SPECTRUM

ISTA

Fall 2014, Vol. 40, No. 2

The Journal of the Illinois Science Teachers Association

In this Issue: **Using a Microwave to Prepare Bacterial Media for Inquiry**
On Returning Thirteen Years Later
Exploring Conceptual Understandings of Groundwater

Plan Ahead:
Science in the South - November 7 - 8, 2014 at Southern Illinois University at Carbondale
NSTA National Conference on Science Education - March 12 - 15, 2015 in Chicago, Illinois

Illinois
Science
Teachers
Association

Spectrum

The Journal of the Illinois Science Teachers Association
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Send submissions and inquiries to the editor. Articles should be directed to individual area focus editors (see next page and *write for the SPECTRUM information).*

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Cover: A student inoculates bactera onto an agar plate. See the article on making bacterial media using a microwave on pages 13-19 in this issue. Photo courtesy of Judy Scheppler.

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The Journal of the Illinois Science Teachers Association

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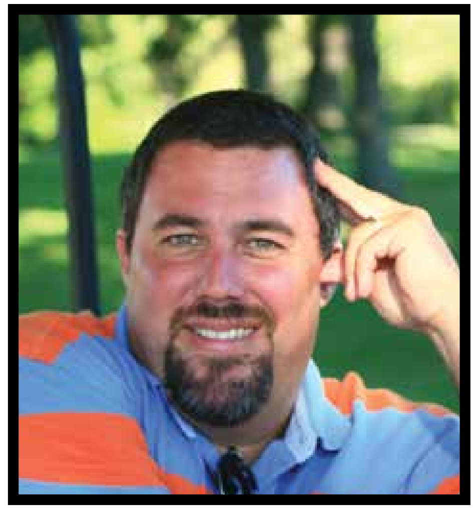
President's Corner
Paul Ritter



The leaves are falling and the wind is blowing. Those warm days are getting fewer and farther between. I can hardly believe that it is October already. That being said, your ISTA regional and appointed directors and the executive committee are working hard for you and your students and our organization. Recently, the Illinois State Board of Education decided to change the rules regarding what groups could provide recognized professional development for educators. This rule change would have had a major impact on our state conference, as well as any other ISTA PD opportunities. The executive committee and many board members started writing letters and making lots phone calls to gather better information. As a result of the ISBE decisions, ISTA organized a conference call with presidents of eleven other professional associations. With a coordinated effort facilitated by ISTA, we and the other associations submitted our comments and recommendations to the State Board. In response to our actions, the Illinois State Board of Education is now going to recognize ISTA and the other state subject-specific associations as providers of professional development. Three cheers for everyone who made it happen. Hip, Hip, Hooray!

Looking for engaging workshops like I am? Want to present about things you are doing? Drew Donahoo and the Science in the South (SIS) planning committee are putting together a great program for the 19th Annual Science in the South Conference. Please note that presenters receive free conference registrations. The conference will focus on new Illinois Learning Standards for Science with a full day of presentations and exhibits on Friday, November 7, a social event on Friday evening, and field trips or workshops on Saturday, Nov. 8. It will be at the Southern Illinois University at Carbondale Student Center and parking will be included with registration. Other conference information including for commercial and non-commercial exhibitors is available at this website.https://www.dce.siu.edu/index.php/conferences/242-science-in-the-south See you there.

Do you have students who have taken great ideas and made them a reality? Are your student's projects making a positive difference in your community? Do you know any high schoolers that could answer yes to the above? If so, the University of Illinois and ISTA wants to recognize them: http://innovative100.engineering.illinois.edu/

The Celebrating High School Innovators event will honor high school students across Illinois who have been able to meet current and emerging social needs through innovation in one of five areas: 1) Arts, Media, and Literature, 2) Business Entrepreneurship, 3) Food, Health, and Nutrition, 4) Social Entrepreneurship, and 5) STEM. These are not necessarily the students with perfect test scores or a 4.0 GPA, but those whose curiosity, creativity, passion, and dedication have led them to change their communities and have inspired those around them to do the same.

The one hundred competition finalists will have their achievements recognized in a first-of-its-kind celebration at the University of Illinois where they will be hosted for a two day event designed by students. In attendance will be innovative professionals in each of the areas, along with high-level university and government officials. Finalists will have the opportunity to network with other student innovators from their area of interest, be profiled in a book of young innovators, and become a part of a statewide study into how to better encourage innovation in our school systems. Have them apply today: http://innovative100.engineering.illinois.edu/apply

Have you ever thought about running for an office with ISTA - as a regional director or executive board member? If you have, that is fantastic because it is election time here at ISTA and we are ready for you to be a leader. If not..... Why not? You have what it takes. By getting elected, you could help our organization be the very best it could be in representing the thousands of formal and informal science educators of Illinois. In turn, this would have a major impact on the lives of our children. All too often people just sit back waiting for someone else to be the leader because they are not sure what to do. Well... I am here to tell you..... You can do it. You can be the champion. You can be the person who makes the difference. What is holding you back? Not sure what to do? Time? Worried you will make some wrong decision of some sort? I understand the time argument, but we always find the time to make great things happen. We learn from each other and our different perspectives. What we can't do, is wait for some knight in shining armor to come in and champion our cause or save the day. The real hero in the story is YOU. With your decision to run, you are single highhandedly saying you are willing to stand up for what's right, the future of science education and the best education for our children. Mahatma Gandhi once said, “Be the change that you wish to see in the world.” You are the change. Please consider being our hero and run for one of our open positions.

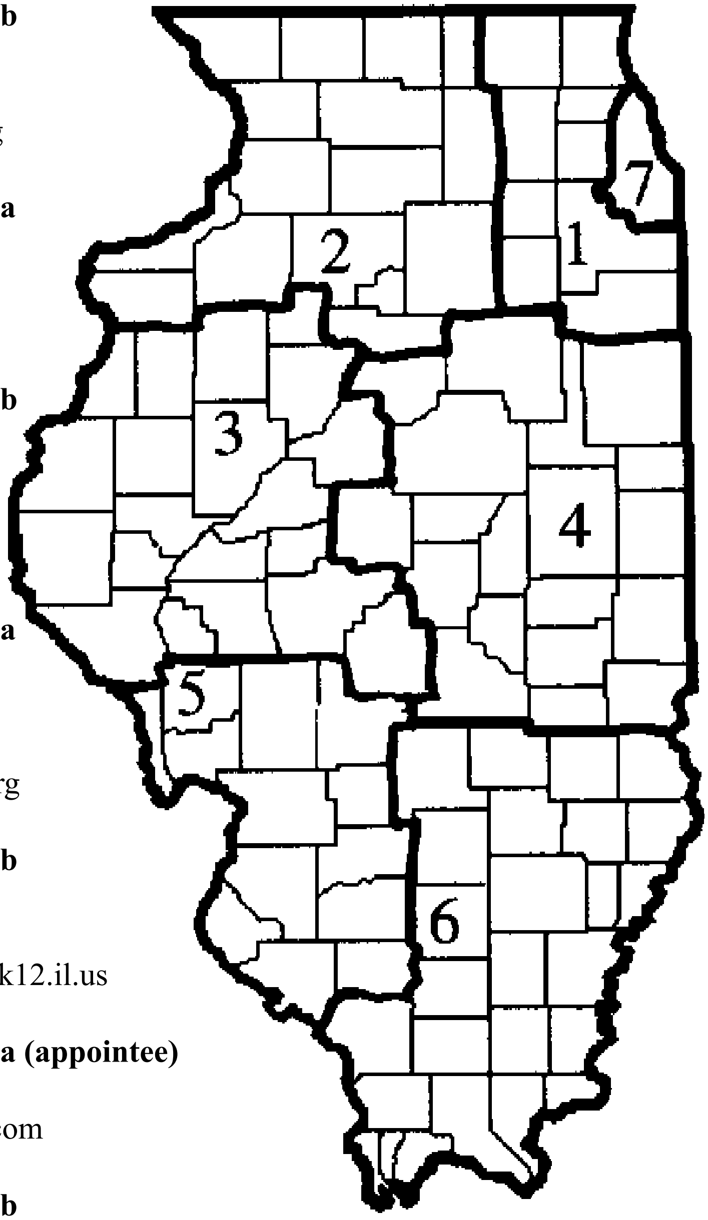
Paul

NSTA 2015

in Chicago at McCormick Place

March 12 - 15, 2015

Regional Directors



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http://www.ista-il.org/

According to ISTA bylaws, regional directors may serve only two consecutive terms. Directors noted with an “a” are in the first of a two-year term; those noted with a “b” are in the second consecutive two-year term.

