Biotechnology Education:
A Multiple Instructional Strategies Approach

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The creation of an environment in which students are best able to learn is of primary concern for any teacher. Regardless of content, good instructors desire to meet the educational needs of their students. While increased understanding and comprehension is always desired, teachers presented with new curriculua or content areas are faced with the challenge of delivering and learning the new material, as well as teaching in the most effective manner. Teachers do not often have the time to consider and reflect on the appropriateness of a new curriculum, its content and structure, or instructional strategies for delivery. A call for the inclusion of biotechnology in technology education curricula (ITEA, 2000) raised these challenges for many technology education instructors. Questions about why and how to integrate biotechnology into existing programs will become more prominent in the near future: *Why should biotechnology be included in technology education? What is biotechnology? How is the study of biotechnology structured?* and *What are some appropriate strategies for teaching biotechnology?* This paper will provide a brief rationale for the inclusion of biotechnology in technology education, a definition of biotechnology, a structure of the content area, and an overview of pertinent learning theory. Most of the discussion focuses on an approach to biotechnology instruction that employs elements of the teaching and learning principles found in behavioral, cognitive, and constructivist theories.

Biotechnology: Rationale for Inclusion

Few fields in the modern world have advances as rapid as those that have taken place in biotechnology. Since determining the structure of DNA in the mid-1950s advances in cellular biology, medicine, genetic engineering, and bioprocessing have emerged so quickly and on such a large scale that educators have been hard-pressed to keep up with new developments. From an educational standpoint, *Project 2061* of the *Science for All Americans* initiative (SFAA, 1989) determined a need for reform in science, mathematics, and technology in order to better reflect the rapidly changing world of science and technology. Biotechnology education was specifically identified for inclusion in science,

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mathematics, and technology curricula. Within the field of technology education, biotechnology has slowly emerged as a legitimate area of study.

Savage and Sterry (1991) asserted that biotechnology should be included as a content organizer in the technology education framework alongside communication, production, and transportation. Five years later, the *Technology for All Americans* project (ITEA, 1996) included biological systems as part of its structure for the study of technology. Currently, biotechnology is included among the standards for technological literacy in the United States and abroad (ITEA, 2000; NZME, 1995).

Biotechnology: Definition and Structure

Without an accepted definition of biotechnology, it is difficult to distinguish what is and what is not biotechnology, and any attempt to develop biotechnology curricula would be confounded by a lack of sufficient guidelines (Wells, 1995). The Office of Technology Assessment (OTA, 1988, 1991) defined biotechnology as *any technique that uses living organisms (or parts of organisms) to make or modify products, to improve plants or animals, or to develop microorganisms for specific purposes.* Other federal agencies, such as the Federal Coordinating Council for Science, Engineering, and Technology (FCCSET, 1992, 1993) and the Biotechnology Research Subcommittee (BRS, 1995) adopted this definition in an effort to address audiences ranging across government, industry, and academia. The *Technology for All Americans* project (ITEA, 1996) employed this definition of biotechnology as well in its *Rationale and Structure for the Study of Technology.* By accepting a common definition, disparate communities can enter the "collaborative venture that is biotechnology research and development" (BRS, 1995, p.3).

From a technology education standpoint it is equally important that an agreed upon definition be established. "Without the profession's adoption of [an] established definition there will continue to be misconceptions surrounding [biotechnology] and persistent difficulty with its inclusion into technology education programs" (Wells, 1995, p.12). As a result ITEA (2000), in its *Standards for Technological Literacy*, followed OTA (1988, 1991) and FCCSET (1992, 1993) in defining biotechnology. This definition, being widely accepted across government, industry, academic institutions, and within technology education itself, serves as an appropriate foundation for biotechnology education.

With a clear definition established, biotechnology's "position within the technology education curriculum is more evident, and instructors will find points of inclusion they recognize and can incorporate" (Wells, 1995, p.12). Though having accepted a definition, the profession continues to work toward formulating an overall structure that outlines the content of biotechnology. While there have been a few efforts to determine appropriate content organizers for biotechnology (Brown, Kemp, & Hall, 1998; Savage & Sterry, 1991), arguably the most inclusive are the eight Knowledge Areas (Wells, 1994)—foundations of biotechnology, environment, agriculture, bioprocessing, genetic engineering, biochemistry, medicine, and bioethics—established in the taxonometric structure for biotechnology. Subdivisions within the eight Knowledge Areas further specify the content dimensions (see Figure 1). The *Technology Education Biotechnology Curriculum* (Wells, White, & Dunham, 2000) is based on this taxonomy, and the biotechnology activities presented in this paper are part of that curriculum.

