Exploring MEMS Resonators-Sensors in Middle School Science

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Summary

MEMS- micro-electro-mechanical system. Resonance can be defined as the ability of a material to store and transfer energy from one domain to another; it is back and forth energy transfer. We explored and designed multiple experiments in which we converted energy from the mechanical domain to the electrical domain. We also experimented with piezoelectric material as temperature and pressure sensors. One of the goals of RET is to translate these STEM experiences to my middle school classroom.

Multiple studies have reported that students achieve greater conceptional understanding of STEM through design-based and open inquiry. As an educator, I will provide more opportunities for DBL in my science class. With the research and experimental design through RET, I am motivated to provide authentic DBL and open inquiry opportunities to all my students. My lesson plan from RET this summer is a reflection of how DBL/open inquiry has influenced my pedagogical thinking.

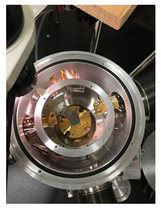
Research Activities

Problem: Design an experiment to convert energy from mechanical domain to electrical domain.

Experiment 1: Converting acoustic energy(vibrations) from a tuning fork to electrical energy using a microphone and oscilloscope.

Experiment 2 :How can a piezoelectric buzzer be used as a temperature sensor? Key Concepts learned: Quality factor and Young's Modulus.

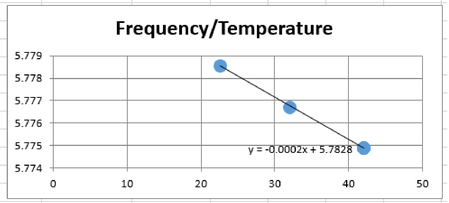
Frequency in KHz	Temperature in degrees C
29.82	23.80
29.66	48.80
29.29	64.00
29.20	67.70
29.08	69.30
29.45	46.55



Experiment 3: How does a change in temperature and pressure affect the quality factor, frequency, and temperature coefficient frequency(TCF)?
Using a cryogenic vacuum chamber, the data showed as temperature increased, both the resonance frequency and quality factor decreased.

Effects of Temperature and Pressure on Q Factor and Frequency

Time	Temperature	Frequency	Pressure	Q factor
12:00	22.59	5.77856	2	3600
2:00	32.08	5.77669	5.8	4644
2:36	42	5.774873	7.4	4583
2:51	42	5.774891	8	4558
3:21	42	5.774875	8.7	4498



Lesson Plan

Lesson Objective(s)/Learning Goal(s):
Design an experiment that will convert and measure acoustic/vibrations (mechanical energy) of a vibrating string and soundboard of a guitar/violin to electrical energy, using a microphone and oscilloscope; then compare the results when a piezo film sensor is attached directly to the device.

Description of Lesson Activities/Experiences: This will be DBL/open inquiry experiment.

Activities

1.Engage- Quick Write 5 min: Write everything you know about potential/kinetic energy, resonators, piezoelectric material/crystal, sensors, and resonant frequency.

2. Explorer: YouTube video on resonant frequency: After watching the video, add to your quick write, and come up with 2 inquiry-oriented questions to investigate resonant/natural frequency. Share your ideas with your lab group. Each person gets a turn to share- positive criticism only.

3. Explorer (2): Read article on piezoelectric materials and resonators. Small group discussion and reflection. Modify your Quick Write. Formulate your hypothesis based on the lesson objective.

4. Explain: Explain your new understanding of resonators and resonance frequency and piezoelectric material-science journal/small group

5. Extend/Elaborate: apply/extend the new understanding by designing an investigation that will convert acoustic energy(vibrations) from a tuning fork, guitar/violin string to electrical energy, using a microphone & oscilloscope. Then compare the results of the experiment when a piezo film sensor is attached directly to the device. WRITE YOUR CONCLUSION~ Formal Lab Report.

EXTEND PART B: Now students will apply their new knowledge by designing a Lab that will test the effects of temperature on resonance frequency using a PIEZO FILM SENSOR and an oscilloscope.
6. Evaluate: assessment through open-ended questions- post test.

Lesson Learned and Assumptions

1. The design based and open inquiry approach is the most effective way to teach science that will have a lifetime impact on students.
2. Authentic DBL leads to self-discovery, self-learning, and self-monitor.
3. Design base increases rigor of the lesson and problem-solving process, but is lacking in our schools.
4. Many teachers do not try design approach with low performing students.
5. These teachers assume that it is a waste of time and student achievement will drop. Contrary to that belief, design base/open inquiry is an effective way to help boost achievement among all subgroups.

Implementation Strategy

5E Model of Instruction of Instruction-An Open Inquiry Investigation
- Engage: Quick Write- 5 min
- Explorer: YouTube video and article. Predicts and formulate hypotheses.
- Explain: In your own words
- Extend/Elaborate: Investigation/redesign- experimental design.
- Evaluate: open-ended questions

Marzano's Learning Strategies:
DQ1: Providing Clear Learning Goals and Scales (Rubrics)
DQ4: Helping Students Generate and Test Hypotheses
21. Organizing Students for Cognitively Complex Tasks
22. Engaging Students in Cognitively Complex Tasks Involving Hypothesis Generation and Testing
23. Providing Resources and Guidance

NOTE: Although many of the elements from DQ 2 and 3 are used in this lesson, the predominant elements are from DQ 4-elements 21, 22, and 23.

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References

Mehalik, M. M., Doppelt, Y., & Schuun, C. D. (2008). Middle-School Science Through Design-Based Learning versus Scripted Inquiry: Better Overall Science Concept Learning and Equity Gap Reduction. *Journal Of Engineering Education*, *97*(1), 71-85.

Safaeifar, Hossein, and Abdollah Karimi. "The Effect of Temperature on the Natural Kim, Bongsang, Chandra Mohan Jha, Rob Norris Candler, Matthew Hopcroft, Manu Agarwal, Gary Yama, Renata Melamud, Saurabh Chandorkar, and Thomas W. Kenny. "TEMPERATURE DEPENDENCE OF QUALITY FACTOR IN MEMS RESONATORS."*Journal of Microelect romechanical Systems* 17.3 (2008): 755-66.

H. Kim, S. Priya, H. Stephanou and K. Uchino, "Consideration of Impedance Matching Techniques for Efficient Piezoelectric Energy Harvesting," in *IEEE Transactions on Ultrasonics, Ferroelectrics, and Frequency Control*, vol. 54, no. 9, pp. 1851-1859, September 2007.