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Hands-on STEM: Chemistry, Physics, and Other Science Resources for K-12 Education

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Chemistry, Physics, and Other Science Resources for K-12 Education

STEM (Science, Technology, Engineering, and Mathematics) education is essential to understanding science in modern society and preparing a new generation to fill necessary technical roles and participate in decision-making and discourse about advancements in science and its impact on society.[1] The complex science of COVID-19 and the resulting pandemic has underscored the need for basic science literacy and its role and function within K-12 education.[2] For teachers, preparing materials to engage and encourage students in STEM can be challenging. This article provides resources to help make preparation and planning easier for elementary and secondary educators.

With basic science literacy needs comes a secondary goal of STEM education: the preparation of future STEM teachers, who, in turn, will inspire curious students.[3] For Adventist education to reach this goal, we need to foster the development of more female faculty in the fields in which they are underrepresented at our institutions.[4] This starts in high school because STEM at this level is pivotal for increasing the number of women in STEM fields. For young women, hands-on experience in these fields during high school has been shown to increase the pursuit of STEM careers by females.[5] In general, the use of inquiry activities, hands-on activities designed to encourage students to explore the concepts being taught, stimulates curiosity and engagement among all students.[6] Combining these activities with active learning increases the performance and retention of students who are underrepresented in STEM.[7]

A great place to start the experimentation for educators and students alike is with something familiar: food. Many teachers have already started exploring this area by growing familiar food-producing plants with their students.

Our Experience

The Andrews University Department of Chemistry and Biochemistry recently (July 2021) hosted a Chemistry Activities Teachers Workshop funded through Loma Linda University from the Versacare Foundation.[8] We were able to host the workshop remotely after providing the participating teachers with a boxed lab-supplies kit. Several lab activities described below were part of the workshop, during which presenters performed the experiments together with participants while highlighting ways to approach the activity with a classroom of students.

Of the participants responding to the after-workshop survey, 80 percent indicated (1) that it was helpful to see and do the activities live with the workshop instructor; and (2) it was helpful to have a remote opportunity for teacher development in the summer (80 percent indicated they would not have been able to participate otherwise). Of the respondents, 80 percent felt that their ability to share science/chemistry experiments and activities with their students grew from participation in the workshop.

Faculty in the Andrews University Department of Chemistry and Biochemistry continue to look for more opportunities to offer this experience to teachers! We (and other STEM departments) are planning another summer workshop session while we look again for funding. We encourage field trips to our campus and have visited other campuses with hands-on activities.

A great place to start the experimentation for educators and students alike is with something familiar: food. Many teachers have already started exploring this area by growing familiar food-producing plants with their students. Experiments can be designed that not only explore the biological process of plant growth but also, by adding different substances to the plants and changing the environment, explore the effects of too much or too little water, nutrients supplied, light conditions, or air conditions. Another part of the scientific process also occurs when students record notes and observations. When there are several "subjects" in the same group (such as multiple plants, or several students replicating the same conditions for their cookie experiment), there is a real-life opportunity to help students apply statistical analysis to the results.

Another example of food experimentation is analyzing different sweeteners. A classroom of students can be asked to taste sweeteners after they have predicted sweetness levels (masking the identity of which sweetener a student tastes allows for an unbiased analysis). This activity and a related one on enzymes (e.g., spitting in a bowl of pudding to see what happens to the consistency) were modified (see this activity: https://sites. google.com/andrews.edu/k-12-educational-resources/resource-links) with permission from Cordelia Running at Purdue, who has created a wonderful set of college general-science education experiments.[9]

Molecular gastronomy enthusiasts will be familiar with sodium alginate polymers and the interesting way they are used for food applications; this can lead to excellent science teaching opportunities. A recent publication by Corcoran et al.[10] documents some experiments that can be used with students from elementary through high school levels and highlights sustainable practices to add to a discussion with students. The al-

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Additional Resources

Below are several additional links with useful correlations and experiments that can be used in chemistry, physics, and other science classes. A good place to begin is with a correlation between the Next Generation Science Standards (NGSS) (K-12 science standards) and *ByDesign: A Journey to Excellence Through Science* textbooks. This link provides an NGSS and *ByDesign* correlation to activities: https://docs.google.com/spreadsheets/d/1xsK0DZ0DAAbMVb9oArEiU3NN8KY-U6Z598fFLkyt9rQ/edit?usp=sharing.

