Mimicking Bone Bioscaffolds with K'NEX: Developing Student Creativity and Problem-Solving Skills (P12 Resource Exchange)

Dr. Margaret F. Bennewitz, University of Pittsburgh

Margaret Bennewitz is a NRSA F32 postdoctoral scholar at the University of Pittsburgh in the Vascular Medicine Institute. During her postdoctoral studies, she has developed an in vivo multiphoton fluorescence microscopy technique for visualizing blood cell trafficking within the pulmonary microcirculation of live sickle cell disease mice. Using multiphoton microscopy, she aims to identify the cellular and molecular events promoting pulmonary vaso-occlusion in sickle cell disease mice. She is engaged in the teaching community at the university through being a member of Pitt-CIRTL. Her teaching as research project was implemented at the university's Camp BioE for high school and middle school students last year. She received her BS degree in Bioengineering from the University of Pittsburgh in 2007 and her PhD from Yale University in Biomedical Engineering in 2012.

Mr. Ruben Hartogs, University of Pittsburgh

Ruben Hartogs is a junior undergraduate student at the University of Pittsburgh pursuing a degree in bioengineering with a concentration in medical devices and a minor in mechanical engineering. He is currently on co-op at Zimmer Biomet, an orthopedic medical devices and joint replacement company. Over the summer, Ruben was a counselor for the University of Pittsburgh's Camp BioE, a camp introducing middle and high school students to the concepts of tissue engineering and regenerative medicine to inspire an interest in bioengineering. There, he developed an activity to teach students about the development and applications of bioscaffolds in tissue engineering.

Dr. Mary E. Besterfield-Sacre, University of Pittsburgh

Dr. Mary Besterfield-Sacre is an Associate Professor and Fulton C. Noss Faculty Fellow in Industrial Engineering at the University of Pittsburgh. She is the Director for the Engineering Education Research Center (EERC) in the Swanson School of Engineering, and serves as a Center Associate for the Learning Research and Development Center. Her principal research is in engineering education assessment, which has been funded by the NSF, Department of Ed, Sloan, EIF, and NCIIA. Dr. Sacre's current research focuses on three distinct but highly correlated areas – innovative design and entrepreneurship, engineering modeling, and global competency in engineering. She is currently associate editor for the AEE Journal.

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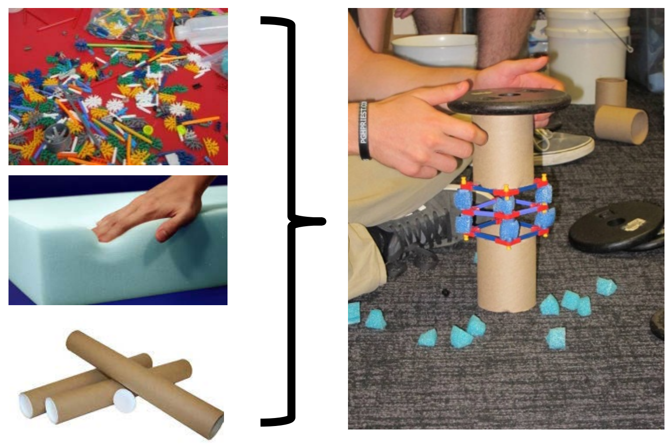
University of Pittsburgh

<u>Target grade levels</u>: 6^{th}-12^{th} grade

<u>Purpose:</u> Bone can become injured by trauma or disease. The field of tissue engineering strives to replace or repair injured bone through the combination of cells and porous scaffolds made of biomaterials. This paper describes how middle school and high school teachers can introduce their students to college-level tissue engineering principles and problem solving methods using simple materials. K'NEX^{TM} toy construction sets are used to mimic the construction of a bone bioscaffold, as they are durable and can yield a variety of geometrical shapes. K'NEX^{TM} pieces fit together in an all-or-nothing manner and form stable connections. Students will develop their creativity and problem solving skills through the scaffold design and testing process.

<u>Materials</u>:
- K'NEX^{TM} toy construction sets
- Foam cubes
- Cardboard tubing
- Weights (0.5, 1, 2.5, 5 lbs)
- Ruler

The K'NEX^{TM} toy sets are used to mimic the cortical bone which supports and protects. Foam represents trabecular bone or spongy bone. Cardboard tubing represents healthy bone.



