A COURSE ON TISSUE ENGINEERING AT NORTHWESTERN UNIVERSITY: PAST, PRESENT AND FUTURE DIRECTIONS

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Tissue Engineering in Biomedical Engineering Department

Motivation:

to establish and strengthen tissue engineering education programs in higher education institutions

Fundamental Courses:

- **BME 310 Molecular and Cellular Aspects of Bioengineering**
- **BME 314 Models in Biochemistry and Molecular Biology**
- **BME 315 Applications of Genetic Engineering to Immunology**
- **BME 371 Mechanics of Biological Tissues**

Applied Courses:

- **BME 315, BME 371**
- **BME 317 Biochemical Sensors**
- **BME 343 Biomaterials and Medical Devices**
- **BME 379 Artificial Organs**
- **BME 346 Tissue Engineering**

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BME 346 Tissue Engineering Course

Quarter system:

10 weeks

Class Meetings:

Two class meetings/week:	**TTh**
Tuesdays, regular lecture	**80 min.**
Thursdays, lab session	**up to 4 hours, 2 sessions**
Number of Students:	**mostly BME seniors**
	limited to 30
Office hours:	**any time**

Assessment and Grading:

Midterm examination:	**30%**
Final examination:	**30%**
Homework and lab. reports:	**30%**
Independent project:	**10%**

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BME 346 Tissue Engineering Course

Learning objectives are:

- **to understand the principles and concepts of molecular, cellular and tissue engineering,**
- **to learn basic tissue engineering techniques,**
- **to demonstrate the ability to apply tissue engineering principles and approaches to practical problems,**

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BME 346 Tissue Engineering Course

Furthermore, it is aimed to promote and help students to develop

- **laboratory skills (*via laboratory experiments*)**
- **lifelong skills such as adaptive expertise (*via independent project assignment*),**
- **written presentation and communication skills (*via laboratory reports* and *independent project development*).**

<u>design and conduct</u> an "*independent research project*" with a focus on a real life problem

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BME 346 Tissue Engineering Course

Lecture 1. **Introduction to tissue engineering**

Experiment 1. **Animal anesthesia, blood vessel cannulation, and tissue/organ fixation**

Lecture 2. **Molecular engineering**

2.1 Principles and techniques of gene therapy

2.2 Virus-mediated gene transfer into mammalian cells

2.3 Liposome-mediated gene transfer into mammalian cells

Experiment 2. **Tissue/organ identification and dissection, and specimen sectioning, staining, and examination**

Lecture 3. **Molecular engineering (continued)**

2.4 Receptor-mediated gene transfer into mammalian cells

2.5 $CaPO_4$-mediated gene transfer into mammalian cells

2.6 Electroporation-mediated gene transfer into mammalian cells

2.7 Gene gun-mediated gene transfer into mammalian cells

Experiment 3. **Electroporation-mediated gene transfer into selected tissues**

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BME 346 Tissue Engineering Course

Lecture 4. **Molecular Engineering: Gene therapy for neural disease and cancer**

Experiment 4. **Examination of transferred gene**

Lecture 5. **Molecular engineering: Gene therapy for cardiovascular and pulmonary disease**

Experiment 5. **Experimental hypertension**

Lecture 6. **Cellular engineering**

6.1 Biological basis of cellular engineering

6.2 Neural cell engineering and nerve fiber regeneration

Experiment 6. **Measurement of blood pressure in hypertensive animals**

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Lecture 7. **Cellular engineering**

7.1 *In vivo* keratinocyte and corneal epithelial cell engineering

7.2 *In vivo* hepatocyte engineering

Experiment 7. **Polymer implantation in selected organs and tissues**

Lecture 8. **Cellular engineering**

8.1 *In vivo* pancreatic cell engineering

8.2 *In vivo* myocyte engineering

Experiment 8. **Biological responses to implanted polymer materials**

Lecture 9. **Organ engineering: Cardiovascular engineering**

Experiment 9. **Independent project**

Experiment 9. **Independent project (continued)**

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BME 346 Tissue Engineering Course: Laboratory Sessions

Groups: **3-4 students/group; 4 groups/session**

Two laboratory sessions: **morning and afternoon**

Laboratory**: equipped with optical microscopes including fluorescence microscopes, surgical microscopes, electrophoresis devices, PCR, centrifuges, electroporation apparatus, cryo-microtome, cell culture incubators.**

First 8 Experiments:

Experimental procedures: supplied to students

- **basic animal handling, tissue and cell identification, vascular cannulation, specimen preparation,**
- **gene transfer into various tissue and organs,**
- **polymer implantation,**
- **creating disease models (e.g. hypertension)**

Laboratory reports: formal reports; due the next week of lab. session

Professor/TA correct(s) and return(s) the lab. reports promptly (formative assessment)

