Creating a Unique Learning Environment at an Interdisciplinary Bioengineering Research Facility

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Attributes of Engineer of 2020

- "Creativity (invention, innovation, thinking outside the box, art) is an indispensable quality for engineering, and given the growing scope of the challenges ahead and the complexity and diversity of the technologies of the 21st century, creativity will grow in importance"
  - *Reported by National Academy of Engineering in the Engineer of 2020*
- Real-world problems rarely fit within a single discipline
  - The preparation of scientists and engineers needs to be better aligned with the interdisciplinary skills for which there will be an increasing demand according to projections
  - *Reported by National Academy of Engineering (2005)*
- Interdisciplinary research is:
  - a mode of research by teams or individuals that integrates information, data, techniques, tools, perspectives, concepts, and/or theories from two or more disciplines or bodies of specialized knowledge to advance fundamental understanding to solve problems whose solutions are beyond the scope of a single discipline or area of research practice
  - *Defined by National Academies Committee on Science, Engineering, and Public Policy (COSEPUP)*

Active, Inquiry-Based, and Collaborative Learning

- A large body of recent research published by the National Research Council in "How People Learn: Brain, Mind, Experience and School," supports engaging students with undergraduate research
- Studies have shown that by actively engaging undergraduate students in research, their retention of scientific principles and learning retention increases
  - *"The results show that many standard instructional practices in undergraduate teaching are relatively ineffective at helping students master and retain the important concepts of their disciplines over the long term. Moreover, these practices do not adequately develop creative thinking, investigative, and collaborative problem-solving skills that employers often seek….students assimilate new knowledge more effectively in courses including active, inquiry-based, and collaborative learning."*

Wood, William B. and Gentile, James M. (2003) Teaching in a Research Context. Science, 302 (5650), 1510.

Rationale

- An enmeshing of disciplines is creating an interdisciplinary environment in the workplace, which has created a need for undergraduates to be exposed to an interdisciplinary educational environment
- Students need to be prepared for a global working environment and characteristics such as creativity, the ability to work on an interdisciplinary team and transfer new knowledge in innovative ways are necessary
- To prepare undergraduates for careers that cross disciplinary boundaries, students need to practice interdisciplinary communication in academic programs that connect students in diverse disciplines
- But how do you teach students creativity and innovation? How do you teach students to work effectively and collaborate in diverse groups to solve interdisciplinary problems that tend to be ill-defined?

Biotechnology Program

- Academic minor in biotechnology developed as an interdisciplinary effort among the College of Technology, the College of Science, and the College of Pharmacy
- Program is administered within the Department of Industrial Technology
- Available to any Purdue University student majoring in any four-year degree baccalaureate degree program
- Develop an inquiry-based biotechnology curriculum that produces students who are able to:
  - Function in interdisciplinary teams to solve ill-defined problems effectively and efficiently
  - Transfer knowledge across disciplinary contexts and
  - Subsequently transfer knowledge to the post-graduate environment where they function in interdisciplinary teams

Teaching Creativity by Integrating Engineering Design and Scientific Inquiry

- Objective of biotechnology program is to
  - Engage undergraduate students from multiple disciplines in authentic research
  - Create a learning environment that encourages creativity and design by integrating knowledge from biology, engineering and technology and applying it to develop new experimental analyses
- Specific objectives
  - Learn basic terms for biotechnology
  - Understand basic concepts for biotechnology
  - Acquire basic research skills
- Accomplish objectives through
  - Hands-on, inquiry-based laboratory experiments
  - Bioinformatics modules
  - Creative writing assignments

ABET *2007-2008 Criteria for Accrediting Engineering Programs*

- A program must demonstrate that graduates have:
  - an understanding of biology and physiology
  - the capability to apply advanced mathematics (including differential equations and statistics), science, and engineering to solve the problems at the interface of engineering and biology
  - the ability to make measurements on and interpret data from living systems, addressing the problems associated with the interaction between living and non-living materials and systems

What are the fundamental objectives of engineering instructional laboratories?