<u>Time required for the activity</u>: 1-1.5 hours

<u>Learning goals</u>:

1) **Designing and creating a scaffold that meets mechanical specifications**
    - *Criteria:* The bioscaffold must hold 10 pounds but fail soon after additional weight.
    - *Rationale:* A bone scaffold that is too weak will collapse under the patient's weight. A bone scaffold that is too strong will not be desirable either. Really strong scaffolds hold too much weight and will remove normal stress distributed to the surrounding healthy bone. The lack of stimulation causes the healthy bone around the scaffold to become less dense and thus weaker.
2) **Analyzing the role of geometry on scaffold strength**
    - Do students know which geometrical shapes are the strongest and which are the weakest? Does this exercise improve understanding of geometry's impact on scaffold strength?
3) **Recognizing the real-world applications of bioscaffolds**
    - A brief introduction can be given by the teacher prior to the scaffold building activity to explain to students the biological and clinical importance of bone bioscaffolds. Students can be asked questions after the activity is completed.

<u>Procedure and Assessments</u>:

1) **Introduce the activity by explaining the real-world relevance of bioscaffolds.**

- *Please contact the author for an introduction presentation for the activity.*

2) **Have students complete a pre-assessment activity about geometric strength.**
   - Students will rank each shape (square, parallelogram, rectangle, and triangle) in increasing order from 1-4 (1 = weakest, 2 = weak, 3 = strong, 4 = strongest).
   - Students will complete this exercise again at the end of the activity. Results can be compared to assess if the activity improved student understanding of geometrical strength. *Please see the geometry worksheet.*
3) **Arrange the room accordingly:**
   - Break students up into teams of 2 and put K'NEX^{TM} and foam cubes on each table.
   - Weights, cardboard tubing, and rulers can be in a central location for testing.
4) **Explain to students the requirements of bioscaffolds. Each scaffold must:**
   - Hold 10 pounds but fail soon after adding additional weight.
   - Be between 4 to 5 inches in height and 2.5 to 4 inches in diameter.
   - Incorporate both K'NEX^{TM} and foam, and interface stably with the cardboard tubes.
5) **Explain the testing procedure:**
   - Stand up one piece of cardboard, place a constructed scaffold on top, and then add the other piece of cardboard on top of the scaffold.
   - Load desired weight on top of the stack and let it stand for at least 5 seconds.
   - Then add more weight until failure. Failure is defined as any breaking of connections or any permanent deformation of the scaffold.
   - Observe each test and record the weight at which the scaffold failed.
6) **Have students design, construct, and test scaffolds in an iterative process.**
   - After testing failure, help students assess why their initial design did not work to meet mechanical specifications. Encourage them to make another design and try again. *Please see the prompt worksheet for example questions to ask students.*
7) **Additional assessments for the end of the exercise:**
   - Have students complete the rest of the *geometry worksheet* and compare with 2).
   - Teachers can assess student performance using an analytic rubric which addresses technical performance (weight requirements), creativity, and aesthetics. *Please see the analytic rubric worksheet.*
   - Students can be asked relevant questions at the conclusion of the activity to assess their understanding of the real-world applications of bioscaffolds. *Please see the real-world applications worksheet.*

<u>Applications</u>: This hands-on activity introduces students to open-ended design questions that engineers face every day. Students create their own scaffolds comprised of different geometrical shapes and they begin to understand the troubleshooting process as they discover why their design(s) failed and how to make improvements. This activity interfaces with the iterative engineering design process outlined in the *Next Generation Science Standards* for K-12. Additionally, we have researched the impact of verbal prompts (hints from facilitators using the prompt worksheet) on student technical performance and creativity. Given the small sample size, we found that thought-provoking questions from facilitators may improve student technical performance, yet creativity is not negatively affected. Both middle school and high school students were able to complete the activity. Please contact mfb26@pitt.edu for presentation and worksheets. We would like to acknowledge Ms. Juel Smith and Dr. Steven Abramowitch for their guidance in developing and implementing this activity in the Pitt Camp BioE.