Foundations of Biotechnology	Genetic Engineering
Defining Biotechnology	Probing Techniques
Historical Background	Genetic Engineering Applications
Relevant Terms	Genetic Code
Career Information	Molecular Biology Techniques
Social Impacts of Biotechnology	Analysis of DNA
Environment	**Biochemistry**
Bioremediation	Enzymology
Biological Controls	Control and Regulation
Biotreatment Systems	Proteins
Biorestoration	Methods of Analysis
Environmental Safety	Carbohydrates
Agriculture	**Medicine**
Tissue Culturing	Molecular Medicine
Plant and Animal Applications	Immunology
Agrichemicals	Genetic Therapeutics
Aquaculture	Health Care Technologies
Food Science	Social Impact of Medicine
Bioprocessing	**Bioethics**
Fermentation	Principles of Ethics
Bioproducts	Impacts of Using Biotechnology
Microbial Applications	Potentials of Gene Therapy
Separation and Purification Techniques	Patenting of Life
Processing Design: Monitoring and Growth	Forensics

Figure 1. Taxonomy for biotechnology education (Wells, 1994)

Learning Theory in Technology Education

Technology education, like all disciplines, has ebbed and flowed with the changing tides of learning theory. And as is often the case, residue from the previous tide remains behind, mixing with new methods of teaching. Three influences in technology education have been the behavioral, cognitive, and constructivist philosophies. While all of them generate some criticism and praise from academics and researchers, it is apparent that technology education has been shaped by all three and retains characteristics of each one.

Behaviorism.

Behaviorism has deep-rooted connections with technology education's approach to instruction. In general, within the United States, teachers are the locus of control in the classroom. Not only are instructors central to classroom activity, they out-talk students by a ratio of three-to-one, with a vast majority of the instruction originating from the teacher (Goodlad, 1993). Historically this instructional approach has been similar within technology education. Petrina (1993, 1994) argued that the popular modular approaches to technology education are behavioral in nature. While these methods promote stability and certainty with respect to outcomes, "there is little discussion and few opportunities for students to contribute their own feelings, ideas, or concerns during the course of instruction" (DeMiranda & Folkestad, 2000, p.2). In addition, behavioral philosophy asserts the acquisition of competencies, and standards of performance serve as a measure of learning (Spurgeon & Moore, 1997). Technology education, with the advent of the *Standards for Technological Literacy* (ITEA, 2000), has adopted this philosophy as well.

Cognition

Cognitive learning theory also has close connections with technology education. While Lewis, Petrina, and Hill (1998) pointed out that problem-solving is a "process or 'cognitive' skill" (p.3), both Savage and Sterry (1990) and Pucel (1992) argued that it is a central aspect of technology education. This suggests that a cognitive approach to learning, as manifested in the problem-solving tradition of technology education, is a core value of educational theory in technology education (Lewis, Petrina, and Hill, 1998).

Constructivism

Constructivist theory frames learning as an active and continuous process whereby the learner takes information from the environment, especially social contexts, and constructs personal interpretations and assigns meaning based on prior knowledge and experience (Glasersfeld, 1995). Learning takes place as students discuss and share problems and solutions in meaningful contexts, through collaboration, by developing unique solutions and participating in thoughtful reflection (Jonassen, 1994). Many suggest that these strategies are appropriate for technology education, although underemployed (DeMiranda & Folkestad, 2000; Minstrell, 1984; Pea and Gomez, 1993).

This brief overview presented on learning theory in technology education indicates the degree to which their influence has, and continues to shape the teaching strategies of technology educators. Arguably, for the technology education content and typical instructional environments, a teaching approach that incorporates a blend of elements from these theories will be most successful in promoting knowledge acquisition. Biotechnology, like the other content areas of technology education, is naturally interdisciplinary and lends itself to a blended approach of behavioral, cognitive, and constructivist principles in the design of instruction. It was from this premise that the *Technology Education*

Biotechnology Curriculum (TEBC), including the two activities selected for discussion in this paper, was developed.