- Sloan Foundation funded a colloquy to assemble a group of experienced engineering educators to determine laboratory objectives for evaluating efficacy of laboratory programs
- Colloquy convened in January 2002 and converged on a list of 13 objectives
  - Feisel, Lyle D. and Rosa, Albert J. The Role of the Laboratory in Undergraduate Engineering Education. Journal of Engineering Education 121-130 (2005)

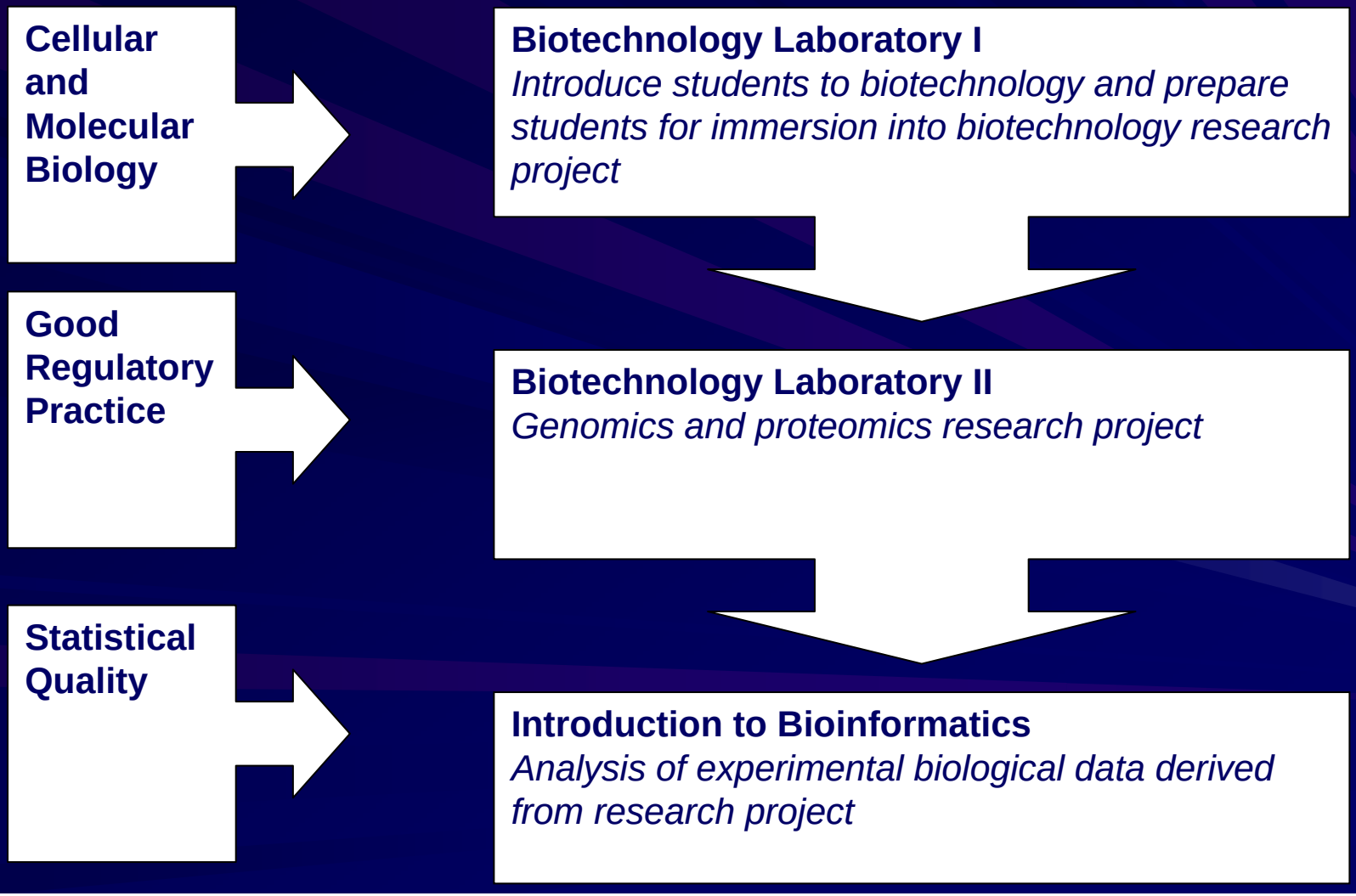
Fundamental Objectives of Engineering Instructional Laboratories