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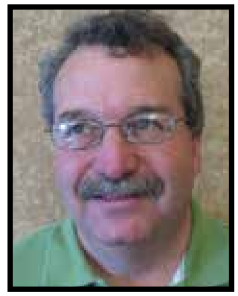
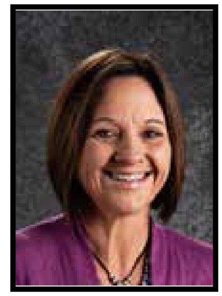
carrollk@shiloh.k12.us





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Career Building	Steph Marlette
Career Development	Kendra Carroll
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E-Communications	Hethyr Tregerman
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Informal Science	Lindsey Snyder
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Membership Secretary	Pam Spaniol
Nominations and Elections	Paul Ritter
Publications	Judith A. Scheppler
Safety	Cindy Birkner
Science Matters	Mary Lou Lipscomb
Special Education	Maya Israel

Making Differences for You

ISTA Membership Benefits

- Discounted rates for conferences including 2015 NSTA Chicago
- Lifelong science education friends, connections, and resources
- Ability to participate in PEL hour-credit workshops that will connect with new Illinois science standards and the national NGSS standards
- Ability to collaborate with leading Illinois science teachers from kindergarten through college levels
- Access to discussion forums
- Professional development opportunities
- Access to ISTA's ListServ
- Free monthly e-mail newsletter or e-blast containing current science information and events of interest to attend in Illinois
- Additional memberships (by mail) for convenience, shared benefits, and savings for the below:
    - Fermilab Friends of Science Education, http://ed.fnal.gov/ffse
    - The Illinois Section of the American Association of Physics Teachers, http://isaapt.org/
    - The Illinois Association of Chemistry Teachers, www.iact-online.org/
    - The Environmental Education Association of Illinois, www.eeai.net/
    - The Council for Elementary Science International, www.cesiscience.org/
    - The Chicago Council for Science and Technology, www.c2st.org
- **Join ISTA or renew your membership at www.ista-il.org/membership**

Print Form

19th ANNUAL SCIENCE IN THE SOUTH CONFERENCE
SOUTHERN ILLINOIS UNIVERSITY CARBONDALE
November 7-8, 2014
PARTICIPANT REGISTRATION

15D0901501

First Name: ______________________________

Last Name: ______________________________

School: ______________________________

Home Address: ______________________________

City, State, Zip: ______________________________

Day Phone: ______________________________

Cell Phone: ______________________________

E-mail: ______________________________

Grade Level (K-12): ____________ Special Dietary Needs: ____________

____

I plan to attend lunch: ☐ Yes ☐ No **I would like a parking pass** (no addt'l charge): ☐ Yes ☐ No

I plan to attend the Evening Gala: **$25** (featuring hors d'oeuvres and beverages.) ☐ Yes ☐ No

Payment Information

Participant Fees (Includes Lunch): **On or before 10/24/14**: $80 **After 10/24/14**: $95

Student Fees: **$22** (Includes Lunch)

Credit Card # ______________________________ Exp. Date: __________

Name on Card: ______________________________

Billing Address: ______________________________

Payer Email (required): ______________________________

Bill the school: ______________________________

____

ATTN: ______________________________

Return to: Science in the South
Continuing Education and Outreach
Mail Code 6705
Southern Illinois University
Carbondale, IL 62901

Questions? Drew Donahoo
Phone: (618) 536-7751
Fax: (618) 453-5680
Email: drewdonahoo@siu.edu

Science in the South

November 6 - 8, 2014

Southern Illinois University at Carbondale

See the ISTA website for conference details and registration information.

Luncheon Keynote Speaker:
John Schwegman
Nature Conservationist at the Illinois Department of Natural Resources
"Natural Divisions of Illinois"

Do *You* Know an Exemplary Science Student?

ISTA members in good standing who would like to honor one high school science student each year, may request an **ISTA medallion and certificate** by contacting pamela.spaniol@yahoo.com. The first medallion is free of charge; additional medallions may be obtained for $15 each.

This award program is supported by contributions from the Illinois Petroleum Resources Board.

NSTA National Conference

Coming to Chicago!

March 12 - 15, 2015

McCormick Place

Want to Volunteer?
Assistance is needed from volunteering at the conference helping attendees, to supervising field trips, stuffing conference bags, and more. Volunteers may be eligible for waiver or partial waiver of registration fees, depending on the number of hours volunteered. Go to the ISTA website to sign-up.

Sign-Up to Volunteer
https://docs.google.com/forms/d/1PMHmxhPXjN2DMpkMsZJ4W3ZAsYOaftQFEYH0rnxINmI/viewform?usp=send_form

Local Contacts

Conference Chair Wendy Jackson - wjackso7@depaul.edu
Program Coordinator Natacia Campbell - natacia.campbell@gmail.com
Local Arrangements Coordinator Judy Scheppler - quella@imsa.edu

Conference Strands
Natural Resources, Natural Partnerships
Teaching Every Child by Embracing Diversity
The Science of Design: Structure and Function
Student Learning: How Do We Know What They Know?

NSTA 2015

Book Reviews

By Thomas Hansen

Succeeding with Inquiry in the Science and Math Classrooms. 2013. Jeff C. Marshall. Alexandria, VA: ASCD.

Teachers may be very interested in the system Jeff Marshall has created for helping students learn to use inquiry in their classroom activities. Marshall has established some helpful ways to encourage students to develop skills, methods, ideas, strategies, and attitudes related to inquiry.

Marshall uses a developmental and sometimes metacognitive approach that forms good problem-solving skills in general. He makes the point that science teachers, especially, are familiar with inquiry-based instruction because of the nature of the national standards they employ. He also explains that the new standards to be used in the mathematics curriculum lend themselves easily to inquiry-based activities, learning, and assessment also.

Marshall uses three elements in improving student learning: 1) inquiry-based instruction, with four phases (Engage, Explore, Explain, and Extend); 2) formative assessment; and 3) teacher reflective practice. He provides in-depth explanations of the four phases, and he includes several science and math teaching scenarios. They are all plausible and interesting activities, and they are based on research and standards.

The book could be used for both science and math lessons, and the inquiry fit seems to be a natural one. Inquiry also can be used as a way to build and unite interdisciplinary units among math, science, and other subjects within the curriculum, this being a more natural way to approach learning and teaching tasks. The Illinois Learning Standards facilitate this because of the parallel language used across subjects and the similar phrases used within benchmarks. For example, these Social Science benchmarks can be used to build on math concepts:

15.A.4c Analyze the impact of inflation on an individual and the economy as a whole;

15.A.5c Analyze the impact of various deter¬minants on the levels of GDP (e.g., quantity/quality of natural/capital resources, size/skills of the labor force).

15.B.5a Analyze the impact of changes in non-price determinants (e.g., changes in consumer income, changes in tastes and preferences) on consumer demand.

15.B.5b Analyze how inflation and interest rates affect consumer purchasing power.

Another example is using the Illinois Foreign Language benchmarks to further develop skills and approaches in inquiry:

29.A.5 Analyze and interpret manners and customs within the social, academic and work environments of selected target language societies.

29.C.5c Compare topics, types and styles of media communication in areas where the target language is spoken.

29.D.5 Analyze different perspectives of historical events using a variety of media and technology tools.

These Foreign Language benchmarks reinforce math skills and inquiry together:

30.A.5a Describe and explain factors affecting economic conditions in target language country(ies) compared to the United States.

30.A.3b Use the target language to gather and organize data to solve math problems.
30.A.4b Use the target language to analyze and solve math problems based on timetables, schedules, charts and graphs in the target language.
30.A.5b Use the target language for math skills such as statistical analysis, estimating and approximating in experiments or research projects.
30.B.5a Use the target language to analyze data relating to job opportunities, preparation, wages/salaries, etc., of occupations in areas where the target language is spoken.

Using science-based inquiry approaches is easy among the learning areas in this state because all seven goals subjects of the Illinois Learning Standards are based on the format, benchmarks, and assessment-related language of the national science standards. Many more natural and realistic units and lessons can be designed because we usually use skills and content together in everyday life.
This is a helpful and clearly written book I am recommending not just because of its clear examples for science and math classrooms, but also because of its strong potential for use in interdisciplinary configurations. This text is full of interesting examples of how to use Marshall's approach to helping provide classroom projects and scenarios for students to explore. A bit involved for a brief professional development session, the book is better suited to use in a course for teachers or teacher candidates. Readers should know, however, that the first ten or twelve pages explain Marshall's approach in depth and are perhaps a bit too wordy for more experienced teachers or administrators or curriculum designers. If you are working with a group of experienced educators, you may wish to have them skim the first chapter and then get to work right away on however the book will be used.

Proposals That Work: A Guide for Planning Dissertations and Grant Proposals (6th ed.). 2014. Locke, L. F., Wyrick Spirduso, W., & Silverman, S. J.   Los Angeles: Sage.

There are many popular books out there about writing proposals for research, for dissertations, and for grant funds. But which book is more comprehensive if you are planning a career of focused research over time?

One very helpful book for writing research proposals to institutions and grant applications to federal agencies is Proposals That Work, now in its sixth edition. This book is full of relevant information and is comprehensive, if one is serious about a longer-term career-oriented research plan. It covers the basics of writing dissertation proposals, dissertations, research proposals, and grant proposals. This book is essential for the serious graduate student planning to pursue focused research as a main part of their professional career.

The authors include three main sections, with one on the functions and structure of a proposal overall, plus the details on different types of proposals, research methods, and proposal formats. The second section is about finding the funds to conduct research, including a section on planning and writing the grant proposal itself. A third section shows four example grant proposals for: an experimental study; a qualitative study; an online study, and a funded grant.
From information on mixed methods research to planning the grant budget, Proposals That Work is of the three books the most comprehensive and applicable to longer-term research plans. Writing for clarity is stressed throughout this book.