Biotechnology: A Multiple Instructional Strategies Approach

Important to the delivery of biotechnology content is a pedagogical foundation built on solid learning and instructional theory. Biotechnology content, as part of the technology education curriculum, can be delivered employing teaching strategies common across technology education content areas that utilize instructional approaches based on behavioral, cognitive, and constructivist philosophy (ITEA, 2000). The remainder of this paper looks at two biotechnology activities from the TEBC (Wells, et al., 2000), and discusses the blend of learning theory that supports the delivery of biotechnology content in the technology education classroom. The first example, taken from the Agriculture Knowledge Area, examines the use of photobioreactors in the production of alternative, non-chemical fertilizers. The second activity, taken from the Bioethics Knowledge Area, probes bioethical issues surrounding the use of the growth hormone *bovine somatotropin* (BST) in milk production. The delivery of these two activities can be shown to rest on solid pedagogical footing by recognizing the behavioral, cognitive and constructivist principles purposefully designed into the teaching and learning strategies.

Behavioral Elements

Students rely on teachers for information at the beginning of any learning activity. From a behavioral perspective, teachers manipulate and orient the learning environment depending on the desired outcome (Skinner, 1971). A teacher directs student learning by establishing classroom conditions: the context of the activity, the student task, the expected outcomes, and the resources and information available to the student.

Setting the Context. Typically, it is the teacher who sets the context for an instructional activity. Depending on the circumstances, teachers determine what type of activity will be appropriate in meeting the instructional needs of their students. In setting the context for the photobioreactor activity, teachers alert students to the commercial use of photobioreactors for growing algae and other green pigmented cell lines. Part of this context is also the awareness that algae are useful as an alternative to chemical fertilizers, and preferable because of their low impact on the environment. In the bioethics activity the teacher sets the context by informing students that BST is a growth hormone used in the dairy industry to increase milk productivity in cows. This is a bioethical concern because the use of hormones raises issues of public safety (Wells, et al., 2000).

From a behavioral standpoint, the context for both activities is directed and established by the teacher, who is free to vary that context in accordance with local issues or conditions. For example, teachers may adopt a local perspective where photobioreactors are used in food production, or they may choose to capitalize on a situation where growth hormones are used by a local industry to increase livestock production. In any case, it is the teacher that sets the context and provides for the student the setting in which learning is to take place.

Stating the Challenge. It is within the teacher-set context that the student activity will occur. In the photobioreactor activity the student is given the task of designing and building a photobioreactor that grows algae for use as an alternative fertilizer on food crops. Although algae are used in a variety of ways, this challenge directs the student to use it as an environmentally-friendly fertilizer (see Appendix A). The exact outcome of the activity will vary from teacher to teacher: one could require a model, prototype, or simply a drawing of the photobioreactor system as a demonstration of acquired knowledge. Similarly, the bioethics activity requires that students participate in a mock courtroom setting where they debate the use of BST in the milk industry (see Appendix B). Again, outcomes will vary: a courtroom debate with members of the class taking sides, or a poster display that highlights arguments from both sides of the issue. By presenting a challenge or problem to be solved, the instructor dictates the tasks to be performed by the class and the ways in which that challenge is to be fulfilled.

Establishing Evaluation. The evaluation element in these biotechnology activities also serves to direct student learning. A set of evaluation questions, given in conjunction with the context and challenge, alerts students of teacher expectations and assists in the initiation of the activity. These questions direct students toward research information needed to complete the problem, purposefully guiding them toward an understanding of the biotechnology processes involved. In these biotechnology activities students are asked to learn about both the biological process and its technological application. The evaluation questions, therefore, ask students about the type of organism (or part of an organism) that is used, as well as its life and growth requirements. In the photobioreactor activity, students are asked questions related to how the system grows algae and distributes it directly to the field: How does the system work? What other photobioreactor techniques are possible? and How does the system meet the life and growth requirements of the algae? (see Appendix C). The BST evaluation questions guide the class in determining the biological and technological information necessary to defend a position regarding such questions as: What organisms (or parts of organisms) are involved in BST biotechnology? How are these organisms used to increase milk production? and What are the advantages and disadvantages of BST use? (see Appendix B).