More links for chemistry, physics, and other sciences are listed below:

CHEMISTRY

Science Correlation Standards
https://docs.google.com/spreadsheets/d/1xsK0DZ0DAAbMVb9oArEiU3NN8KY-U6Z598fFLkyt9rQ/edit?usp=sharing

American Chemical Society
"Inquiry in Action":https://www.acs.org/content/acs/en/education/resources/k-8/inquiryinaction.html

"Adventures in Chemistry"
https://www.acs.org/content/acs/en/education/whatischemistry/ adventures-in-chemistry.html

***ChemMatters* Magazine**
https://www.acs.org/content/acs/en/education/re sources/high school/chem matters.html

Middle School Chemistry
https://www.middleschoolchemistry.com/

Exploratorium: "What Is a Science Snack?"
https://www.exploratorium.edu/snacks

Steve Spangler Science
https://www.stevespanglerscience.com/?gclid=Cj0KCQjwiNSLBhCPARIsAKNS4_czQQ1qxYfAMI-TmIj3tRLdGp2yHGpZYtT13wJRXTJXFDrgL1TrjU kaAsF_EALw_wcB

Royal Society Science
Primary School Science at Home
https://royalsociety.org/topics-policy/education-skills/teacher-resources-and-opportunities/resources-for-teachers/science-at-home/primary/

Royal Society of Chemistry: Steps Into Science Resources
https://edu.rsc.org/primary-science/find-resources

Secondary Resources
https://edu.rsc.org/resources/secondary

PHYSICS

About Hyperphysics
http://hyperphysics.phy-astr.gsu.edu/hbase/hph.html

Hyperphysics-Chemistry
http://hyperphysics.phy-astr.gsu.edu/hbase/Chemical/chemcon.html#c1

ComPADRE: Resources and Services for Physics Education
https://compadre.org

Science Buddies: Elementary School Physics Lesson Plans
https://www.sciencebuddies.org/teacher-resources/lesson-plans/subjects/physics/elementary-school

American Physical Society Resources for High School Teachers
http://www.aps.org/programs/education/highschool/teachers/index.cfm

American Physical Society: Resources for Teachers in Grades Kindergarten-Middle School
http://www.aps.org/programs/education/k8/index.cfm

Adventures of Cyberbee: Physics Is Phun
http://www.cyberbee.com/physics_sites.html

SCIENCE

National Science Foundation Classroom Resources
https://www.nsf.gov/news/classroom/index.jsp

Hyperphysics: Biology Concepts
http://hyperphysics.phy-astr.gsu.edu/hbase/Biology/biocon.html#heacon

PhET Interactive Simulations
https://phet.colorado.edu/

Share My Lesson: Science
https://sharemylesson.com/subject/science

ginate worms experiment[11] from the Royal Society is an excellent, succinct classroom activity.

Resources

Below is a discussion of each resource with links. This website (https://sites.google.com/andrews.edu/k-12-educational -resources/home?authuser=0) provides all the links AND attempts to correlate the resource to chapters in *ByDesign: A Journey to Excellence Through Science* textbooks produced by the North American Division for grades 1 to 8. While it may not be necessary to make a direct parallel with the textbook topic and the activities suggested, it's often helpful in creating a connection between the teacher and the students. Grades 9-12 textbooks in use are more variable; there is not yet a set of curricular connections available for them.

Teachers should feel equipped to do hands-on curiosity-driven experimentation. The resources listed below are free or available at a moderate cost. There are books and other materials for purchase, but the freely available Web information offers perhaps more activities than time available.

Chemistry

Inquiry in Action, Grades K-5[12] by the American Chemical Society (ACS) is a collection of resources aligned to the Next Generation Science Standards (NGSS) (K-12 science standards).[13] These lessons provide activities that help connect students and teachers to everyday things. But more than that, they provide science background information to aid teachers who feel they need a little more information, perhaps a refresher on the concepts.

A favorite simple activity uses M&M candies to investigate dissolving properties and can be used for many different grade levels. This activity makes it possible to encourage students to ask their questions about M&Ms and colors and even explore those questions. Further help for K-5 teachers is available at the Adventures in Chemistry website, which features hands-on activities, videos, and games.[14]

A favorite simple activity uses M&M candies to investigate dissolving properties and can be used for many different grade levels. This activity makes it possible to encourage students to ask their questions about M&Ms and colors and even explore those questions.

Another resource aligned with the NGSS from the ACS is Middle School Chemistry, Grades 6-8.[15] This Web resource contains many tools for the teacher, including background information, student readings, test questions, and activities. Each activity includes the layout of more formal experimentation with sections that include objectives, evaluations, and safety information. Further alignment with Common Core English Language Arts (CCELA) (K-12 literacy standards)[16] makes this Web resource particularly helpful.

