Introducing Application Based Nanotechnology Modules to High School Students: Results from an Exploratory Study

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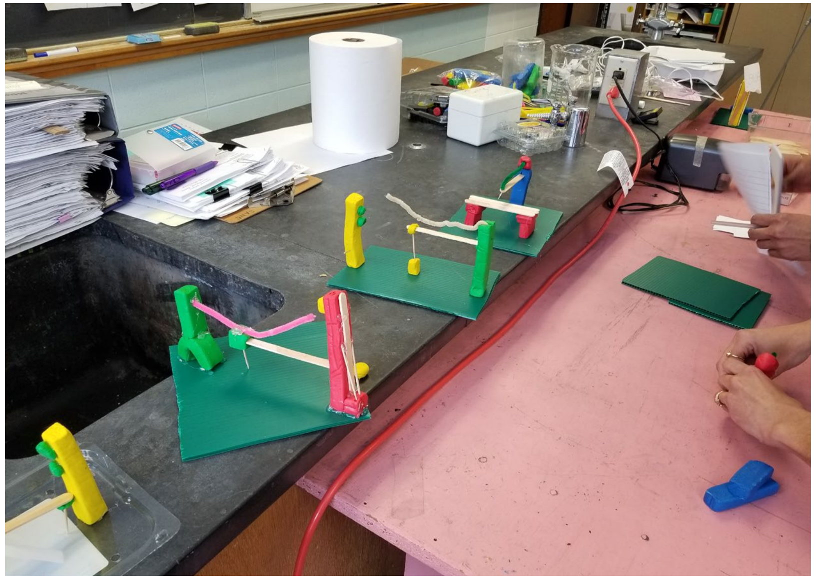
Aim:
To study student response to a learning experience that leverages technology analysis and application, to introduce novel Nanoscience concepts.

Research Questions

- What do we know about student readiness towards learning Nano-Science and Nanotechnology (NST) concepts ?
- In what ways does student engagement in NST learning experiences impact their STEM attitudes ?

Background and Framework: Disciplinary Learning and Technology



Student-made non-functional prototypes of an atomic force microscope, as they explore various subsystems of the tool.

- Student participation in hands-on exploration of technological tools to facilitate enhanced interest and understanding of NST concepts.
- Constructionist theories of learning support working with physical artifacts as a productive way to engage learners in disciplinary practices and build conceptual knowledge (Papert, 1980).

Background and Framework:
Motivation for Future STEM Careers

- Intent to major in STEM disciplines in college is largely influenced in part by exposure to math and science courses and confidence in their own skills (Wang, 2013).
- Exposure and experiences in the field of Nanoscience may have the potential to:
  - Positively impact student interest and likelihood of persistence in future STEM careers.
  - Make an impact for high school students, where they are close to making career choices.

Background and Framework: Educational Reconstruction

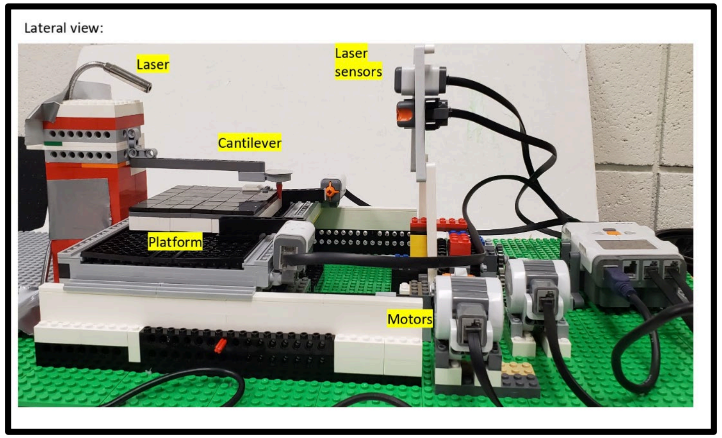
- We draw from Educational Reconstruction to inform the design process of our learning modules.
- Educational Reconstruction: a cyclical process of theoretical reflection, conceptual analysis, small-scale curriculum development, and classroom research on the interaction of teaching and learning processes (Duit et al. 2012).
- Our study,
  - Identify grade appropriate, standards aligned content.
  - Analysis of science education literature on teaching NST concepts
  - Designing the module
  - Implement the module
  - Study students' readiness, attitudes, what aspects helped further their understanding and conceptual difficulties they faced. Use results to redesign module.

Recursive process

Pilot Module on Atomic Force Microscopy (AFM): Participants

- The module was piloted at a middle school in a Northeastern state.
- Four classrooms of 8^{th} grade students over two days.
- 77 total students.

Pilot AFM Module: Module structure
Part One: LEGO based AFM Exploration



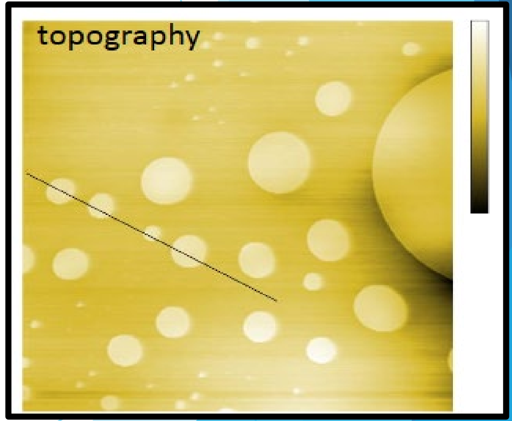
- *Learning Objective*: To develop an understanding of the various sub systems and components of an AFM. And how they work together to magnify at a nanoscale.
- *Module includes* a demonstration of a functional LEGO model of an AFM.
- *Module design justification*: LEGOs used intentionally to make the technological tool more accessible and easier to “see” the various working principles.
- The model images irregularities on a platform using a Lego cantilever. A laser and light sensor system, is used to sense the cantilever deflections that are further plotted using a graphical interface (LabView) program.

