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Learning to Teach

Language Arts, Mathematics, Science, and Social Studies *Through Research and Practice*

A publication of the Department of Curriculum and Instruction:
Leigh Chiarelott, Ph.D., Chair | University of Toledo

Learning to Teach
Language Arts, Mathematics, Science, and Social Studies
Through Research and Practice

Learning to Teach Language Arts, Mathematics, Science, and Social Studies Through Research and Practice publishes manuscripts that address curricular innovations, thoughtful discussion of current issues for practice, or essays that inform, advocate for a position or persuade. Manuscripts must address content education.

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Section on Language Arts

Section on Mathematics

Section on Science

Section on Social Studies

Language Arts

Poetry & Pedagogy
An Apologia for Poetry in the Secondary Classroom

Brett Strickland

Abstract: Teacher anxiety and lack of formal training regarding poetry has resulted in a cycle of teachers—particularly secondary language arts teachers—avoiding the reading and writing of poetry in the classroom. The measurable benefits and practical application of poetry in the classroom is discussed, as well as why poetry is an important facet of the English language arts (ELA) curriculum and how poetry can be incorporated into other content areas such as chemistry and math. This manuscript argues that poetry can be an effective tool not only for fostering empathy and imagination, but also for teaching skills such as comprehension and fluency that are useful across the content areas in general.

Introduction: Poetry and the Contemporary Language Arts Teacher

I would like to begin by apologizing to English language arts (ELA) teachers in general, and then extend that apology to encompass teachers of all content areas. I am sorry. At some point in your education, most likely in junior high or high school, possibly not until college, you had a traumatic experience with poetry, and you now teach poetry to your students in a state of perpetual PTSD—hesitant, slightly guilty, and always aware of your perceived critics. The reasons for this trauma are legion, ranging from a negative experience with poetry as a student to having no formal training in the teaching of poetry. And if the teaching of poetry has fallen into disuse in the language arts, it is easy to imagine how ill regarded poetry is in content areas such as chemistry and math. What this article aims to do is show that poetry is, in fact, a tool that can help foster an environment of student learning, not only in the language arts, but also across the content areas.

Research supports this dreary picture of contemporary ELA teachers and their aversion to poetry. In one of the larger studies of its kind, in which 100 teachers participated in a year-long study, authors Hughes and Dymoke (2011) found that high school English teachers felt an enormous "sense of inadequacy about their own knowledge and teaching skills where poetry was concerned"(p. 46). Because of this perceived sense of inadequacy, poetry was rarely found in many of the teachers' rooms. Survey responses for why the teachers felt unprepared for poetry included the teachers having negative experiences with poetry as students themselves, having no poetry courses in high school or college, or having to dissect a poem line by line. While some teachers did have positive experiences with poetry, the majority of the teachers shared a discomfort or anxiousness regarding the teaching of poetry. Thus, the goal of the article study was to find strategies that helped alleviate some of the stresses teachers felt from teaching poetry in their secondary classrooms (Hughes & Dymoke, 2011).

Since the classrooms were in both North American and England, the researches set up a Wiki where teachers were exposed to poems, read definitions of poems, and talked about and wrote poems over the course of a year. The first part of the year was spent learning about poems, especially British and Romantic poetry (with some American classics such as T.S. Eliot and Sylvia Plath), with the second part of the year applied to poetry pedagogy, or the practical classroom implications. Qualitative methods such as including surveys, seminar notes, and interview transcripts were used to collect data for the study. Through online discussion, seven preconceptions about poetry were discovered. Important preconceptions included ideas such as: poetry is boring, poetry is for the elite, poetry is inaccessible, poetry is frivolous, evaluating student poetry is too difficult, analysis is at the heart of understanding poetry, and finally, poetry is a solitary art and therefore unfit for the collaborative nature of the classroom (Hughes & Dymoke, 2011).

As the research data from this project shows, actually studying poetry and spending time reading and writing it and applying it to the classroom had a powerful effect on the teachers who took the course. At the end, the majority of teachers cited a profoundly changed opinion of poetry, and a collaborative effort was made to create a list of ways to use poetry in the classroom, which is something of an antithesis of the list of preconceptions. Basic guidelines the teachers suggest include: beginning with contemporary poetry to engage student interest, making poetry relevant by drawing lines between the text and students' lives, demystifying poetry by showing it does not need to be dissected to be enjoyed, avoiding an overemphasis on finding meaning, spreading poetry throughout the year rather than piling it all into a single unit, evaluating the poem instead of the poet, and finally, providing students with ample opportunities to discuss the poem in an open and collaborative environment (Hughes & Dymoke, 2011).

