Increasing Student Knowledge Acquisition and Transfer Through the Use of Heuristics in a Team/Lab-Based Protein Engineering Course

Morgan L. Bocci, Dr. J. Robby Sanders, and Dr. Pedro E. Arce
Department of Chemical Engineering, Tennessee Technological University, Cookeville, Tennessee, United States of America

Introduction, Motivation, and Background

The Renaissance Foundry model incorporates both knowledge acquisition and knowledge transfer paradigms that are integrated through utilization of “resources” towards the development of prototype solutions to problems often required to be identified by student teams [1]. In the protein engineering course reported on herein numerous strategies were pursued for increasing both acquisition and transfer outcomes in the students. Teamwork is a critical aspect of the activities in the course in which student teams of chemical engineering students are guided through the process to produce a modified version of a fluorescent protein. Especially in the constraints of a summer semester, the pace of the course is accelerated necessitating the use of focused, hands-on team-based activities, analogies, and other heuristics (i.e. electrophoresis heuristic) to maximize learning in this fast-paced environment. This effort is greatly enhanced through the expert guidance of TA’s who have taken the course prior. To facilitate knowledge acquisition of the principles of the polymerase chain reaction (PCR) that is used to modify and amplify a DNA base sequence,, teams participate in an activity guided by a visual approach of “binding” primers to template DNA and carrying out the steps in each cycle of PCR as described by Chambers et al. [2] This approach allows students the ability to see and understand what is happening in their reaction mixtures of clear fluid. Analogies are used to familiarize students with aspects of molecular biology.

Class Layout, Preparation, and Management

9 Week Summer Course:
- »2 hours guided lectures with discussions
- »3 hours lab

Student Teams:
- »3 randomly- selected students in each team
  - 2 domestic students and 1 international
  - 1 domestic student and 2 international
  - 3 international students
- » Work through modification of superfolder GFP

Assessments:
- »Lab notebooks and Pre/Post Tests

Skills obtained:
- »Basic techniques in molecular biology
- »Sterile lab methods
- »Polymerase Chain Reaction (PCR)
  - Site-directed mutagenesis
- »Addition of an affinity tag
- »Protein expression and extraction
- »Protein purification