- Instrumentation. *Apply appropriate sensors, instrumentation, and/or software tools to make measurements of physical quantities*
- Data Analysis. *Demonstrate the ability to collect, analyze, and interpret data, and to form and support conclusions. Make order of magnitude judgments and use measurement unit systems and conversions*
- Design. *Design, build, or assemble a part, product, or system, including using specific methodologies, equipment, or materials; meeting client requirements; developing system specifications from requirements; and testing and debugging a prototype, system, or process using appropriate tools to satisfy requirements*
- Creativity. *Demonstrate appropriate levels of independent thought, creativity, and capability in real-world problem solving*
- Psychomotor. *Demonstrate competence in selection, modification, and operation of appropriate engineering tools and resources*
- Safety. *Identify health, safety, and environmental issues related to technological processes and activities, and deal with them responsibly*
- Communication. *Communicate effectively about laboratory work with a specific audience, both orally and in writing, at levels ranging from executive summaries to comprehensive technical reports*

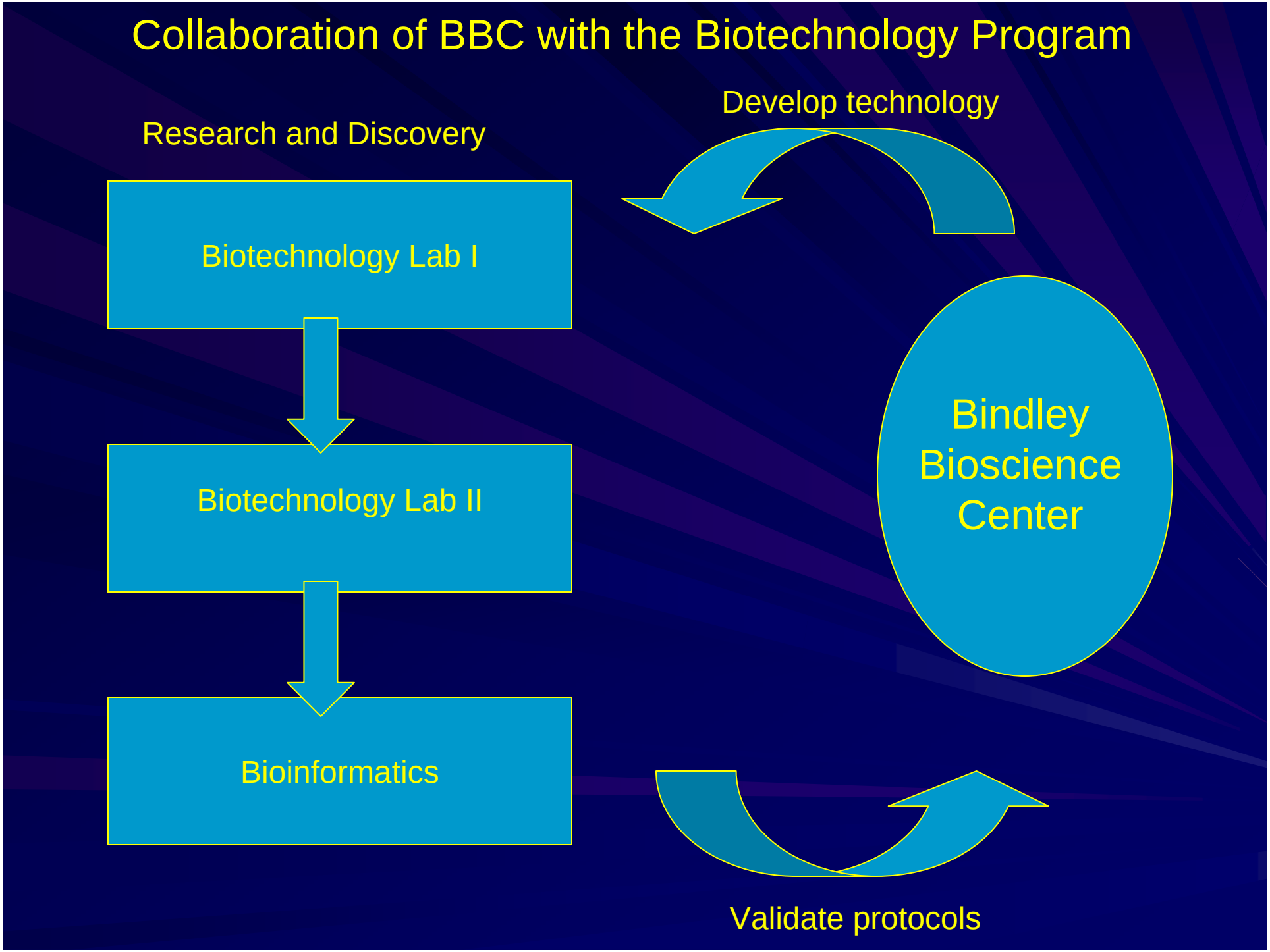
Methods

- A partnership with an interdisciplinary bioengineering research facility, Bindley Bioscience Center within Discovery Park at Purdue University
  - provides the students with hands-on experience on bioengineering research instrumentation
  - exposes them to a research environment as opposed to a traditional teaching lab by providing research laboratory space and expertise for the biotechnology laboratory courses