The book also includes basic and clear information on how to actually write the proposals. A lot of the common sense advice about planning, networking, relationships, and accuracy also apply to writing applications for grants.   This book is especially recommended for graduate students who are serious about their studies and careers, a lot of what they do toward the end of graduate school being linked directly to what they will most likely be doing at the beginning of their career.

An important reminder for any grant writer is that in many grant competitions run by US agencies, the readers have been chosen because they are experts in other types of grant programs, they are directors of grant projects, or they are well-known in other fields but aware of how good grant projects are organized. Embracing the call for clarity found in this book is essential if you want to get your research plan accepted and get some grant dollars for major research projects.

Writing for an educated and informed group of readers is important, at the same time you provide clear definitions and examples to assist them in understanding your grant proposal. Using this book can help you design proposals of various types to win those grant competitions. This title is a good guide for the newer proposal writer and a good reference book also. It could also be used in grant-writing courses with a longer duration. Because of the length and depth of the book, it is less suited to short workshop format.

How the Poor Can Save Capitalism: Rebuilding the Path to the Middle Class. 2014. John Hope Bryant. San Francisco, CA: Berrett-Koehler.

Educators may be interested in the financial literacy education and other methods proposed by the author of this book to help change America. At the core of this book is the need to teach kids about how capitalism works and how those kids can succeed.

John Hope Bryant explains in this brief book his reasons for wanting to help the poor, explains how the poor do not understand capitalism, and shows the importance of investing in education as the principle way to help. Bryant shows a firm understanding of how to bridge different worlds.

Bryant tells of several interesting strategies that can be used to reach the poor, educate them on important information they need to succeed, and move up into financial security. He has already had some success in the schools with his financial literacy education programs. He has organized his efforts so they can have broader appeal and use nationwide as he works to help those in poverty.

He has two main ways to solve the financial issues of the poor. The first is the Hope Plan which includes several key components. One is establishing federally-funded financial literacy education for every child in the nation. In the long run, this can pay off. The second way is through Project 5117, a four-pronged approach to fighting economic inequality. One piece has to do with empowering five million young people with financial literacy; another is to help one million of them to become entrepreneurs in their home communities. Bryant has clear ideas how to achieve his goals, and he has already begun work on them.

Bryant hopes for a new generation of educated, empowered, inspired young people, who are informed homeowners and contributing business owners. He has already gotten the support of some strong allies in the political and entertainment worlds.

We educators need to consider Bryant's ideas and plans. Helping the poor is an honorable endeavor. And as Bryant shows, it is a good investment. I recommend this book because I feel strongly we need some good rigorous models for assisting the poor, helping them to participate in the dialogue, and helping them to contribute to society.

Author Information

Thomas Hansen, Ph.D., is an independent consultant with a variety of roles in education and advocacy. Current areas of work include grant writing and grant reviewing. He also teaches courses in education and teacher certification as an adjunct professor. He has had over fifty book and movie reviews published and over forty articles and essays printed.

Watts Cooking: Using a Microwave to Prepare Bacterial Media for Inquiry-Based Experiments

Judith A. Scheppler
Illinois Mathematics and Science Academy

Abstract
Microbiology provides an excellent opportunity to capture student interest, encourage exploration, and to begin the development of research skills. With a low power microwave, similar to the type found in homes, and a short list of materials easily obtainable and/or found in many biology laboratories, you can begin to open this exciting world to your life science and biology classes. Microwaves are available at very reasonable prices, and can substitute for a much more expensive laboratory autoclave. Your students can choose and design inquiry investigations as well as learn basic laboratory techniques.

Bacterial Culture
Students across all grade ranges and ability levels are naturally fascinated by the growth of microorganisms, especially those growing in their environment. However, in order to observe and study bacteria, growth media, or food that the bacteria need to thrive, must be prepared and sterilized. In a research or clinical laboratory this is done by heating the media to 121 ºC and 15 psi pressure, a process known as autoclaving. This kills both vegetative and spore forms of microbes and is the most effective method of sterilization. However, an autoclave (figure 1) can be very costly and is not always available in schools with increasingly tight science budgets. Purchasing prepared media plates can be costly. Using a low power microwave provides an inexpensive alternative for preparing sterile media to be used in investigations of bacterial growth most often performed in schools. The depth of these investigations will depend on the knowledge base students bring to this experience.

Preparation and Sterilization of Luria-Bertani Agar for Bacterial Growth
Bacteria media plates will need to be prepared at least one day in advance of carrying out any experiment. The following procedure should be used to prepare sterile Luria-Bertani (LB) agar media, in a microwave, for use in experiments with bacteria. Other kinds of bacterial media may be prepared in a similar manner. Luria-Bertani broth is made with the same formulation, leaving out the agar; the agar (similar to gelatin in Jello-O) serves to make the media semi-solid.

Materials
- sterile swabs (Q-tips, though not sterile, are clean and work fine)
- balance
- microwave
- hot pads
- 1 ml pipetting device and 1 ml pipettes
- four sterile plastic petri dishes per student group
- one 250 ml flask or bottle per group (make sure it isn't too tall for the microwave)
- wax marking pencil or permanent marker
- tryptone
- yeast extract
- sodium chloride
- agar
- solution of 0.1 N NaOH
- distilled water
- beaker or tray containing 10% chlorine bleach for disposal of used swabs and Petri dishes



Figure 1. Left: A large industrial size autoclave; cost $10,000+ plus plumbing and electrical work required. Middle: A small table-top autoclave; cost ~$2000 - $5000 or more. Right: A household microwave; cost $100 or less.

Optional materials for Sabouraud's agar
- peptone
- dextrose

Procedure

1) Obtain four sterile Petri dishes and label the bottom with your name, date, and "LB," then turn the plates right side up. This identifies who made the plates, how old they are, and what media is contained in the Petri dish. The Petri dishes are already sterile, so do not take the lids off the plates until the media is poured into the bottom.

2) Weigh out the following ingredients for "LB" and place all of them into a 250ml flask or bottle:

1 gram of tryptone
0.5 gram of yeast extract
1 gram of NaC1
1.5 grams of agar

- Use a container that holds two to three times the volume of media you wish to make so that the media can boil vigorously without boiling over. Make sure your contained will fit in the microwave.

3) Add 100 ml of distilled water and 1 ml of 0.1 N NaOH. Do not put a lid on the container.

Students should be assisted with the following steps

4) Microwave the media for 60-90 seconds to bring the solution to boiling and to dissolve the ingredients. The media should boil vigorously for about 5 seconds, but microwaving for too long will boil the solution over. Once done, the solution should appear clear with no media granules visible. If the media is not clear, then continue microwaving in short 10-15 second bursts until all components are dissolved (figure 2).

- This procedure was worked out for a 1000 or 1100 watt microwave; microwave ovens of lesser power will require slightly longer times.

5) Once all of the ingredients have dissolved, microwave the solution for 15-20 seconds to bring it to boiling. The solution should boil vigorously again, but not boil over.

6) Bring the media to boiling two more times by repeating step 5 twice.

- Be very careful because the bottle is very hot. Media may superheat. This means that it may boil up when agitated, even after the initial rolling boil has stopped. Allow the bottle to stay in the microwave for a few minutes before handling to reduce the danger associated with superheating. Use hot pads when handling the media from the microwave.

7) Place the bottle of LB agar media in a water bath, adjusted to 56 ºC, and allow the media to cool. Loosely cover the bottle with its lid or a piece of foil. This temperature will prevent the media from solidifying, but allow it to be handled more safely and easily. Petri dishes may be poured immediately after microwaving, with close and careful supervision, but it is best to

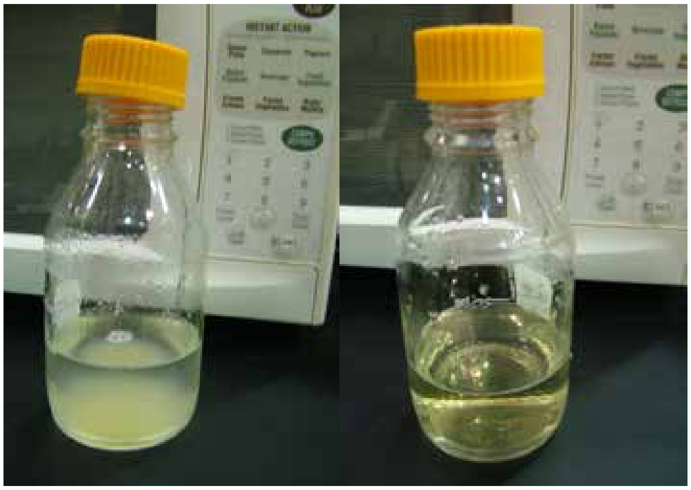

Figure 2. Left: Flask with poorly dissolved agar; note the cloudiness of the liquid and the powder granules at the bottom. Right: Flask with agar that has been properly heated in a microwave to thoroughly dissolve the agar. Note that the liquid is clear.

cool the media to avoid student burns and melting plates.