Course Progression

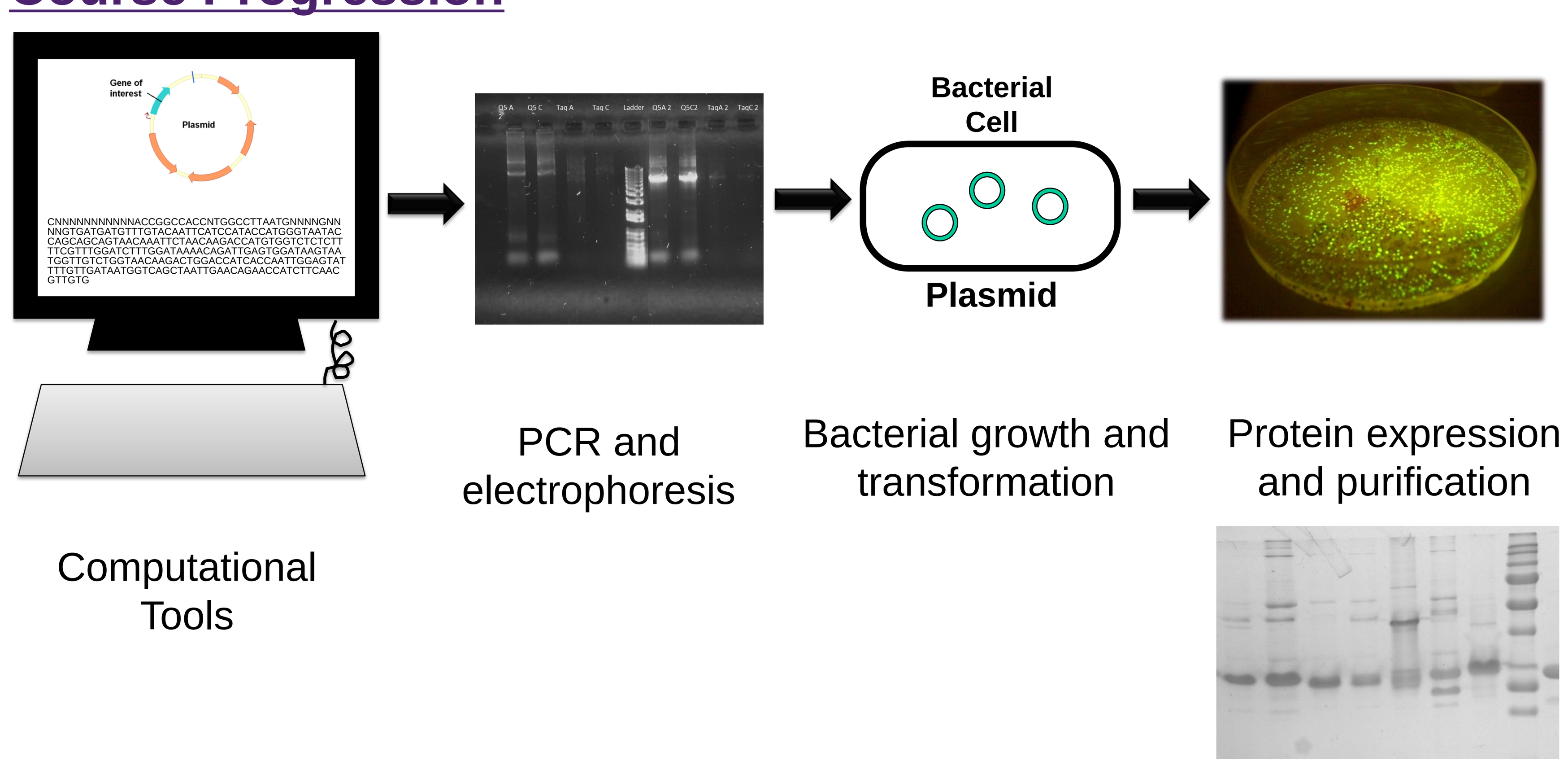


Figure 1. Overview of the basic concepts learned in the class moving from computational modeling of the protein to making mutations via the polymerase chain reaction (PCR), expressing the protein in bacteria, and quantifying and purifying the new protein adapted from previous versions of the class [3].