Pilot AFM Module: Module Structure
Part Two: Real AFM Study

- *Learning Objective*: Demonstrate use of a real AFM to study physical properties of polymers.

- *Module includes* answering the central question: “Why can a Styrofoam cup be broken easily but not a plastic cup?”

- *Engagement*: Students study and compare AFM produced images of the surface of a plastic cup and a styro-foam cup. They are guided to observe phase shifts in the materials responsible for their physical properties making one stronger than the other.



Sample of an AFM produced topographical image

Data Sources and Analysis

- S-STEM Surveys
  - Paired t-tests on class averages pre- and post- scores to track changes in general student attitudes towards STEM and interest (Friday Institute, 2012).

- Group Reflections
  - Small groups response to, *How does the AFM image the surface? To image something very small how must the LEGO AFM be changed? What are some problems with the LEGO model?*
  - Qualitative analysis looking at larger themes, not necessarily looking for scientific accuracy or ”correctness” in responses

- Individual Student Reflections
  - Students' response to *Did the AFM help you understand the differences in the physical properties of the two cups? How?*
  - Qualitative analysis to identify themes/categories within responses, and frequency analysis for those themes.
  - Inter-rater reliability of 90% after two successive rounds of categorizing responses by themes

Individual Reflection Categories for Student Responses

Reflection Category	Description	Example response
A. Rephrased question, no reasoning. (66.7%)	Response acknowledges difference between the two images OR states that the image was not useful without any reasoning.	"You could see the differences between the 2 cups."
B. Image description. (13.7%)	Response describes the image but does not include any reasoning or the purpose of the AFM, imaging process, or properties of the cup.	"It explained that the plastic had more polymer and the styro foam had less"
C. Includes the purpose of AFM in magnification to nano scale. (7.6%)	Response mentions the "zoomed in" aspect of the images relating back to the use of the AFM for magnification.	"It showed a closeup image of what styro foam looks like."
D. Description of the imaging process. (7.6%)	Response includes how the image was formed either by including the mechanics of the AFM system and/or the mapping done using software.	"It showed what held better and how the differences happen. When a soft spot touched, the graph would rise up and when a hard spot got touched it would go down."
E. Description of the image and connects it to cup properties. (3%)	Response includes a description of the image and/or model and connects it with strengths of the materials (cups).	"It showed that the styrofoam cup was made of one type of material, so it broke easier. Plastic cup was made of two materials, one of them found in rubber so it was more durable."
F. No response (1.5%)		

Results: S-STEM Surveys

Students chose a value on a scale of 1-5, 5 being most interested in a type of career. Below are the averages of the student responses.

	Pre	Post
Physics	2.25245098	2.16947464
Enviro	2.12490325	2.06145833
Bio/Zoo	2.49218481	2.46666667
Veterinary	2.77325206	2.72984602
Math	2.37967622	2.77436594
Medicine	2.8122205	2.94492754
Earth Sci	2.00814306	1.98804348
Comp Sci	2.12626195	2.19927536
Med Science	2.44210096	2.45375906
Chemsitry	2.25392372	2.2415308
Engineering	2.77361756	2.82024457

Students chose a value on a scale of 1-5, 5 being most interested in a taking advanced classes (college level) in the mentioned subjects. Below are the averages of student responses.

	Pre	Post
Math	3.63929066	3.64439103
Science	2.79897231	2.74937764
Engineering/ Tech	3.06061328	2.98532139

Paired t-tests on pre- and post- data show no significant changes.

Results: Student Reflections

- **Individual Reflections**
  - Responses exhibit variation in: understanding the question itself; constructing scientific explanations; the functioning of AFM or the imaging process.
  - Few responses exhibit understanding of how the AFM maps a surface, at small scales.
- **Group Reflections**
  - Reflections highlight working of individual subsystems. No elaboration on how the subsystems work to produce an image.
  - Reflections focus on scale/size of individual subsystems to be able to map at a nanoscale.

Discussion

- Students describe AFM produced images and identify the function of each mechanical element of the AFM and scale to achieve magnified image.
- A small yet definite number of student, connect the image to the properties of the material being imaged, demonstrating potential for students to make that connection with more support.
- Most students are unable to articulate the imaging process or analyze the image
- Image analysis itself includes two aspects:
  - Understanding the AFM as a tool (its' structure, working subsystems)
  - Understanding AFM's functioning modes (when and why would one use each mode)
- Support development of two related yet distinct aspects in the module:
  - The structure of tool (AFM subsystems and how they work together to produce an image)
  - The AFM's application (interpreting the image produced by AFM).

Implications

- At the moment, there are no direct claims to be made about the intervention.
- Study strongly suggests the need to restructure and revise module to allow for more time on LEGO model exploration; and structure experience to explore how various subsystems function together.
- Next steps:
  - Structure a *separate*, *second* module to explore applications of AFM as a technological tool to have two submodules:
    - Submodule on LEGO model of AFM for students to explore the AFM's components and functions, making use of hands on experiences such as model making.
    - Submodule on the real AFM and its' images, to explore the AFM's capability to image objects at nanoscale and explore the physical properties of materials.
  - Re-implement to better study student understanding of the material and STEM attitudes.

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