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BME 346 Tissue Engineering Course-Independent Projects

9th Experiment:

Independent project

Groups: come up with a proposal

Professor: discusses the feasibility of the proposal with the group (no later than the last two weeks of the quarter)

Laboratory meetings: flexible (as long as students make an arrangement with the Professor), two weeks time span

Report: a formal project report/group

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BME 346 Tissue Engineering Course
Independent projects developed by students (1997-2001)

Gene transfer: **Electroporation; Gene transfer into the lung; Gene transfer into the skin cells; Liposome mediated gene transfer**

***Polymer Implants*: Biocompatibility; Comparison of different implants; Therapeutic capacity; Effect of growth factor**

***Hypertension*: Physiological response; Anatomical response; Effect on myocardial cell density; AT1 receptor; Effect of hypertension on the heart; *Atherosclerosis* creation**

Influence of *kidney removal* on blood pressure

Effect of *hypoxia*

Investigating *histological structure and properties*; Lung; Kidneys; Brain; Ischemia

***Regeneration*: Bone; Liver**

***Mechanical Properties* of soft tissue**

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Feedback from Students

"…lectures are interesting and the freedom of the lab exercises allows you to study many different topics. An excellent course!"

"…Labs are very interesting and innovative"

"…It is the most exciting field I have been exposed to. I wasn't expecting the degree of complexity or challenge in tissue engineering, but I am glad that I was wrong, because those facets make me energetic about working in this field. This course was one of the best I have taken…"

"…this class is a wonderful preparation for medical school and graduate school…"

"…only wish there was a second part to the class to use the techniques that now "mastered" "

"Great labs-this is what all BME classes should be like"

Reference: CTEC (Course and Teacher Evaluation Council, Northwestern University)

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Some conclusions

- **Integrated lecture-laboratory approach established over the years to teach tissue engineering at NU,**
- **Lecture material has been compiled,**
- **Independent projects helped students to achieve their learning objectives and the goals of the course,**
- **Student engagement and motivation were high,**
- **One of the most popular courses in BME (NU) (The Course and Teacher Evaluation Council reports),**
- **Polymer implants, hypertension and gene transfer techniques are among the topics students show high interest.**

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Question: Could we do better than this?

Answer:

We do not know yet!

It needs to be investigated!

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VaNTH ERC FOR BIOENGINEERING EDUCATIONAL TECHNOLOGIES

Vanderbilt•Northwestern•Texas•Harvard/MIT Engineering Research Center

VaNTH ERC:

Vanderbilt, Northwestern, University of Texas, and Harvard/MIT Engineering Research Center (ERC) in Bioengineering Educational Technologies

Goals:

Development, assessment and dissemination of HPL-compliant educational materials for bioengineering

Active Domains:

- **Systems physiology**
- **Bio-optics**
- **Biotechnology**
- **Biomechanics**

Team:

Bioengineering faculty (DE)

Learning scientists from school of education (LS)

Learning technologists from computer science (LT)

Assessment experts from school of education and/or Searle Center for Teaching Excellence (AE)