Practical Benefits of Poetry in the Secondary Classroom

Certainly, these are basic principles that can help students learn to appreciate poetry, but many English Language Arts (ELA) teachers are still wary of using poetry in their classroom because they are unsure of poetry's practical benefits. While poetry increases imagination, empathy, and compassion in students, modern educators are faced with the necessity of identifying growth in students, and there is no test that that measures a child's level of compassion. Teacher concerns are exacerbated by the change in new Common Core State Standards, which places a greater emphasis on nonfiction, business, and technical writing than previous state standards. So how can students benefit from poetry in practical, measurable ways?

In the article "What's the Perfect Text for Struggling Readers? Try Poetry," authors Rasinski and Zimmerman (2013) recommend poetry as a remedial strategy for struggling readers. In this article, the authors recommend some basic strategies that have helped students improve their reading fluency skills and ability to pick up on context clues. They attribute these gains in reading ability to poetry and point out some basic facets of poetry that make poems beneficial to use for the struggling classroom reader. Rasinski and Zimmerman point out that when using poems as resource texts, poems are relatively short, so they are easy for students with a short attention span to read in a single sitting. In addition, the authors point out that the students with whom they worked made significant gains in word recognition and reading fluency. Improving these two important skills led to overall gains in reading comprehension, which is one of the most important goals in reading.

In a similar article, a student of Rasinki's discusses how poetry was used as a remediation strategy for struggling students. After several tests performed on students who read a passage, including the number of events the reader was able to remember, the number of words the reader was able to read in a minute, the number of words the reader correctly pronounced, and retelling score, the author compared the students' Words Correct Per Minute (WCPM) score with the national average and found that almost half of the students in the class were significantly lower (by 20 percent or more) than their peers (Wilfong, 2008). Instead of pulling students out of class for remedial instruction, which the teacher worried would lead to the students receiving watered down instruction, with the agreement of the principal she decided to use poetry as an intervention strategy—specifically, Wilfong decided to have struggling readers participate in what she called the Poetry Academy.

Important components of the Poetry Academy included repeated readings of poems, listening while following along, assisted reading, and modeling. After five weeks, the principal asked Wilfong (2008) to retest the students according to the same original criteria, and at that point, there was already enough fluency and comprehension growth evident for the principal to take notice. Students were also measured against a control group, and the gains the 86 students made were compared with the gains that a normal student would make in the same period. Students grew at a higher rate than the students who did not participate in the Poetry Academy in the number of words per minute that the students could recognize and read fluently. So it is clear that poetry is an important tool in the ELA classroom, and can benefit students in tangible, identifiable ways. But can poetry be an asset in secondary classes outside of the ELA room?

Poetry Across the Content Areas: Real People Doing Real Science

Imagine a science classroom in which students struggle to see themselves as scientists. They read the assigned material, they turn in their homework, and they participate in the in-class labs, but still the majority of students fail to immerse themselves in the spirit of inquiry, which the teacher has been working to foster. Discussions falter, and independent projects lack focus or drive. Perhaps these are females who see science as a male-dominated field. Perhaps this is an urban classroom, where the students view a future career in the sciences as an impossibility. In short, the students fail to see the real people performing the real science they are learning about.

One way science teachers combat these preconceptions, argue authors Kane and Rule (2004), is through poetry, which can be used across subject matters to help students of all ability levels make personal connections. Kane and Rule argue that "there is a convincing literature base showing that teachers in a variety of content areas at all levels have used poetry for many years to enrich their curricula and assists in the learning of concepts, procedures, theories, and terms" (p. 658). In the classroom example above, students could read Adrienne Rich's poem "Planetarium" to introduce a unit on the astronomer Caroline Herschel, allowing students to think about "a real person doing science" (p. 660).