Providing Information. In providing specific information about the biological and technological processes, the teacher establishes a more exact context for the class and the biotechnology activity. The photobioreactor activity explores the use of algae as an alternative fertilizer. Students can be told that they will be using Spirulina, an algae that grows rapidly and has a high concentration of nutrients. Like all organisms Spirulina grows best when certain conditions such as light, nutrients, pH, and CO_2, are optimized. A photobioreactor maximizes these conditions through its design: the use of clear plastic tubing for efficient and volumetric distribution of light; efficient delivery of light from the source to the algae; air lift pumps to keep the algae in suspension; mechanism for CO_2 and O_2 exchange; pH and growth sensors.

By setting the context and challenge, providing targeted evaluation questions, and offering pertinent information to direct the student towards a desired outcome (a biotechnical solution), the instructor is employing behavioral instructional strategies. However, instead of providing *all* the information, students can also research and discover this information independently. From a cognitive perspective it is not always necessary, or even desirable, that the teacher serve as the sole source of knowledge for the student. Biotechnology activities, given the interdisciplinary nature of the topic, provide a rich setting for student engagement in problem solving, investigation, and discovery—a hallmark of the cognitive orientation (Bruner, 1965). As students research and discover on their own the information needed to solve the biotechnology challenge, they move from a directed behavioral context to one of cognitive structuring.

Cognitive Elements

Once placed within a context and given adequate direction, the locus of learning in these biotechnology activities shifts to the student. Cognitive theory recognizes that "the human mind is not simply a passive exchange-terminal system where stimuli arrive and the appropriate responses leave. Rather, the thinking person interprets sensations and gives meaning to the events that impinge upon his [or her] consciousness" (Grippin & Peters, 1984, p.70). Given a context, a problem, and appropriate background information, the learner is freed to arrange these ingredients in various ways until a solution is found (Hergenhahn, 1988). Bruner (1965) emphasized that learning occurs through this type of discovery. Encouraged to explore, students rearrange and transform evidence in such a way that new insights are gained. The internal cognitive structure of the student is changed as a result of interacting with the environment and being exposed to an increasing number of experiences (Piaget, 1966). As students investigate, gather, and reassemble information, learning takes place. "Learning involves the [cognitive] reorganization of experiences in order to make sense of stimuli from the environment" (Merriam & Caffarella, 1999, p.254). After the teacher has set the parameters for the biotechnology activities, the focus shifts to the student who must then begin to reorganize, investigate, and solve the problem. Carefully designed introductory activities and problem-solving methodologies were two instructional strategies used in the biotechnology activities to set the cognitive stage from which a photobioreactor or bioethics solution might be conceived.

Introductory Activities. During the presentation of new biotechnology concepts, a teacher may use introductory activities to frame *advanced organizers*, which prepare students for future learning (Ausubel, 1968). By examining photobioreactors already in use students are provided a basic understanding of what photobioreactors are and their various applications. This exposure creates a new awareness from which students are able to draw on as they complete their own challenge. Two good examples of photobioreactors in use can be found on the Internet. The BioCoil Project (Cascade High School, 1995) uses algae grown in a photobioreactor to clean community wastewater. The BioFence (Biosynthesis, 2000) photobioreactor grows algae as a food supplement. A virtual tour of these two websites can provide the class with an understanding of how photobioreactors work, how they are designed, and what they produce, while concurrently presenting them with an advanced cognitive framework.

Figure 2. BioCoil BioFence. The BioCoil is a photobioreactor used to clean wastewater. The BioFence grows algae as a good supplement.

In debating the use of BST, students will engage in ethical decision-making processes. Introductory activities about how to make an ethical decision can equip a class with a cognitive structure within which the bioethical debate over BST can be understood. The following introductory activity investigates the ways in which one’s perspective of an issue may affect individual opinions or decisions:

1. Place an irregularly shaped box in the center of the room. The sides of the box should be covered in varied shapes of different color and size.
2. Ask students to describe the box from their point of view. *Do they agree with the description of the box given by others in the class? Why or why not? What are the factors that affect how one describes the box?* (Wells, et al, 2000).