8) Pour the liquid LB agar media into the bottom of the four petri dishes. Pour slowly and stop when the media has covered the bottom of the plate (about 20-25 ml). Be sure to work in an aseptic manner. This means do not leave the Petri dishes open on the lab table and replace the covers as quickly as possible.

9) Allow the plates to sit at room temperature until the agar has solidified. Do not move or tilt the plates until the media has hardened. Plates may be stored at room temperature for several days before use. Plates should be stored inverted, with the solidified agar media in the "top" so that condensation (a potential source of contamination) can't fall onto the agar (figure 3). For longer storage, place the inverted agar plates in a plastic bag to prevent dehydration of the media and store them stacked in the refrigerator. Plates may be stored in the refrigerator for one month or longer.

Bacterial Incubation

Once the media plates have been inoculated with bacteria, the Petri dishes are incubated upside down. The dish will rest on its cover and the bottom, containing the media, will be on top. This prevents any moisture, which may have condensed in the lid when the warm media was poured, from falling into the bacteria and contaminating them or disrupting colony formation. Most bacteria like to grow in warm places. Usually 37 ºC, which is also body temperature, is perfect. Obtaining this temperature, however, requires an incubator that many classrooms may not have. A very viable alternative is to grow the bacteria at room temperature, usually about 25 ºC. The bacteria will still grow, just more slowly than they would at 37 ºC. Try to pick one of the warmer locations in the room, such as away from the windows in the winter. Avoid placing the Petri dishes directly onto a radiator or heating vent, however, as the metal may get hot enough when in direct contact with the plastic Petri dish to melt it and the agar. Growth is usually assessed after 24 hours, but plates may need to incubate for 48 hours or longer if incubation temperatures are less than 37 ºC.

An Inexpensive Incubator

A heating pad and Styrofoam container can be used to make an inexpensive incubator. Place a heating pad in the bottom of a plastic or Styrofoam bin, then put four jars in each corner and put another bin on top of the jars. Put the plates in the upper bin, and cover your incubator with a lid.

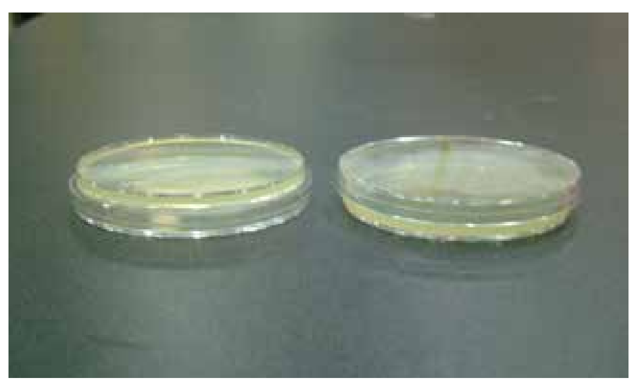

Figure 3. Left: A Petri dish turned upside down. Right: An agar-filled Petri dish with the agar in the bottom; note the condensation on the lid of the dish. Petri dishes with agar should be stored upside down, and dishes should be incubated upside down to prevent condensation from falling onto the inoculated agar.

Dry Heat for Sterilization

Your household oven can be used to dry sterilize items such as glassware and forceps. Make sure that the items you wish to sterilize will not melt or burst into flames. Forceps can be wrapped in aluminum foil and beakers and flasks can be covered with aluminum foil. Make sure that any screw-on caps are loosened. Place the items in an oven heated to 170 °C (340 °F) for one hour. Allow the items to cool to room temperature before using.

Classroom Inquiry and Data Analysis

As early as the elementary grades, students can use prepared agar plates to investigate such phenomena as the antibacterial effectiveness of different brands of liquid soaps or hand sanitizers. Students can touch their fingers to the media before and after using the product to study the reduction of bacteria on washed or treated hands. Plates should be taped shut immediately after inoculation and not opened by the students when they examine their results.

The more sophisticated experimenter may wish to vary the amount of soap or sanitizer used or the length of time spent washing hands. For a different environmental study, students may wish to investigate the quality and quantity of bacteria found in different locations such as on telephone mouth or ear pieces, buttons on a candy machine, drinking fountains, lockers, water faucets (no toilets; or swabbing other students), and so forth, in their school. Using swabs, such as Q-tips, they may swab different identified areas to pick up the bacteria then gently rub the swab across the media plate, being careful not to drag the swab on the agar and tear the media.

Data analysis for classroom bacterial growth experiments can be both quantitative and qualitative. Students can count the number of bacteria obtained from a given location and compare quantities at different sites. Besides observing the numbers of colonies, students can also identify types of organisms by colony morphology. Discussion of these colonies could include the way in which the organisms spread out on the media as well as a comparison of their shape, color, and texture. Incubation at room temperature might produce the growth of mold colonies as well as bacteria. Molds tend to prefer temperatures lower than 37 ºC. The more advanced learners could be encouraged to classify the microbes and relate them to the locations where they were found.

Science Fair Investigations

Bacteriology experiments provide a wealth of investigations that students can easily extend into science fair investigations. Students can experiment with changes in the physical and chemical conditions of the media to determine the effect on bacterial growth. For example, changes in temperature and pH will alter bacterial growth, as will changing the salt concentration (osmotic pressure). Many household products claim to be germicidal, killing microbes, or bacteriostatic, stopping or slowing their continued growth. Students may test whether these agents actually perform as claimed by using a modification of the Kirby-Bauer disc assay (Bauer et al, 1966). This assay traditionally uses discs which have been impregnated with antibiotics to test whether a particular bacterial isolate is treatable with an antibiotic. Students may test their own compounds by using sterile filter discs, approximately 1 cm in diameter (Scheppler et al, 2003).

Inoculation of Agar With Bacteria

1) Begin with an overnight liquid culture of bacteria, or scrape some bacteria off of an agar plate and place it into liquid media making a bacterial suspension. Good strains to use include *Escherichia coli* (MM294 or K-12), *Staphylococcus epidermidis*, and *Bacillus cereus.* These are common organisms found in and on humans and in the environment, but are considered safe to use in the classroom.

2) Dip a sterile swab or Q-tip into the bacterial culture and inoculate an LB agar plate by gently wiping the bacteria-laden swab all over the surface of the agar.

Preparation of Test Agents

3) Prepare a solution of the desired test agent. For convenience, solutions may be poured into

Figure 4. Filter paper discs, impregnated or soaked in a solution being tested for anti-bacterial properties, is gently placed onto Luria-Bertani agar that has been inoculated with B. *cereus.*

sterile empty petri dishes. It may be desirable to test different concentrations of the agent by diluting the product according to the manufacturer's directions for use. Many products are intended to be used at full strength.

- Potential test solutions include various drinks (coffee, tea, soda); different spices (salt, pepper, cumin, ginger, hot peppers); different mouth wash brands; cleaning products, and so forth. Your students can choose, conduct background research, and provide rationales for their choices (Scheppler et al, 2003).

Application of Agent-Impregnated Discs to Bacterially Inoculated Media

4) Using a sterile forceps, dip a sterile filter disc in the solution and place the disc onto the surface of the agar. Students will need to set up appropriate controls (figure 4).

Bacterial growth

5) Incubate the plate, inoculated with the bacteria and containing the disc at 37 ºC for 24 hours; incubate longer at room temperature

6) Observe the plate for bacterial growth. If the inoculated bacteria are sensitive to the antibiotic, an area free of bacteria growth will be observed around the outside of the disc.

Analysis

Students can measure the diameter of the area free of bacterial growth. Replicates can be averaged, and standard deviation determined. Students can perform simple statistical analysis comparing one test agent on different bacteria, or comparing different test agents on the same bacteria (figures 5 and 6.)

Bacterial Transformation

Using plasmid DNA to change bacteria is one of the laboratory exercises included in the Advanced Placement (AP) Biology curriculum (College Board, 2012). A very simple procedure for performing this lab, adapted from Hanahan et al (1983), is included in the AP lab manual, and in Scheppler et al (2000). Many teachers purchase prepared kits. Purchasing the individual components to perform this laboratory may cost more initially, but there will be plenty of reagents which can be used for multiple classes as well as science fair investigations. The reagents, if stored according to the manufacturer's instructions, will last for several years or longer.

Microbe Isolation

Students may wish to experiment with different media to select and isolate different types of organisms. LB agar, which will grow bacteria preferentially, and Sabouraud's agar, which will grow yeast (fungi) may be used. The lower pH of Sabouraud's agar inhibits many bacteria, but favors growth of fungi. The recipe for Sabouraud's agar is 1 g peptone, 4 g dextrose, and 1.5 g agar per 100 ml distilled water. The mixture is microwaved for sterilization in a manner similar to the LB agar media and plates are poured using sterile petri dishes as discussed previously.