- The model used to develop the curriculum modules for the biotechnology program was adapted from the NSF-funded Center for Authentic Science Practice in Education (CASPiE)

Integration of BBC Research Activities into the Courses within the Biotechnology Program



Collaboration of BBC with the Biotechnology Program



Research Module

- Students
  - collaborate with BBC to create a novel peptide tag that will allow the manipulation of binding affinities in order to mimic a living system
  - identify interacting proteins and characterize dynamic protein complexes.
- The technology developed is unique from currently available affinity systems as it will be possible to
  - control the stringency of the binding conditions
  - modulate the partners within the molecular complexes and thus identify unique protein-protein interactions

Technology Development

- Guest Lecture from the U.S. Patent Office
  - In collaboration with Burton Morgan Entrepreneurship Center
- Disclosure Form
  - I understand that I will be working on a semester project utilizing technology that is currently under investigation for a patent and I agree not to disclose or discuss information regarding this technology with individuals outside the Biotechnology Laboratory II (IT227) course
  - Signature:Date

Laboratory Safety

- Go to the Howard Hughes Medical Institute Online Laboratory Safety Course at http://www.hhmi.org/about/harvest/labsafe/safescience.html
  - Register as a guest under “Colleagues and Visitors” at the “Knowing How to Practice Safe Science”
  - Print your score as a record of your course participation

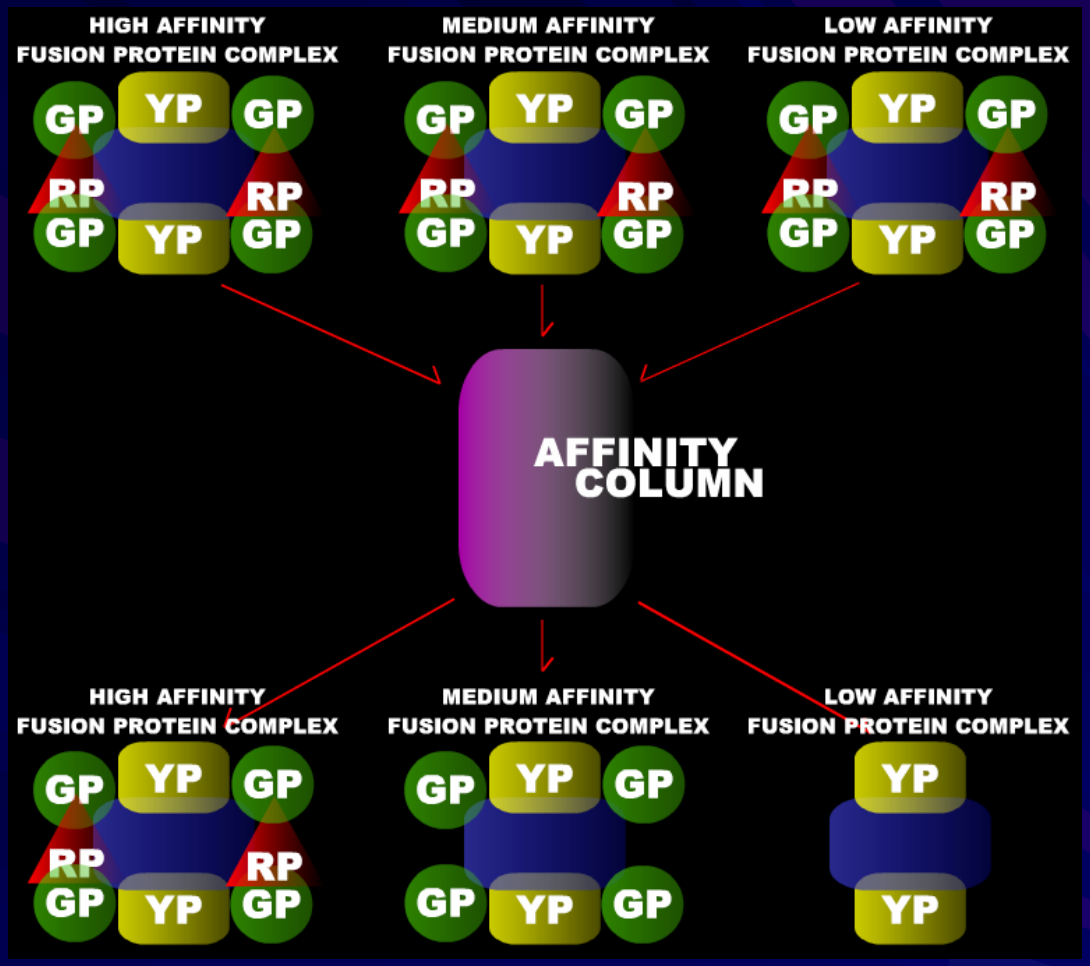
Center for Authentic Science Practice in Education (CASPiE)