This activity develops the idea that opinions, including bioethical opinions, depend upon one's perspective or point of view. To further develop this idea, a follow-on activity may explore the "ethical" issue of breakfast. The teacher assigns a "value" to student groups: taste, time, expense. The student groups must then choose what they will have for breakfast based on their assigned value. These two introductory activities promote a decision-making process that emphasizes points of view and/or personal values, while also offering a framework from which the BST bioethical issue can be discussed and explored. As students research and develop arguments for or against the use of BST they will have in place a cognitive structure that helps them to think about the BST issue from an ethical perspective.

Problem-solving Methodology. A problem-solving methodology is a second cognitive element that can be employed in biotechnology education. Familiar to most in technology education, problem-solving often consists of four phases: design, production, evaluation, and presentation. A hallmark of the cognitive learning orientation, the problem-solving methodology focuses on the internal mental processes of the student (Merriam & Caffarella, 1999). Knowles (1984) claims that the problem-solving approach emphasizes the discovery approach of Bruner (1965) by involving three almost simultaneous processes:

(1) acquisition of new information;
(2) transformation, or the process of manipulating knowledge to make it fit new tasks; and
(3) evaluation, or checking whether the way we have manipulated information is adequate to the task. (Knowles, 1984, p.25)

To complete the photobioreactor challenge students must acquire new information, transform that information into a solution, and then evaluate the appropriateness of their system in addressing the specific details of the problem. In the design phase, students gather the following information: *What are the components of a photobioreactor system? For whom is the system being designed? Where is the system to be located? What types of photobioreactors are possible?* This information is transformed into multiple design ideas and checked for adequacy with respect to the challenge. In the production phase, students gather materials and transform them, according to the design, into a new, unique photobioreactor. The presentation requires that students check the adequacy of their biotechnology solution by revisiting the steps they followed and the evaluation questions given at the outset of the activity.

The BST activity, while addressing a different type of biotechnology problem, can nonetheless employ the problem-solving process. Teams gather information that illuminates the issue: *What are the impacts of BST on food safety? What are the economic impacts of BST? How does the use of BST affect large or small farms?* This information is transformed into an argument for or against the use of BST in milk production. Displays, props, and opening and closing arguments are constructed for use in the courtroom scenario. Each group evaluates the effectiveness and adequacy of their arguments in support of their position before participating in the debate.

The cognitive orientation to learning holds that both advance organizers and internal mental processes, such as problem-solving, are important agents of learning (Ausubel, 1967; Bruner, 1965). While the introductory activities and problem-solving methodology provide a means to acquire, transform, and evaluate new knowledge, students will themselves construct new knowledge as they investigate biotechnology. As the class completes these biotechnology activities they will make sense of their experience through their interaction with others in this context.

Constructivist Elements

During the process of completing the photobioreactor and BST activities, students generate many products. These products can be a physical artifact, an accumulation of knowledge, or a new understanding of the world in which they live. Constructivism holds that a key feature of learning is *constructed meaning*, where one's cognitive structures are adapted to the physical environment; "it is how people make sense of their experience" (Merriam & Caffarella, 1999, p.261). Social constructivists maintain that learning occurs "when individuals engage socially in talk and in activity about shared problems or tasks" (Driver, Asoko, Leach, Mortimer, & Scott, 1994, p.7). Learning takes place as students discuss and share problems and solutions. Several instructional strategies associated with a constructivist learning environment—meaningful contexts, collaboration, unique solutions, and thoughtful reflection (Jonassen, 1994)—can be incorporated into the photobioreactor and BST activities.

Meaningful Contexts. A major characteristic of the constructivist learning environment is the presence of authentic tasks set within a meaningful environment (Jonassen, 1994). The photobioreactor and BST activities are authentic for several reasons. First, they are part of the real world in which students live, and present issues that have significant impact on socio-cultural structures. Second, students are exposed to, and interact with, fertilizers and hormones every day by way of the food they eat and the environments in which they live. Third, students are likely to have had personal experiences related to the issues addressed in these activities: fertilizing their lawns and drinking milk. Because these activities are authentic and occur as part of the students' real world, the learning context they create promotes individual meaning and positively affects student engagement and learning.