Microbes in Soil

There are approximately 10^8 bacteria in a gram of soil. The numbers and types of microorganisms isolated from soil will vary depending on the time of year and the location and quality of the soil sample. Students might compare different soil types such as sand, garden soil, dusty soil from a baseball diamond, and so on. This experi-

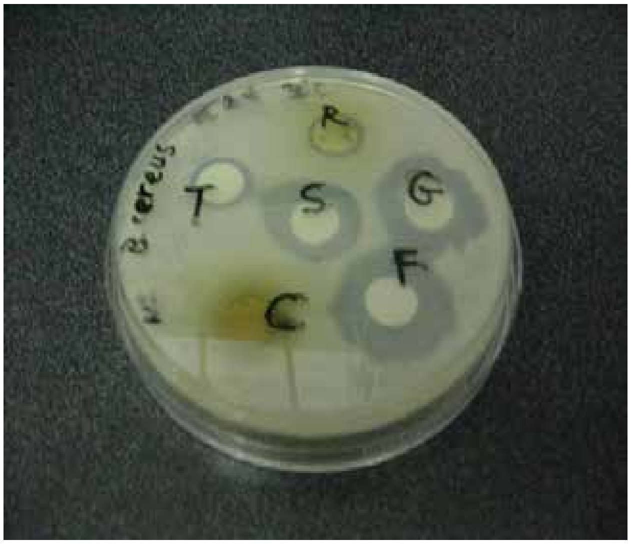

Figure 5. A Kirby Bauer disc assay. Filter paper discs were inoculated with various spice solutions and placed onto Luria Bertani agar inoculated with *B. cereus*. The plate was incubated overnight at 37°C to allow the bacteria to grow. Note that the discs labelled F and G have large zones of clearing around them, where the bactera did not grow. The discs labelled T and R have small small zones of clearing. The disc labelled S has a medium zone of clearing, and the disc labelled C shows no clearing.

ment could potentially develop into a year-long class project where students collect a soil sample each month, characterize the microbes present in the sample, and then correlate their data with environmental conditions such as temperature, rainfall, pH of the soil, and other factors.

To isolates bacteria from soil, students place 1 g of soil into 100 ml of sterile water. After vigorous mixing, 1 ml amounts of the microbe and water mixture are spread onto both LB and Sabouraud's agar plates using a sterile swab or spreader. Place the used swab in a beaker or tray of 10% bleach for disinfection. The plates are then incubated for one to seven days at room temperature and growth is observed. Fungi may require longer incubation periods for growth than bacteria. Students may need to spread smaller amounts of the soil inoculum onto the plates to obtain countable numbers of bacteria and fungi.

Safety Considerations

Students must use safe practices, which include good laboratory techniques during an experiment, proper clean-up after the experiment is finished, and adequate clean-up if a spill or other accident occurs. *E. coli* (MM294 or K-12) is an appropriate bacterium to use for bacterial transformation, altering growth conditions, and examining growth inhibition since it was designed for laboratory use and is not a wild-type strain. It is very important that any household items that you adapt for use in the classroom be used only for classroom experiments, and not revert to use for food or other non-laboratory activities.

When isolating bacteria from the environment it is possible that students may find bacteria that have the potential for causing illness. Although they are exposed to these organisms all the time, one must take appropriate precautions. Tape the dishes closed before students make and record their observations and do not allow them to open the dishes. When they are swabbing areas of the environment, do not allow them to swab other students, especially the mouth, nose, throat, ears, and so forth.

Note that some science fairs, expositions, and competitions may restrict where students and schools obtain their microbial cultures. It is possible that they will not permit investigations to be entered into a science competition that have used microbes grown from a primary culture obtained from humans or other warm-blooded organisms because of the risk of culturing a human pathogen. (A primary culture is one obtained directly from the organism.) Educators should review

Figure 6. A ruler can be used to measure the zone of inhibition around a compound impregnated disc and student can collect quantitative data and perfomr statistical analysis.

these guidelines and consider their own level of expertise when conducting experiments using microbes. There are many reputable biological supply companies that sell known, pure, and safe microbial cultures that can be used in these types of experiments.

At the elementary school level it is recommended that media plates be prepared for students, and that teachers encourage them to take part in the experimental design. Beginning in the middle school years, students should be able to mix ingredients together to make and pour their own media plates. Making bacterial media allows them to practice their laboratory skills of measuring both solid and liquid components. Students can then use the plates they made to conduct their own experiments.

Once the experiments are completed, you must disinfect the materials before discarding them. While autoclaving is the gold standard for sterilization, both in preparation of media for an experiment and for disposing of materials, other methods are satisfactory. An inexpensive alternative for disposal is household bleach. Prepare a 10% bleach solution and soak any swabs, equipment, and bacteria-containing petri dishes in it for at least an hour. This is sufficient to kill the bacteria and disinfect the surfaces. Follow your institution's guidelines for disposal.

Discussion

Preparing bacterial media in the microwave is an inexpensive and effective way to provide opportunities for students to participate more in laboratory experiments and to actually design their own experiments. These are appropriate exercises for inquiry-based learning.

I have successfully prepared LB agar in the microwave with many students as well as educators in various workshops. The younger students, ages about 10 years old (middle school age) and older, are closely supervised and assisted when pouring their plates. The classroom is set-up with two weighing stations and one microwave, so other activities are planned concurrently. Faculty workshop participants unanimously found the activity of preparing bacterial media in the microwave easy and useful. Most had not prepared agar petri dishes before. Discussions centered around the many ways that the plates could be used to examine bacterial growth in the classroom. All agreed that making the LB agar plates from scratch was less expensive then purchasing the media already prepared or purchasing a pre-packaged kit experiment. Using this method, the bacterial transformation laboratory from the AP Biology curricula becomes accessible to all biology students and could be used as a tool for various science fair investigations.

Once you have mastered preparing your own agar media for the growth of microbes, many experiments become easy to perform. For more ideas, obtain a microbiology laboratory manual and try out other experiments. Most experiments can be modified to address the needs and interests of your students. The possibilities are unending and your students will experience new growth.

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On Returning Thirteen Years Later!
An Educator's New Challenges Addressed

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Technology, as never before in history, makes today's students different than those who are just being introduced to the Internet.

In the winter of 2013 I begin to feel the impassiveness enter my life as I realized the disconnectedness that can come from teaching in the ivory tower. I do not say that to criticize others, but to say that I was teaching a generation of teachers and educational leaders who were functioning, in the most part, in a very different world from which I taught for over a decade ago. One might not think that little changes in a decade and in many ways the classroom is very resistant to change. But, it had. At least, the students had changed. Technology, as never before in history, made today's students different than those who were just being introduced to the Internet. To remedy this, and to ensure that I would be a better teacher and professor of education, I decided I needed to make a radical change. I needed to return to the secondary classroom to regain the love and passion for teaching kids that spurred me on to the career to begin with, and to better understand what teachers face now. It was not a choice that was easily made and those who knew me were not truly comforting. Some thought the move was career suicide. Whether that turns out to be the case or not, the move was necessary for me to avoid becoming an irrelevant and out-of-touch professor, some of which I have taken for classes myself.

The move back to the secondary classroom, however, has turned out to be exactly what I wanted and needed. A revival of the soul, a learning experience, a stretching of my mind and patience, in teaching secondary students the concepts of science. Herein is what I have learned from my return. In my experiences teaching in the 1990s I realized that I had students who could not read. Getting them to read the text was difficult. To overcome that, I tried desperately to build mini-lessons that tried to simplify the truths into small chunks that could be understood…whether the textbook was read or not. There were some successes and there were some failures. But rather than frustrate me, I took it on as a challenge and thus began my career to learn all that I could about how we learn. Knowing how students' best learn, we should be able to determine how to best teach. This is, nevertheless, a personal matter and what works for me may not work for another and what works for them may not work for me, as personal gifts are different among colleagues. Teaching is a science, but teaching is also an art. Nevertheless, the principles of learning tend to be guidelines for success. In returning to the classroom after a thirteen years hiatus¸ I am happy to say that there are some lessons I have learned from the new generation of students in our schools.

First, I found that todays' students, for the most part, can read…but won't! Some read, but do not entirely comprehend what they read, but they can read. It would be very easy for my teacher brain to just say that most students are lazy…and some of that would be true and justifiable in a court of law. But, that usually does little good in helping students to learn so I tried to dig deeper. Today's technology has drastically changed today's students. With Facebook, smartphone texting, and other of applications communication, and so forth, students read more now than ever…but they are reading less. That is, they are reading, but they are reading bits and blurbs. That is, they are reading and comprehending… but they are not reading paragraphs and structured writing. This creates a dilemma since most chapters in the science textbook are twenty-five to fifty pages long. I begin to try different strategies to get the students to read their assignments. Here are four strategies that helped me to overcome this reading quandary.

Teaching Reading Skills

At my re-entry to the classroom, I began to experience the district's new emphasis and focus on common core curriculum, which was being applied across disciplines. As I sought to determine what this really meant I saw the past flash before my mind from the back to basics days. Here, again, reading and mathematics were the centerpiece. At first, my response was to let it glide by my mind as I teach science, not reading. And though a few of us may teach math, most of us do not, except when it applies to science concepts. But, here I found the seed to help me understand how to overcome the reading issue. It was a strategy to get the students off to a good start in a chapter.

I spent some time the first three weeks teaching students how to read a textbook, and more specifically, how to read and decipher a paragraph. From that I led them step-by-step to write down the main points presented in each paragraph. This was, granted, painstakingly hard and time-consuming since I teach (and love) science, not writing. However, before returning to the classroom I had been teaching and mentoring doctoral students…and writing was one of the weakest areas, even of graduate students, and so, I determined that if I spent so much time teaching graduate students how to write, then like it or not, it would only be natural that I would have to spend a great deal of time teaching secondary students how to read. Reading is, after all, the crux of education. Without reading and comprehension skills we limit our abilities.