An example from this resource, Chapter 5, Lesson 6: "Does Temperature Affect Dissolving?" allows exploration of the effects of energy on dissolving properties of M&Ms. Again, this is an illustration of using everyday materials for something highly relatable for teachers and students alike.

The ACS also provides resources for the next grade group, 8-12, using the *ChemMatters* magazine.[17] While a subscription to the magazine is not free, many articles can be accessed for free on the website. More than just articles on some interesting topics in chemistry, the magazine site includes teacher's guides with worksheets and answers, connections to concepts and science standards, background information for the teacher, and a list of sources and further information. These articles and the teacher's guides that accompany them are an amazing resource for the 7th/8th grade or high school teacher. This author (L.A.) has used some of these articles in her 7th/8th grade AND general-education college-level chemistry course. Another resource is an article on Edutopia listing websites for science teachers[18]; notably, No. 8 is a link to a Periodic Table of Videos![19]

Other available resources are listed in the references below, and one of the authors (L.A.) is collecting all of this information in this evolving website: https://sites.google.com/andrews.edu/k-12-educational-resources/home. They include links to websites from museums, other chemistry societies, and individuals who have freely provided ways to get kids doing science (often with things one can purchase).

Physics

There are many sources for aggregated resources for physics education. We will give a summary of some of the more interesting ones we have found and currently use.

Compadre is the education tool hub for the American Association of Physics Teachers (AAPT).[20] This AAPT digital library has many simulations and tools that are free to the public. The American Physical Society (APS), has collected information for K-8 and high school teachers, and is one of the primary hubs for physics research in the U.S.[21] CyberBee is an independent aggregator with a simple interface but limited selection, although it is curated by former teachers.[22] Last, we have selected Science Buddies as a resource for elementary teachers. This site includes relatively easy demonstrations for teachers to perform or lead, and discussions about the physical phenomena being demonstrated.[23]

The other physics resources listed here are collections of materials produced by HyperPhysics. Developed by Rod Nave at Georgia State University, HyperPhysics is a digital textbook that provides a quick summary of most topics in the field. If provides a quick refresher for teachers preparing a lecture on a topic about which they feel rusty. Originally designed for physics, it has since been expanded to include biology, chemistry, and geology, in partnership with other institutions.[24]

PhETs are simulations of physical situations. They can be used as demonstrations during lectures, as the basis of an inquiry activity during class, a virtual experiment from which to collect data, or as an example to refer to during homework. These versatile animations were developed by the University of Colorado at Boulder. Nobel Laureate, Carl Wieman began this project in 2002 as a teaching tool, and it has grown into a great place to find resources to help keep lectures interesting.[25]

Other Sciences

As mentioned above, HyperPhysics has branched out into chemistry, biology, and geology, creating a great reference link for teachers to access refreshing topics.[26] The National Science Foundation provides a list of links at some different sites for various grade levels.[27] While much of the NSF site is dedicated to research, some of the material is written at a popularized level to try to increase public appreciation of science. Share My Lesson is a teacher-sharing website where teachers can upload their lessons and share them with others.[28] If a starting point is needed to plan a lesson on a difficult topic, the Share My Lesson site is a great resource to see how other teachers have tackled it. Another site with a list of links is from Common Sense Education,[29] providing resources from biology to chemistry to physics. ✐

Resources in this article have been peer reviewed.

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10. Emma R. Corcoran et al., "Thirst for a Solution: Alginate Biopolymer Experiments for the Middle and High School Classroom," *Journal of Chemical Education* 99:2 (December 29, 2021): 1,021-1,025: acs.jchemed.1c00905. doi.10.1021/acs.jchemed.1c00905.

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13. Next Generation Science Standards (NGSS) are a collection of research-based science standards for grades K-12 developed by the National Research Council. The standards are designed to help educators build science literacy, stimulate interest in STEM, and prepare students for college and future STEM occupations. For more, see https://www.nextgenscience.org/get-to-know.

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15. J. H. Kessler, P. M. Galvan, and A. M. Boyd, "Middle School Chemistry," American Chemical Society: https://www.middleschoolchemistry.com/.

16. Common Core English Language Arts (CCELA) help educators prepare students for success as citizens who can read, write, speak, listen, and use language to communicate in all disciplines and careers. For more, see http://www.corestandards.org/ELA-Literacy/.

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24. "HyperPhysics Concepts": http://hyperphysics.phy-astr.gsu.edu/hbase/hph.html.

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26. "HyperPhysics Concepts."

27. National Science Foundation, "Education Classroom Resources" : https://www.nsf.gov/news/classroom/education.jsp.

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