Collaboration. As a part of a team, students interact, discuss, investigate, and create unique solutions to the biotechnology problem. The photobioreactor and BST activities encourage multiple points of view and an environment where unique learning experiences can occur. Teams are expected to discuss, negotiate, and collaborate as they build a novel photobioreactor that meets the specific needs of their scenario. Similarly, students work together to build an argument for or against the use of BST. The role of the teacher in these instructional environments is not to dictate solutions or answers, but rather to participate in the discussion by facilitating and negotiating the new meanings and knowledge being constructed by the student teams. It is the social interaction and negotiation, as opposed to ‘correct’ answers, that generate meaning and foster learning in the constructivist environment (Jonassen, 1994; Driver et al, 1994). Students design and construct unique solutions together while the instructor stimulates and encourages the class to look for solutions that have meaning for them.

As mentioned, such collaboration in the biotechnology activity takes place within the context of a team. Students research, design, construct, and evaluate either a photobioreactor or BST argument as a group. Each member is assigned a role with team responsibilities that contribute to the final solution: the *research analyst* leads the data-gathering portion of the activity; the *design manager* facilitates the discussion surrounding the development of a solution; the *materials specialist* initiates the construction of the prototype and presentation materials; *quality control* guides the group’s analysis of their solution and its adequacy to the challenge (Wells, et al., 2000).

Unique Solutions. Knowledge construction, rather than knowledge reproduction, is another characteristic of the constructivist classroom (Jonassen, 1994). This learning strategy is well suited for biotechnology in that these activities encourage unique solutions to each challenge. In the photobioreactor activity two teams may take different approaches to the same problem: one could decide to use a coil array, while the second might choose the ‘fence’ arrangement in which to grow algae (see Figure 2). Teams addressing the BST problem could choose from any number of perspectives from which to present their case: economic, social, ethical, or medical, depending on their own experience and understanding of the problem. While each solution addresses a single problem, they allow for the experiences, interpretation, and knowledge of each member of the group. Originality in problem-solving demonstrates that students have internalized key concepts, while the multiple representations of reality generated by these activities avoid oversimplification and represent the true complexity of the world.

Thoughtful Reflection. As teams work toward completion of the photobioreactor or BST activity, they continually engage in a process of evaluation by reflecting on the solution at various times during the problem-solving process — formative evaluation. Thoughtful reflection on experience is an important component of the constructivist learning environment (Jonassen, 1994). Formal presentation is the preferred assessment tool for the biotechnology activities because it affords teams the opportunity to reflect on the context, challenge, biotechnology processes, and final solution. As the presentation is assembled, each team is given the opportunity to revisit the context, challenge, design, and construction processes in order to assess the adequacy of their solution in addressing the challenge. Ultimately, final presentations exemplify the students’ acquisition of knowledge resulting from the learning experience.

Conclusions

The teaching of biotechnology in the technology education classroom can be accomplished using a variety of instructional strategies that effectively deliver content and engage students in real world problems. Biotechnology activities such as the two presented in this paper demonstrate a blend of behavioral, cognitive, and constructivist learning theories. A teacher directs student learning by establishing classroom conditions: the context of the activity, the student task, the expected outcomes, and the resources and information available to the student. Introductory activities and a problem-solving methodology are two instructional strategies that shape the cognitive structure in which a photobioreactor or bioethics solution can be generated. The photobioreactor and BST activities both utilize instructional strategies that promote constructivist learning environments—meaningful contexts, collaboration, unique solutions, and thoughtful reflection. This combined behavioral, cognitive, and constructivist approach to teaching biotechnology provides a structure and strategy that reflect the instructional philosophy and traditional approach to content within the technology education profession.

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Appendix A

Photobioreactor Activity Context and Challenge (Wells, et al., 2000b)

Plant & Animal Applications

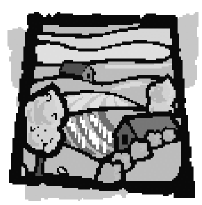
ProbScen 3D

Handout 1

AGRICULTURE

Spirulina Photobioreactor

Context:
Algae are organisms ranging in size from those that are microscopic up to the large seaweeds. Many uses have been found for these organisms. For example, large brown seaweeds are being used to extract alginates, which can be made into varnishes and gelatins. Micro-algae have been recognized for uses ranging from animal, plant, and human foods, to antibiotics, vitamins, and food colorings. Using micro-algae as a food source for humans, animals, and plants has taken on greater importance in recent years. The nutrients and environmental conditions needed for algae to grow are very simple, which makes it appealing as a food crop for people in developing countries. It also appeals to US farmers as a good alternative to chemical fertilizers. A photobioreactor is an easily constructed technology used in growing and harvesting micro-algae. *Spirulina*, a freshwater spiral-form algae, is easily grown in plastic tubing under warm, sunny conditions.