Teaching is a science, but teaching is also an art.

Reading stretches the mind and puts us in disequilibrium. Learning occurs when the brain moves from disequilibrium to equilibrium, according to Piaget. The assignment was assigned to a) read the chapter and provide a highlight for each paragraph, and b) define the vocabulary. The latter is routine practice among many science teachers, but not so with the former. For the first three weeks of the school year we meticulously worked through the textbook discussing what was important and what was not in each paragraph. There were times when I felt like I was wasting my time, and I certainly was not moving through the curriculum (or textbook) as I had desired or planned. But, persistence paid off. Students begin to demonstrate a better understanding, and making this a graded assignment, most completed it. It would be nice to say that 100% of the students benefitted from this strategy, but that was not the case. Most did benefit and continued to do so. Some, of course, found a way around the system or simply did a superficial job and received a superficial grade in return. A few, however, shared how they actually transferred that skill to other courses. One student, for example, said he was in an English class and given a short reading and told to summarize it. He told me he didn't know what to do so he just read each paragraph and wrote what he thought was the main point. BINGO! He made an "A" and was delighted by it. So was I. We continued this reading skill throughout the entire year. It became a part of our routine. I required they submit them and then keep them in their science notebooks. Occasionally, I did not collect them, but kept the notebook requirement.

Todays' students, for the most part, can read ... but won't!

This probably did more to ensure the textbook was read than any other strategy I have used. It, however, was not enough to convey the science concepts to most students. That leads me to the second learning strategy.

Interactive Readers

Reading the text is important. I also provided students with mini-lectures (10 to 20 minute presentations) utilizing PowerPoint with lots of photos, diagrams, and other visuals. In addition, I found that subsidizing lessons with short, outstanding, YouTube™ videos provided useful visual means of illustrating the material to be learned. However, getting students to revisit the textbook was problematic at best. So in my search, I encountered some interactive readers. These provided another means of reteaching the same materials in another manner, and sometimes from another angle. These texts rehashed what they originally read from creating main point statements, but in a more succinct manner. They were generally composed of short paragraphs with pictures, photos, graphs, and so forth and embedded questions in the margins that caused the students to respond to what was just read. My initial inclination was that they would be of little use, but found from student feedback that they were liked and not intimidated by them. I begin developing a routine each day of: a) asking students to give me a summary of what we learned the day before, b) a short mini-lecture, c) followed by an interactive reading assignment, which sometimes required students to use comprehension, application, analysis, or evaluation thinking skills. To avoid boredom or the rut that routine can produce, other types of assignments were intermittently used as needed. These interactive readers are available for purchase, and the ones I found most useful thus far are published by Hold, Rinehart and Winston, and by McDougal Littell. On occasion I would write my own interactive reader and insert images and graphs from the Internet. This, obviously takes more time, but does permit the teacher to have more control over what is discussed for each topic. The benefit, however, is that once these are created, one can save them on their computer and use them again the next year. If three or four science teachers teaching the same content shared in the creation of such, it would be an ideal task for a science learning community. Finally, I found that students could read. I found that students would read if given some reading strategies, such as picking out the most important points of a paragraph and learning to summarize those points. In addition, I discovered that students will read the interactive readers if they are well written and aim to keep the topic brief. Finally, I had to come to realize that students today have such a lack of skill in determining what is important and what is not, that most had no idea or skill in how to study for a test.

Test Reviews

I began creating test reviews, which is nothing new, but with the intent that students answer 20-25 questions about content in the chapter, assuring them that the chapter test would, indeed, ask questions relating to items found on that test review sheet. Several days before a test students become accustomed to getting a test review handout with 20-25 questions on it. These were due on the day of the test which generally gave students three days to complete it. At first not all students took advantage of this guide. After a few weeks I decided something drastic had to be done or students would not

Students will read interactive readers if they are well written and aim to keep the topic brief.

perform as well on tests as they could, or as they should. I did just that. I made the Test Review worth ten homework grades. Students slowly began to catch on that the highlight of their grade for the week, apart from the test, itself, is the test review. Most students got on board after the first report card period ended. Even some parents got on board, which is always welcomed. Students' grades did improve, but there were times when scores were not as expected. I finally realized that other skills needed to be developed that was apparently missing in a majority of students; they could not look at the test review with test questions in mind. This led me to the fourth strategy to ensure their success in my course.

Self-Made Test Questions

Students were completing the test reviews, but were struggling to see how that would be used on a test. For me it was obvious; for them it was not. I decided that they needed to think from the outside in and entertained with the idea of them creating test questions. I soon found that my observation justified my intuition for students began struggling in their attempt at trying to create questions from the book on their own. I then focused on having them create questions just from the test review sheet that they had just completed. After several weeks they become proficient at looking at the test review and converting those into multiple choice type questions. Here, and there, I would have them test one another with those questions, but in the end, creating test-like questions from the Test Reviews seemed to help complete the process. By the end of the first semester, many students had turned around their grade. Some were encouraged by the weight of

Creating their own test questions helped students think how a teacher might ask questions about specific content.

The ability to determine what information is important and what isn't eludes many students.

the Test Reviews; others found that creating their own questions helped them think how a teacher might ask questions about specific content. Reading the textbook was no longer taboo, and, in fact, was necessary to get past the first hurdle. Though a few students still try to beat the system, many have welcomed the predictability of knowing the routine and feeling some control over their grade (a factor that many secondary students have yet to encounter).

Many things have remained the same in our schools since my thirteen year absence. Students still have great needs. Classroom management is still as important as ever, and high stakes testing, unfortunately, still rules the day. Students, however, are continuing to be changed and conditioned by today's technology. The ability to determine what information is important and what isn't eludes many. This can hinder their classroom performance and educational achievement. Adjusting is what teachers do. It's our superpower. Having stepped back into the classroom has been a unique experience for I was able this time to re-enter it with a vast amount of knowledge about learning and educational practices that I did not have during much of my previous tenure. Incorporating the teaching of reading skills, use of interactive readers, completion of a specific test review, and the self-creating of possible multiple choice question from that test review have been useful in helping students to overcome some of their reading deficiencies or indolence.

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Exploring Conceptual Understandings of Groundwater Through Student's Interviews and Drawings

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Abstract
Analysis of student drawings is an underutilized method for probing student understanding of geological concepts. Approximately thirty-five semi-structured interviews were conducted with introductory and non-science major college students from a large state school in the Midwest. Students were asked to make drawings of the groundwater system. Analysis of interviews and student-generated drawings indicates that students hold a number of misconceptions about groundwater and its movement within the Earth. Cognitive levels progressed from simple views such as the groundwater existing as static pools within the Earth, to complex views, for example, the groundwater is a dynamic system of water moving within the Earth. A wide range of cognitive perspectives, such as truncated flow versus naturalistic flow, related to viewing groundwater from a static or dynamic state exists, with significant implications for teaching college Earth science introductory courses.

Introduction
With the growing interest in developing instructional strategies to facilitate conceptual change, there is an increased attention to students' mental representations or mental models of the phenomena presented to them in Earth science classrooms (Wandersee, 1994). Drawings have been used in prior research to explore students' conceptual knowledge, or mental models, of more abstract scientific concepts, for example, the Earth's interior (Dove, 1999; Lilio, 1994; Samarapungavan, Vosniadou and Brewer, 1996). Specifically, Paivios's (1990) dual-coding theory, which argues that information is coded and represented in the mind both visually and verbally, provides a theoretical basis for using pictorial representations as a way to gain insight into student's level of understanding. This investigation of students' geological perceptions, in this case the groundwater system, was conducted through the use of semi-structured interviews that incorporated student-generated drawings.
To achieve this study's objective, the following research questions were formulated to guide the investigation:
1) What conceptions of the groundwater system exist among undergraduate students?
2) How will the use of student-generated drawings elucidate students' mental models of the groundwater system?

Although a considerable amount of alternative conception research has been carried out in science disciplines such as physics and chemistry (Brown, 1989; Clement, 1987; Gabel, 1989; Gabel, 1992), the number of studies that have been conducted in Earth science has been limited and focused on students views of geologic time, plate tectonics, water cycle, rocks, glaciers, earthquakes, soils, and erosion (Bar, 1989; Bezzi & Happs, 1994; Dove, 1997, Happs, 1985 and 1982, Taiwo, A, 1999).
Few science education studies deal explicitly with students' understandings of groundwater formation and movement. Among these studies, Dickerson (2003) identified several prominent, deeply held naïve conceptions among younger children that interfere with groundwater instruction in various contexts. Such conceptions can develop

from formal instruction and emerge from errors or misleading representations in texts, lectures, and inappropriate or misapplied practical experiences throughout the student's history. Wampler (1996, 1997, 1998, 1999, 2000) illustrates the wealth of potential sources of naïve conceptions by regularly publishing articles that illuminate subtle errors regarding groundwater found in popular textbooks. Science teachers unfortunately demonstrate the ability of lectures and laboratories to give birth to naïve conceptions by conveying misinformation or unconnected pieces of appropriate information (National Research Council, 1997). Newspapers, movies, discourse with friends and family, personal experiences, and so forth provide additional sources of naïve conceptions. Embedded in both of these formal and informal learning environments exist a cadre of words and phrases used at times as metaphors and other times as actual descriptors. Meyer (1987) notes several such words including: pools, lakes, rivers, streams, and veins. While providing valuable insight into past work on students' groundwater conceptions, these studies do not investigate college students' conceptions as a part of the global hydrologic system. Furthermore, there is a decided lack of research on how student drawings of the groundwater system can inform instructional practice, with an emphasis on conceptual change.