Renaissance Foundry Model Adaptation

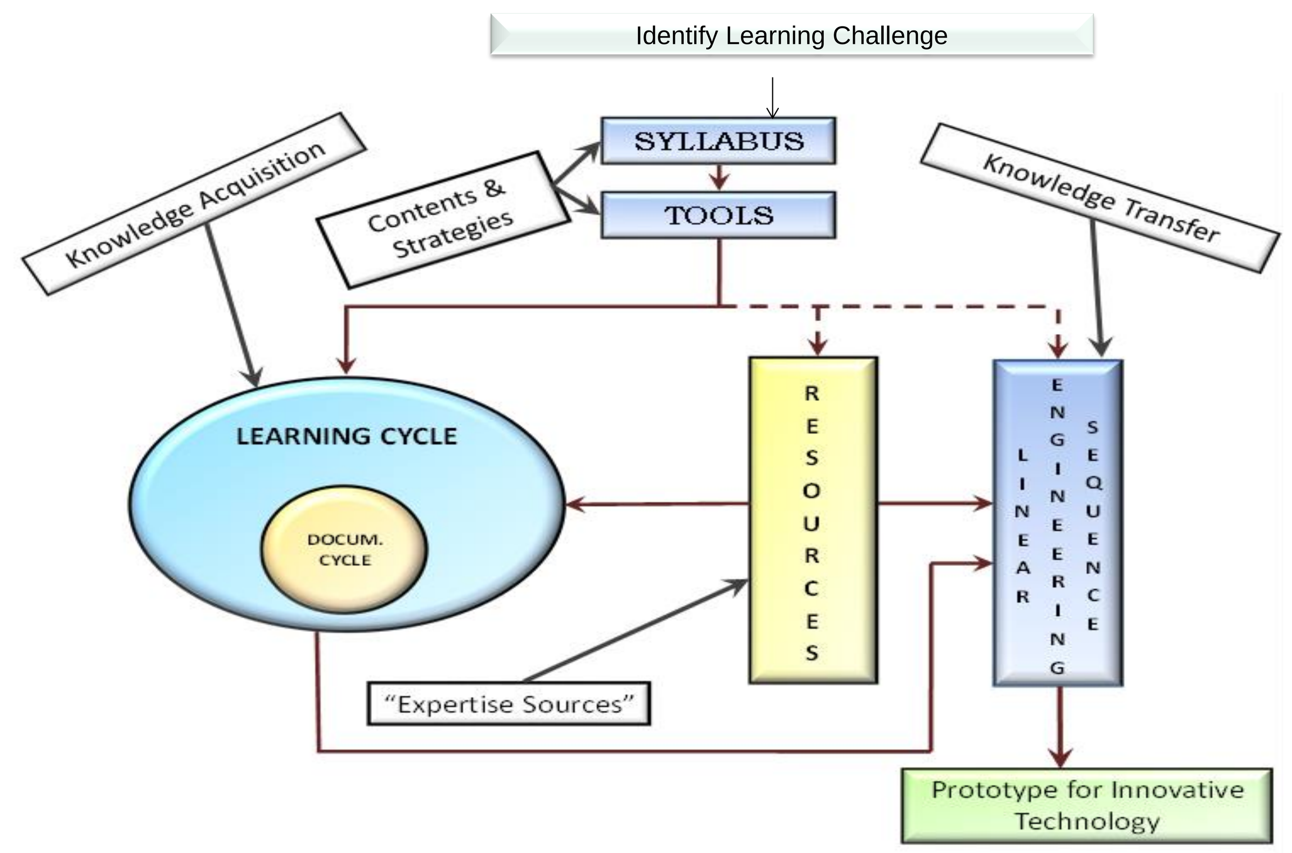


Figure 2. The adapted version of the Renaissance Foundry Model [1] specific for the protein engineering course. Take note of the two paradigms—Knowledge Acquisition(KAP) and Knowledge Transfer (KTP)

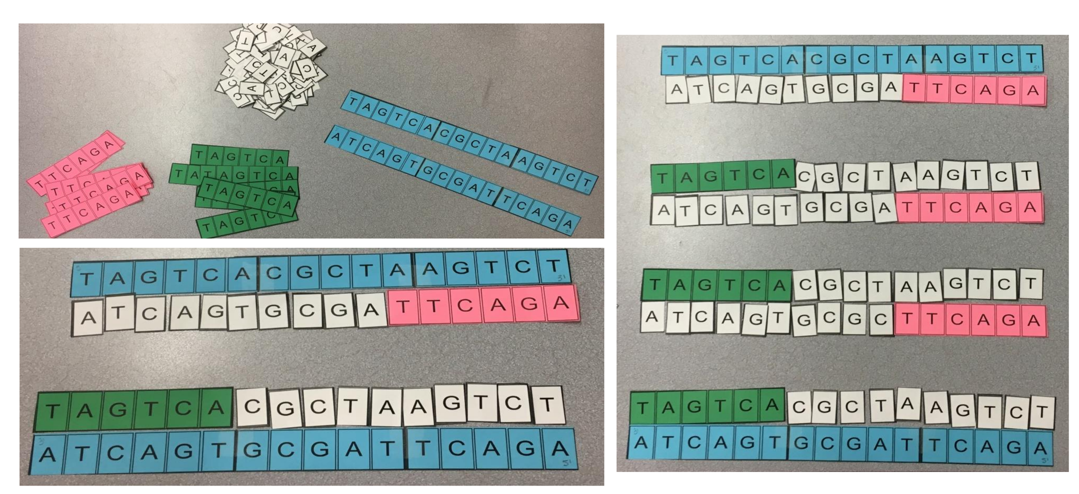
Knowledge Acquisition Paradigm

Figure 3. The students were given examples of compartmentalizing information for classes they had taken (heat transfer) to help show them how to compartmentalize information in protein engineering.

KAP—Heuristics: PCR Simulation

Cycle 0

Cycle 1



Cycle 2

Figure 4. Modified Paper PCR [2] to help give students a visual of how the polymerase chain reaction works to amplify DNA. PCR in the lab is a mixture of clear liquid so this helps show what is happening.

