Case E |
|---|---|---|---|---|---|---|---|---|
| *1. recognizes that a problem exists* | | | | | | | | |
| 1a. identifies the problem | | 9a | 9a | | 9a | | | 3a 3b |
| 1b. examines the context of the problem | | | | | | | | |
| *2. identifies possible reasons for the discrepancy* | | | | | | | | |
| 2a. identifies and gathers pertinent information | | 9b | 9b | 7 | 9b | | | |
| 2b. identifies possible causes of the problem | | 9c | 9c | 6 | 9c | | | |
| *3. devises and implements a plan of action to resolve it* | | | | | | | | |
| 3a. identifies and evaluates problem constraints | | | | | | | | |
| 3b. develops criteria for satisfactory solutions (including social and economic feasibility) | | | | | | | | |
| 3c. generates possible solutions | | 9d | 9d | | 9d | 1 | | |
| 3d. selects a solution by evaluating alternatives against criteria | | 9e | 9e | | 9e | 2a 2b | | |
| 3e. implements solution | | | | | | | | |
| *4. monitors and evaluates progress* | | | | | | | | |
| 4a. gathers data systematically during implementation | 5a | 9f | 9f | | 9f | | | |
| 4b. applies evaluation criteria to implemented solution | 5b | 9g | 9g | | 9g | | | |
| 4c. identifies positive and negative consequences associated with the solution | 4a<br>4b | | | | | | | |
| *5. revises the plan as indicated by findings* | | | | | | | | |
| 5a. refines solution to resolve deficiencies, if possible | | 9h | 9h | | 9h | | 8 | |
| 5b. seeks alternative solutions if goals are not achieved | | 9h | 9h | | 9h | | 8 | |