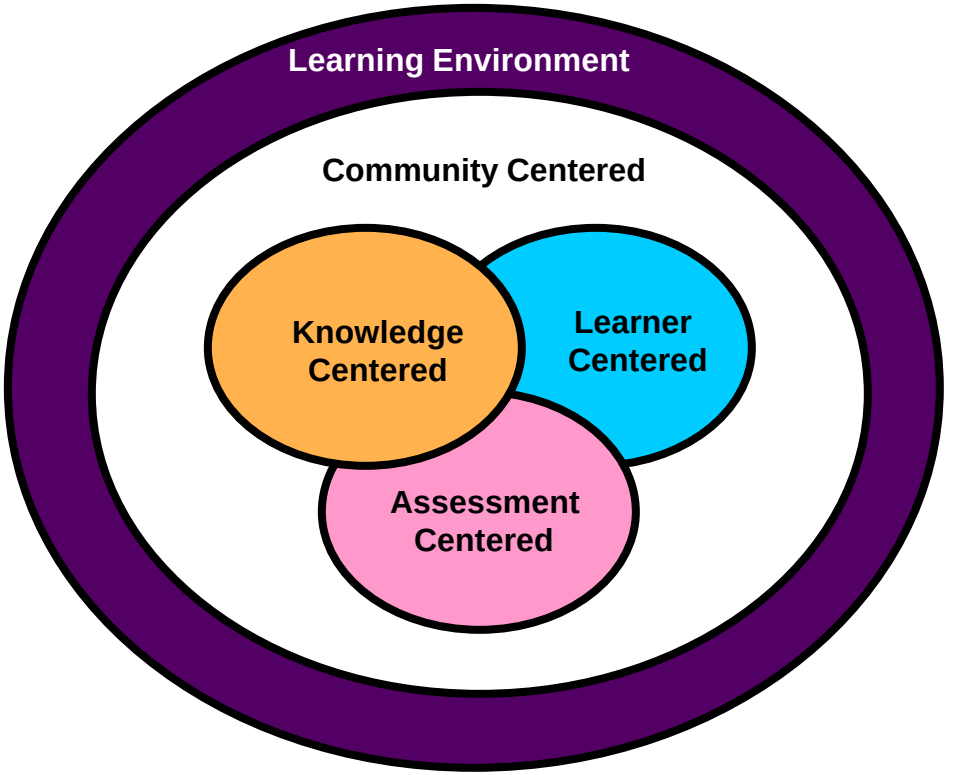
Students

Educational Modules and Tools:

How People Learn (HPL) Framework

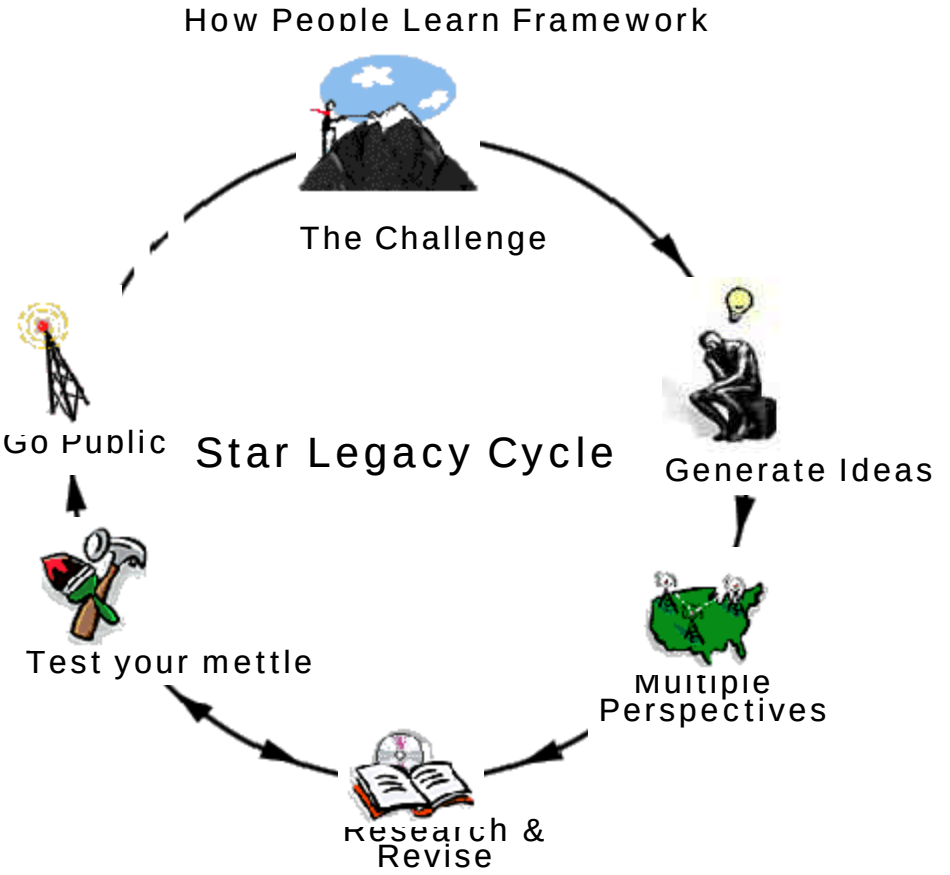
Learning science, learning technology and assessment are continuously being integrated into these modules.

The "How People Learn" Framework:



Reference: John Bransford, et al (1999) How People Learn. National Academy Press.

Star Legacy Cycle:



Tissue Engineering Class:

- **(Re)design the course or part of the course based on learning theory (HPL Framework)**
- **Use "Star Legacy" sequence (LC) to create modular materials**
- **Use existing lecture materials**
- **Focus on gene therapy**

<u>Research</u> potential of modules

for enhancing the classroom learning environment

Assessment:

Spring 2001 Quarter (done):

pre/post tests (2001),
exam questions (between 1997-2001),
laboratory reports (between 1997-2001),
observation of classroom activities

Spring 2002 Quarter (work in progress):

surveys,
exam questions,
pre/post tests,
laboratory reports

➡ **Identify strengths and weaknesses of our students**

Acknowledgements:

- **Ann F. McKenna of NU**
- **H. David Smith of NU**
- **The Spring 1997 through 2001 students of BME 346 course**
- **CTEC-The Course and Teacher Evaluation Council of NU**

This work was supported in part by the Engineering Research Centers Program of the NSF under Award Number EEC-9876363.