- Model that is used to develop the curriculum modules for the biotechnology program is adapted from the NSF-funded CASPiE (PI: Professor Gabriella Weaver)
- CASPiE is an *Undergraduate Research Center* (URC) funded by the Division of Chemistry of the National Science Foundation
- CASPiE was funded to explore innovative ways to involve college freshmen or sophomores in scientific research

CASPiE

- Overall goal is to provide first- and second-year undergraduates with the opportunity to conduct research within their regular laboratory curriculum
- Unique approach uses mainstream courses instead of making research an extracurricular activity for students
  - Program makes the laboratory experience one where research is carried out by the students
  - Laboratory experiments are a component of a larger research project of a scientist
  - The data that the students collect are intended to be used as part of that researcher's work and could, in principle, contribute to publishable work
- Based upon studies examining pedagogies of engagement, this approach should be more effective at engaging students

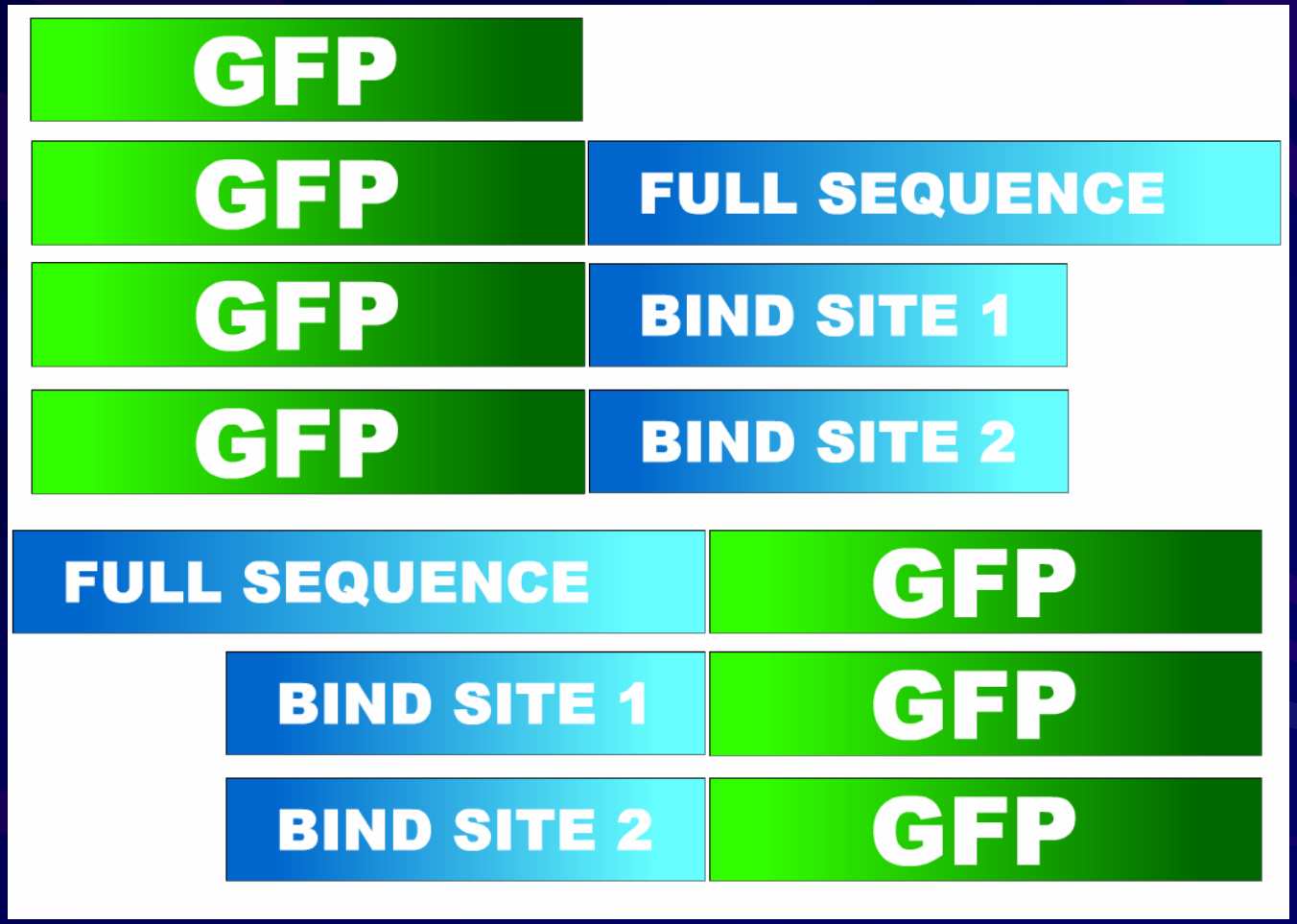
Research Problem: Protein Interactome



Technology will be unique from current affinity systems because it will be possible to control the stringency of the binding conditions and modulate the partners within the molecular complexes. Students will collaborate with an interdisciplinary bioengineering research center to create a novel peptide tag that will allow the manipulation of binding affinities in order to mimic a living

system and characterize dynamic protein complexes