Challenge:
Because of your knowledge of photobioreactors, you have been hired by a local farmer to design a system to grow and harvest *Spirulina* for use as a fertilizer. Your system must use clear plastic tubing for the growth chamber, an air lift pump mechanism for circulating the algae without injuring them, and a method that will determine the best time to harvest the algae crop. The farmer also wants the system to be an energy efficient system that will deliver the bio-fertilizer directly to the field!

Objectives:
1 Demonstrate the production and application of environmentally safe algal fertilizers.
2 Apply technology, science and mathematics to the task of designing and constructing the photobioreactor system.
3 Use basic tools and materials to make a prototype of the system.
4 Communicate project results to others using a design portfolio.

Appendix B

Bovine Somatotropin Activity Context, Challenge and Evaluation Questions
(Wells, et al., 2000b)

Impacts of Using Biotechnology

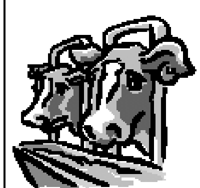
ProbScen 8B

Handout 1

Bioethics

***Bovine Somatotropin* (BST)**

Context:
Congratulations! You have been elected as a representative to the United States Congress. A new bill has been introduced into legislation that will require your immediate attention. The Department of Agriculture, after a short preliminary investigation, wants to ban the use of bovine somatotropin (BST), the growth hormone that increases the production of milk in cows. Presently there is a bill on the floor which will over-ride such a decision. More specifically, the bill states that banning the use of BST is unconstitutional.



Challenge:
Your challenge is to participate in the floor debate as to whether the use of BST should be allowed or banned. Your position should be based on the good of the people you represent. Therefore, depending on your home state, your position may be pro or con.

Objectives:
1 Develop research skills.
2 Use technological assessment to evaluate the use of BST.
3 Develop effective presentation techniques.

Materials:
Computer with graphic software.

References:
Media resource center, and the Internet.

Evaluation:
1 Did you identify the latest research relating to BST?
2 Did you represent the people from your state properly?
3 Was your presentation clear and understandable?

Appendix C

Photobioreactor Activity Evaluation Questions (Wells, et al., 2000b)

Plant & Animal Applications

ProbScen 3D

Handout 2

AGRICULTURE

Materials:
Prototyping materials, standard biological and technological laboratory tools, presentation materials.

Evaluation:

1 State the real-life problem being addressed by the ProbScen.
2 What organisms (or parts of an organism) were used in your solution?
3 Why did you select this particular organism (or parts of an organism) for use in your solution?
4 What are the life or growth requirements of the organism you are using in your solution?
5 What photobioreactor techniques are possible?
6 Which photobioreactor technique did you choose and why?
7 Describe the technological solution you chose to design.
8 Detail the characteristics of your technological system - the parts and how they work.
9 How does your system provide the life or growth requirements needed by the organisms you chose?
10 What mechanisms (sensors and gauges) are used to monitor your system?
11 Explain why the system you designed was the best solution to the problem.
12 Did you identify appropriate photobioreactor designs that will produce an algal fertilizer and deliver it directly to the field?
13 Did you determine the necessary nutrients and growing requirements for the type and quantity of algae you selected?
14 Did your design include an efficient mechanism for indicating when the algae is to be harvested?

References:

1 **The Biocoil Project - 1997-98** http://www.cascadehs.csd.k12.id.us/advbio/97-98/biocoil.html
2 **Earthrise Farms** http://www.earthrise.com
3 **Photobioreactor** http://www.tmo.umich.edu/UMTechnologiesEGCOPY/0515.html
4 **Light Force- Article - Spirulina: Food Of The Future** http://www.worldlightcenter.com/litefree/spfoodfu.htm
5 **The Bio-Fence and aquaculture** http://www.biosynthesis.co.uk/
6 **Microalgae Photo bioreactor** http://www.fishace.demon.co.uk/algae.htm
7 **How the AAPS works** http://www.addavita.demon.co.uk/howthe.htm