The use of drawings as an assessment tool may reveal misconceptions that act as barriers to further learning.

Method

Particpants

Thirty-four interviews were conducted in entry-level undergraduate geoscience courses. Interviewees ranged in age from 18-40, although the majority of the students were freshman and sophomores in college. Interviewees were also 70% female, typically Caucasian, and not anticipating a science major, however the majority were preservice elementary education majors. Interviewees were predominantly recruited through an extra credit offering.

Interviewees were enrolled in a course Earth-Our Habitable Planet, at a Midwestern university that presented a comprehensive view of the materials, processes, and history of the Earth and its four primary interacting systems - the atmosphere (air), hydrosphere (water), biosphere (organisms), and geosphere (rock). The course also considered the changes that human activities are causing in these systems, both globally and locally by discussing topics such as global climate change. The textbook used for the course, Our Blue Planet (Skinner, Botkin & Porter, 1995), provides a brief overview of the groundwater concept. However, within the course, the instructor did not discuss groundwater in any detail. Interviews were conducted at the beginning and middle of the semester. It was presumed that students would have some prior exposure to this concept as it is taught in pre-college grades, usually 6-12. The topic is often used in classroom instruction in conjunction with concepts such as the water cycle. Middle and high school level textbooks typically include two to four paragraphs and a diagram on groundwater (Sager, et.al, 2000; Christophersen, 1995). Finally, the majority of students interviewed for this study had stated that they had taken a high school Earth science course.

Procedure

Interview questions were selected so that students would be largely drawing on prior knowledge of the groundwater system, not only what is observed in nature, but also understandings gained from instruction (the concept is often covered in classroom instruction from middle school through high school). The interview protocol questions guided the initial discussion and drawings. Questions moved overall from the general to the specific, allowing for branching questions to facilitate elaboration or student-generated drawings. All interviews were conducted by the same researcher and typically lasted 50-60 minutes, with 15-20 minutes spent on the topic of groundwater. All interviews were audiotaped and transcribed. Each interviewee created a drawing of groundwater and was informed that the interviewer wanted to learn about their ideas regarding geological concepts and was not concerned about artistic abilities. Students were encouraged to add any elements or characteristics they associated with the topic and to add any notations to the drawing if they wished. Clarification was sought on any element students had drawn or written that was not understood by the researcher. Students were provided a pencil with eraser and an 8 1/2x 11 sheet of white paper to complete drawings. Students also provided demographic information about gender, age, ethnicity, major, prior high school science coursework, and prior college geology coursework. The purpose for using student-generated drawings during the interviews was two-fold: 1) to focus the students attention on the phenomena being discussed; and 2) to facilitate communication between the student and the researcher.

Analysis Techniques

Drawings have been analyzed in prior research using grouping techniques to categorize students into levels of understanding (Dove, 1999), or by indexing (simply counting and recording) the features in students' drawings as a strategy for analysis (Lillo, 1994, Reiss, 2002). In order to gain an overall, cohesive view of each student's conceptions of the groundwater system, the authors chose to analyze both the interviews and drawings together.

Content analysis of interviews and drawings followed two tracks: indexing and thematic analysis. Indexing was limited to documenting student ideas observed in the interviews. The thematic content analysis focused on looking for patterns in the interviews and the drawings as a whole. This analysis focuses on the thematic analysis. Coded themes were identified inductively, with themes emerging naturally as we reviewed the interview transcripts and drawings (Patton, 1990; Denzin and Lincoln, 1998). After a review of transcripts, two researchers identified two themes inherent in the data; Truncated Flow and Naturalistic Flow. To ensure reliability, ten interviews were coded using initially identified themes by the two researchers. Coding results were compared, and modifications were made based upon significant differences in the coding and emergent themes. This process was repeated for the remaining interviews until coding was in 90% agreement. Remaining interviews were evenly distributed to the researchers, with overlap of 10% to allow for continued analysis of reliability.

The emergent themes identified for these interviews focused on students' views of the groundwater and its relationship to the hydrologic system. Specifically, the occurrence of a static conception of water or absence of movement of water, after a certain point, through the hydrologic system (Truncated Flow), and an inherent conception of movement into and out of the groundwater system, and an understanding of underlying processes (Naturalistic Flow) were accounted for in the coding.

Results

Results of students' interviews are discussed under two headings: students' common ideas about groundwater features, and classification of student understanding according to the analysis technique described above.

Common Ideas About Hydrologic Features

Students generally demonstrated a poor understanding of the groundwater, as well as, groundwater as a system that is interconnected to the larger hydrologic system. Some recognized individual features (such as absorption, pore space, and water table), but often failed to explain the relationship of these terms to each other in the overall system. Some features (such as seeping and underground flow) were frequently mentioned, but were poorly understood. Furthermore, it was common for students to be asked several elaboration questions that provided little

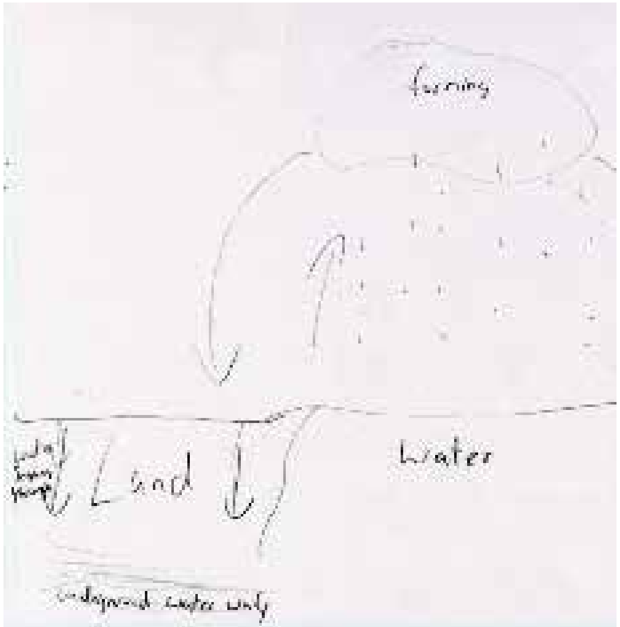

Figure 1. A student's conception of groundwater as Truncated Flow.

additional insight into their conceptions. Other features (such as zone of saturation and recharge) were rarely even mentioned. It was unclear whether many of these students had ever even heard of these terms. Furthermore, misconceptions of this concept were ubiquitous (Figure 1).

As one student put it:
Interviewer: What happens to the water after it rained over land? So if we have a cloud forming and we have rain over land, where's that water gonna go.
Subject: Into the soil.
Interviewer: Ok, how does that work?
Subject: Just all the moisture just seeps down in the soil and I guess there like underground ……I'm sure there's like underground rivers, underground waterways stuff like that, that it forms in.
Interviewer: Go ahead and draw that in and label it.
Subject: I guess it just forms these underground waterways and the underground waterways go like……like a lake maybe.

Students' Conceptions as Truncated or Naturalistic

Thematic content analysis of interviews indicates that students think about the groundwater system along a continuum of understanding. Student discussion of underlying processes related to groundwater was quite limited. Eighty-five percent of students failed to discuss processes, or water movement into, as well as, out of the system, even when probed. Almost all of these students indicated that they viewed water as seeping, or absorbing, into the ground, and then existing in a pool or underground river (as expressed in the interview as well as the drawing) (Truncated Flow).
Naturalistic Flow mental models were explained in terms of action and comprehension of water flow into and out of the groundwater system. For instance:
Interviewer: Ok, what does that mean? What happens to it (the water) when it penetrates the…
Subject: Water has, or soil has little pores in it, and water comes and touches the soil, fills the pours and then goes down to like your water table.

Or, as one student describes:
Interviewer: How does it (water) move through the ground?
Subject: Because of gravity of course. It would naturally want to go down. But depending on the density of the rocks. So there might be some more dense rocks, that might cause it to go left or right. Not necessarily straight down, but a round those objects, but the general direction would be to go down.

Discussion

It is important to note that this study resulted in findings that indicate the range and variability of these students' understanding of groundwater. These results provide a basis from which to further our understanding of students thinking and may contribute to the body of knowledge and research on Earth science misconceptions, conceptual development, and conceptual change. We invite verification and extension of this work by other science education researchers, and do not presume to generalize our findings beyond this sample of students.

Nevertheless, we recognize that a large part of studies related to conceptual change has been the determination of what conceptions of natural phenomena students can be expected to bring to the classroom, which will in turn provide insight into how well students are learning science (Finley et al, 1992). There has been a call in the past decade to teach Earth system science. A system consists of processes that interact with one another to make up our dynamic planet, specifically the idea that the Earth system is comprised of interacting subsystems of water, land, ice, air, and life (Meyer, et.al, 1992). This represents a conceptual context that may be used to promote conceptual change in the college classroom, particularly when teaching interconnecting concepts such as the global hydrologic system.