Green Fluorescent Protein Fusion Constructs



Preparation of Fusion Proteins

- Students began to clone the Green Fluorescent protein gene using a set of primers that had been engineered to generate a series of fusion proteins
- Students learned to design the primers and establish appropriate conditions for PCR
- The engineered primers were ordered from Integrated DNA Technologies and arrived in lyophilized form after purification by SDS-PAGE

GFP Structure Tutorial

- Go to the educational resources page at the Protein Data Bank (PDB) website http://www.pdb.org/pdb/static.do?p=education_discussion/educational_resources/index.html
- Download the pdf file “Exploring the Bioinformatics of Green Fluorescent Protein” underneath Activities/Lessons
- Complete the assessment questions throughout the lesson
- What impact will adding fibrinopeptide tags to GFP have on the structure and function of GFP? Your answer should be supported by what you learned about the structure of GFP in the PDB tutorial and the amino acid sequence of the fibrinopeptide tags.

Primer Design

- Go to Invitrogen's website (www.invitrogen.com) and follow the process to download the bioinformatics program Vector NTI highlighted on the Vector NTI user community.
- Import the needed vector molecules into your database
- Use Vector NTI to perform PCR analysis with the vector
  - amplify the GFP sequence from the vector attaching the appropriate sequence for fusions. Add the restriction enzyme sites to the amino terminus and the appropriate restriction enzyme site, along with stop codons to the carboxy terminus.