KAP—Heuristics: Electrophoresis Model

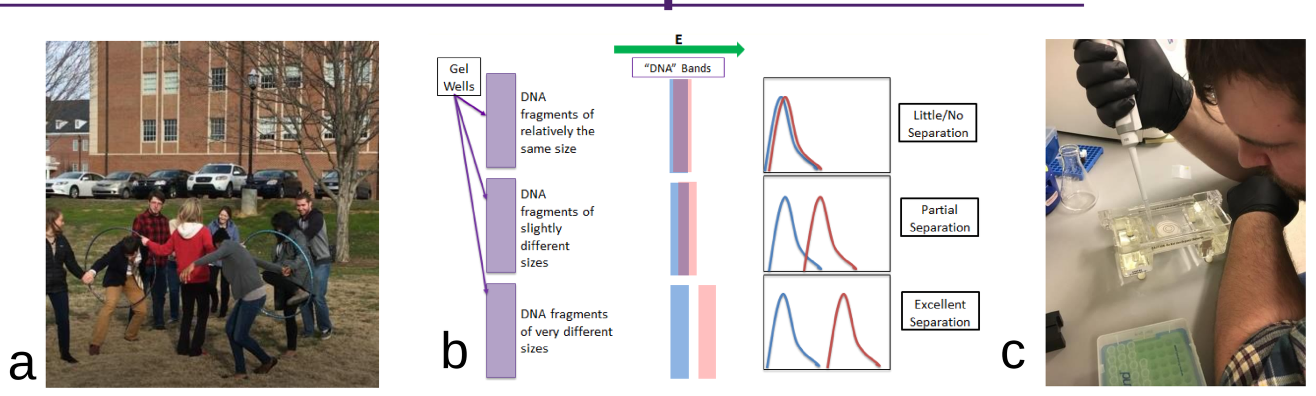


Figure 5. Gel Electrophoresis Model of DNA or SDS-PAGE gels. (a) Kinesthetic learning tool where hula hoops represented pores in the domain and the students represented strands of DNA. (b) depicts the desired learning outcome of transport through a porous medium with an applied electric field. (c) shows the hands on skills learned for running a DNA gel.

Knowledge Transfer Paradigm

Maintain the Learning Challenge:
- »Modify superfolder green fluorescent protein

Resources (bridge to KAP):
- »Experts, peers, facilitators of learning

Linear Engineering Sequence:
- »Prototype of Innovation to solve challenge
  - Student teams
  - Presentations
  - Assessments

Prototype of Innovative Technology

Develop a new fluorescent protein:
- »Identify mutation and design primer
- »Run PCR and sequence DNA
- »Express, purify, and quantify protein

Evaluated by:
- »Facilitators of learning and students
- »Did they make the desired mutation?

Figure 6. Protein Engineering Class

Coaching Model of Instruction[4]

Technical Aspects(know the material very well)
- »Background of TAs and instructor

Tactical Aspects (know when to use a particular drill or change directions)
- »Troubleshoot and observe audience

Educational Aspects (know the purpose and levels and design tasks accordingly)
- »Lab-lecture integration

Psychological Aspects (know the players very well)
- »Small class size

Training Aspects (have the experience to do the job)
- »Facilitator of learning and expert TAs

Future Goals

We would like to be able to gauge the students’ perspective of the course as well as be able to compare results from class to class. We would also like to continue incorporating heuristics into more courses in the department.

References

1. Arce, P.; R. Sanders, A Arce-Trigatti, L. Loggins, J. J. Biernacki, M. Geist, J.A. Pascal, and K. Wiant, “The Renaissance Foundry: A Powerful Learning and Thinking System to Develop 21st Century Da Vinci Engineers,” *Critical Conversations: An Interdisciplinary Journal,* 1, 176, (2015)
2. Chambers, J., C. L. Easter, S.K. Flowers, G. Farkas, “Sequencing a Genome: Inside the Washington University Genome Sequencing Center, Activity Supplement, Paper PCR (DNA Amplification),” Online http://www.nslc.wustl.edu/elgin/genomics/gsc/paperpcr.pdf
3. Rice, J., M. Bocci, and P. Kent, “A Laboratory-Based Approach for an Introduction to Biomolecular Engineering,” Proceedings of the 2016 American Society of Engineering Education Southeast Section Conference, (2016)
4. Creighton, L. L. (2001). Teaching Toolbox: Kicking Old Habits. *ASEE Prism online: exploring the future of engineering education.*

Acknowledgements

Paige Spencer , Department of Chemical Engineering (TTU) Students and staff, College of Engineering (TTU), College of Graduate Studies (TTU)