Clearly our findings suggest that students in introductory geoscience courses have been exposed to the idea of a groundwater system; however, students exhibited a wide range of understanding of the concept. Most interviewed students reported having taken an Earth science course at some point, usually in eighth grade. The authors recognize that alternative frameworks may have either developed during instruction or simply independent of instruction. However, student interviews were conducted in mid to late spring, after students had completed a significant proportion of their college introductory geoscience course, which focused on Earth system science. It is also important to consider that it is often the case that the mechanisms causing a geological process, like the groundwater system, cannot be observed directly, thereby making the concept all that more difficult to teach, as well as learn. The fact that most students exhibited a partial understanding of the groundwater system suggests that the relationships among unique features within the water cycle should be explored further within the classroom. The findings also suggest that students are not familiar with scientific terms such as water table, saturation, or recharge; students' understanding of these terms was limited. Simple use of technical terms, without the ability to explain underlying concepts, likely hinders learning. Additionally, the use of drawings, as an assessment tool may reveal misconceptions that act as barriers to further learning. The use of drawing in introductory geology classrooms will most appreciably lead to the subsequent development of better pedagogical practices that promote conceptual change.

Finally, this study has important ramifications simply because a better understanding of the misconceptions held by such undergraduates is very important for science education of students. The conceptual change process cannot begin without a complete picture of what the student understands about a particular topic. Furthermore, knowledge of such specific misconceptions among this sample of predominately preservice elementary teachers has implications for the training of future science teachers not only at the college level but at the pre-college level as well.

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Using the Knowledge Types-Levels Matrix to Analyze Student Teaching

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"Matt you did a very nice job in introducing the properties of water. The "bell ringer" that you showed on the screen invited students to think about the connection between the change of water density and the change of air temperature." Professor Ada said. "You did a fine job in higher level thinking activities and encouraged the students to explore and explain, the professor continued.

"Thank you kindly for the comments. However, which specific parts of the higher level thinking activity presentation did you not like and why?" Matt asked. The professor did not anticipate the breath of the question and she began to scramble for her observation notes. It took the professor longer than necessary to find the notes and the conversation continued with some challenges because the observation notes were qualitative and sketchy at best.

The above professor-student exchange describes a post conference between a professor and a student teacher illustrating the potential challenge of a purposeful discussion of metacognition based on accurate observations of a student teacher working in the classroom. From the professor's point of view metacognition "knows about knowing;" contrarily, from the student point of view metacognition "learns about learning." For the purpose of improving teaching and learning the two views are equally important. Metacognition knowledge may take different forms such as knowing the right time to use a strategy and how to use it effectively. If a student teacher is to be effective, he must understand his strengths and weaknesses in teaching and learning. This is called metacognitive knowledge. Metacognitive knowledge enables the student teacher to know how to effectively self-regulate his own activities of teaching and learning (Wong, 2013).

The metacognitive knowledge as seen in any typical post teaching reflection conference equips the student teacher to learn from his own experiences, rather than from formal knowledge transferred from a college lecture hall. In the college of education, does the professor coerce student teachers to go down a prescribed learning path, or encourage them to think on their own?

In general, there are three types of knowledge and they are related to one another. The first two are content and procedural knowledge. One would expect a course in comparative psychology to be content-oriented and a course in instrumental music to be procedure-oriented. When the content and the procedure are connected together in a meaningful way, they form the third type of knowledge, conceptual knowledge. As professors in education we encourage student teachers to reflect on the development of their own learning and assess its strength and weaknesses. The reflection described is metacognitive in nature and includes the three components of knowledge: content, procedure, and concept.

Now that we have an understanding of the three basic knowledge types, we need to concern ourselves with depth. Depth is obviously a relative term. In teaching, the teacher has the option of teaching the surface with low-level mental activities with recall and remembering, or to go deep with higher mental activities such as analyzing and evaluating. Bloom's Taxonomy is a classification of learning objectives in education proposed in 1956 by a committee of educators headed by Benjamin Bloom (Bloom et al., 1956). Originally, the work by Bloom was developed around the three domains of cognitive,

	Remember	Understand	Apply	Analyze	Evaluate	Create
Content	1	2	3	4	5	6
Procedure	7	8	9	10	11	12
Concept	13	14	15	16	17	18

Figure 1. Knowledge Types and Levels Matrix

affective, and psychomotor. In view of the traditional skills of knowledge and the scope of this article, only the cognitive domain will be further explored.

The revised classification of Bloom's Taxonomy is a six-level structure. The critical mental activities of learning are listed hierarchically from the bottom to the top of the classification. The bottom level is remembering, to be followed by understanding, applying, analyzing, evaluating, and creating at the top. The bottom levels are considered to be low-level learning skills (that is remembering, understanding, and applying) while the upper levels are considered to be higher-level thinking skills (that is analyzing, evaluating, and creating).

What level of knowledge can the teacher impart? If the teaching focuses on knowledge, recall, or memorization, this is remembering - a low-level mental activity. When the teacher asks students to explain an idea or a concept, the activity calls for understanding - a higher level mental activity than remembering. When the teacher asks students to use what they know in a different way, it is applying; the mental activity sits right in the middle level of Bloom's Taxonomy. When the teacher asks students to distinguish the different parts of an entity, this is the higher level thinking skill of analyzing. When the teacher asks the students to take a position with justification, the mental activity enters the level of evaluating. Finally, when the teacher asks the students to create a fresh point of view or to make a brand new product the mental activity enters the highest level of creating.

With what we just learned about the three knowledge types (content, procedure, and concept) and the six levels of knowledge learning (remembering, understanding, applying, analyzing, evaluating, and creating) we now can go forward one more step by combining the knowledge types and the knowledge levels together. Integrating the knowledge set and the knowledge level set presents a better understanding of what is happening in the classroom.

What do the knowledge set and the knowledge level set have in common? The commonality is knowledge. Is this not similar to presenting the same thing in two ways? Putting the two sets in a three by six structure will give us a matrix (Figure 1). The matrix has two coordinates, vertical and horizontal. On the vertical axis is the three types of knowledge, and on the horizontal axis is the six types knowledge learning.

Looking closely at the intersection of the axes shows the specific knowledge type and level combined. The matrix shows 18 cells. For example, cell #1 is content/remember, cell #2 is content/understand, cell #18 is concept/creates, and so forth.

Let us revisit the post teaching conference described at the beginning of this article. How would the conversation be different if the professor had the knowledge matrix as a score sheet? What can the professor say about the teaching pattern of the student teacher qualitatively and quantitatively? Will the professor be able to focus on a knowledge type that she wants to discuss with reference to the strengths and weaknesses of

	Remember	Understand	Apply	Analyze	Evaluate	Create
Content	1	2	3	4	5	6
Procedure	7	8	9	10	11	12
Concept	13	14	15	16	17	18

Figure 2. Using the matrix to analyze teaching behaviors.

the student teacher (Figure 2)? The matrix score sheet is one concrete way to show teaching information for the student teacher to reflect on for metacognition!

Are you interested in finding out how you teach in the classroom yourself? Try and experiment with using the knowledge matrix. Invite a colleague or even students to tally the type/level of knowledge you teach over time (for example, in a class period). What is your pattern of teaching if tally marks are used to indicate the frequency of using a specific knowledge type/level over a predetermined time range (say every five minutes)? Do your teaching activities aggregate in certain area of the matrix? Do the heavily scored areas indicate low-level mental teaching activities, high-level mental teaching activities, or a mix? We can all improve teaching regardless of whether we are a beginner or a veteran as long as we are reflective on what we do and seek new ways to improve.

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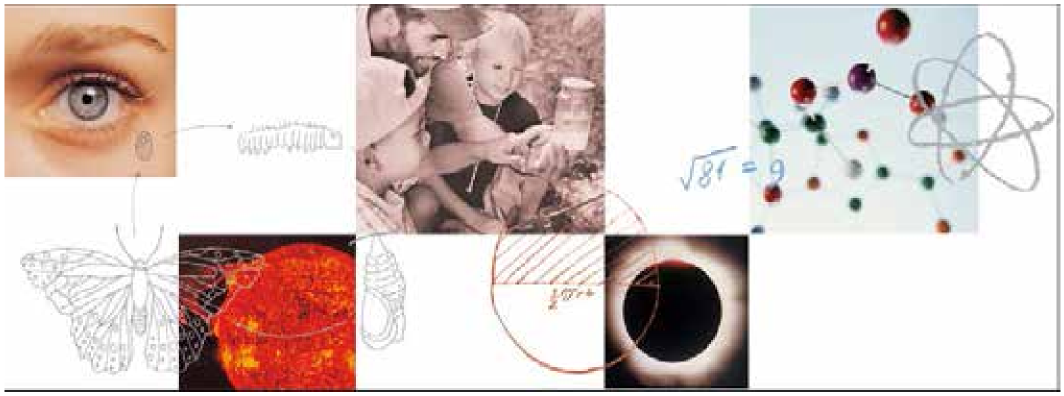

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