Peer Led Team Learning Modules

- Keeping a Research Lab Notebook
- Data Collection, Organization and Interpretation
- Ethical Conduct in Science
- Reading a Research Paper
- Experimental Design
- Poster Preparation
- Peer Review
- Writing a Scientific Paper
- Writing an Abstract

Mass Spectrometry Module

- Students were given a mixture of unknown proteins to identify
- Write an abstract based upon the PLTL model

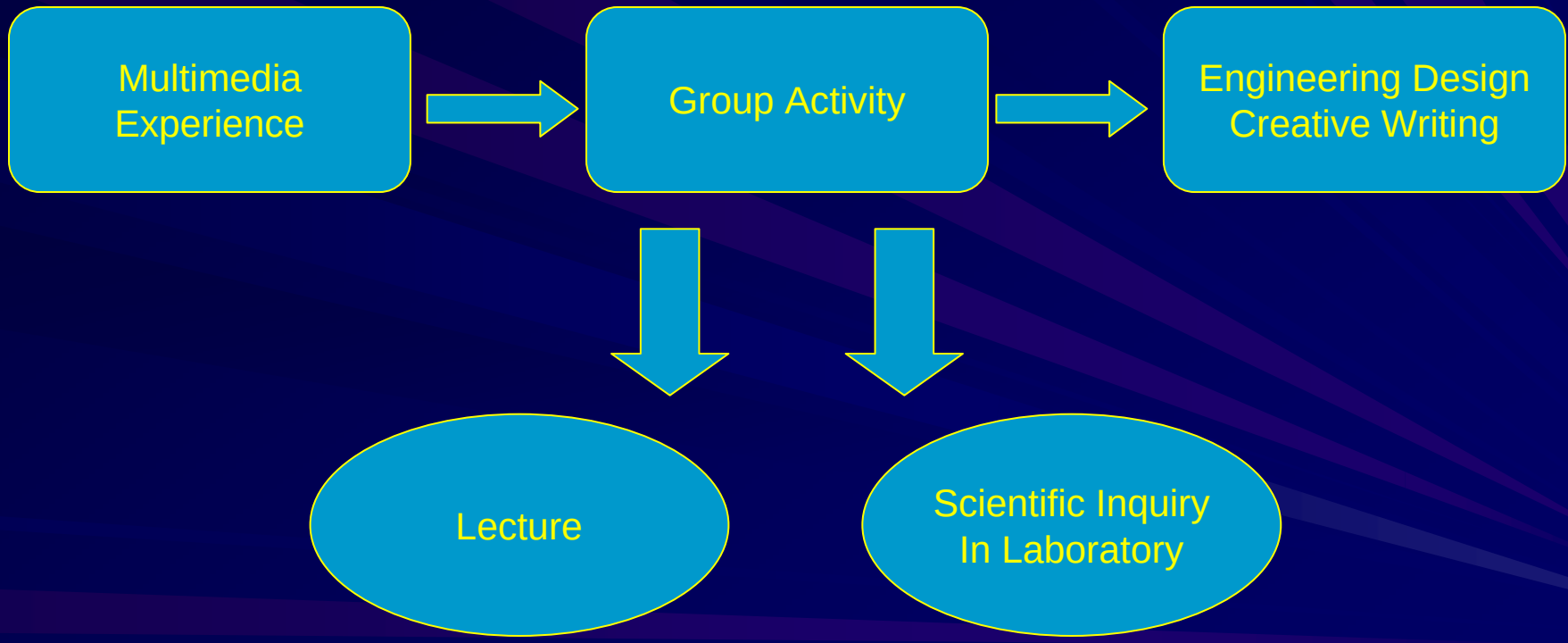
Cell Culture Module

- Students learned aseptic technique, basic maintenance of cells and immunohistochemical staining
- Students developed a poster based on the cell culture module conducted with P19 cells
  - Abstract
  - Materials and Methods (Included the experimental methods for the cells such as: thawing, maintaining, passaging, differentiating, fixing, staining and visualizing)
- Prepared an original poster template

Results and Conclusion

- A CASPiE evaluation “tool kit” is available
  - comprises a set of instruments for CASPiE evaluation and facilitates the data collection process across varied institutions.
  - http://www.purdue.edu/dp/caspie/
- The feedback from the students has been positive and strongly suggests that the learning objectives are being accomplished
- Future work includes adapting the curriculum modules to a graduate level course

Proposed Curriculum Model to Integrate Scientific Inquiry with Engineering Design



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