In social studies, the authors demonstrate how poems can be used to show spatial relationships, and use the example of Whitman's poetry, which showcases engineering marvels, and which can be used to exemplify humanity's progress in space and time. The authors also discuss how Tennyson's "The Charge of the Light Brigade" can be used to discuss the ramifications of capital and human sacrifice for natural resources, which is similar to how the authors suggest the Robert Frost poem "A Brook in the City," be used. Authors also discuss how a poem can distill the complexities of the “historical moment,” and use the example of Gwendolyn Brooks’ poem “We Real Cool” to compare 1960’s urban culture to today.

Initially, science and math seem like subjects that would have little use for poetry. But the language of science is often metaphorical due to the nature of abstract concepts and thinking, and thus not only can the rhetoric of poetry better support student learning in science, in addition, some poems can provide students with insights into actual theories, developments, and specific contributions. Specific examples include supplementing a unit on atomic structure with a Robert Frost poem, as well as how Gary Snyder uses ecological sciences for his poetry, often focusing on how science concepts are structured in language. A quote that summarizes this ideal convergence between poetry and science is best explained when the author quotes another scientist, Watts, as saying:

The main attribute of poetry is that it is a distillation of experience and so shares much with science—both begin from attending to phenomena which must be accurately recorded…Both takes these experiences and try to make a synthesis which accurately represents the observations in a succinct a way as possible…poetry and science can work together to enable learners to grow in familiarity with the concepts, facts, principles, and processes with which they are working. (p. 660)

Another example of poetry supporting a curriculum outside the language arts field might include using Emily Dickinson to introduce a unit on the human body. And in one math class, students wrote metaphors to describe their anxieties about math and to overcome math frustration, and also created computer-generated poems from student images. Students who learned to view poems as supporting curriculum across the content areas in a pre-teaching undergraduate literacy class practiced writing poems related to their content area that touched on a concept, a theory, a person, or tried to demonstrate vocabulary relevant to their subject (Kane & Rule, 2004).

Conclusion: An Environment of Inquiry

The research speaks for itself. Poetry can support student learning not only in the language arts, but also across all content areas, and it is not only for the brilliant, creative student, but for the struggling reader as well. Poetry can foster imagination and empathy, and it can teach students to make personal connections with the material being taught. Poetry, however, can also improve measurable skills such as reading fluency and comprehension. Finally, there are no answer sheets for poems. Rather than create anxiety in teachers, the openness and accessibility of a poem should be seen as a site for fostering student independence and higher-level thinking skills that are important not only for life, but also in the high-stakes tests students face at every level. For the teacher striving to create an environment of inquiry, where the only answers are found through questions and earnest discourse, there may be no better text than a poem.

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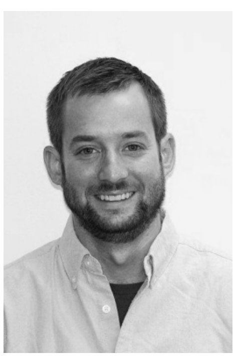

Biography

Brett Strickland graduated from the University of Toledo with a graduate degree in education in 2013. He currently teaches sophomore English at Genoa High School.

Incorporating Popular Culture into Curriculum to Spark Student Interest in Reading
Are You Up to the Challenge?

Jennifer Greenlese

Abstract: In the U.S., where student interest in reading is dropping dramatically, popular culture can be an effective tool with which to motivate students to learn and become better readers. Students need to understand why their learning in the classroom is relevant to them, and this can be done by introducing concepts through popular culture. If students can learn the information necessary to be successful readers through popular culture, and improve their self-efficacy as learners and readers, they may be more motivated to read for their own enjoyment. Students who are motivated to read will perform better in the classroom over time, and this newly sparked interest can transfer to texts that students may have previously found mundane.

Introduction

According to an analysis of data from the National Assessment of Educational Progress in Reading (NAEP) done by the U.S. Department of Education, over the last two decades between 1984 and 2004, interest in reading has plummeted. Students in the lower grades up to the age of nine show no real difference in reading for enjoyment over the years, however, from the ages of thirteen to seventeen this interest starts to disappear. The same study also shows that students of all ages who reported that they liked to read for fun had higher scores on standardized tests than those who reported not being interested in reading (U.S. Department of Education, 2005). This presents a conundrum for teachers. Reading is at the core of all learning in the classroom, and if students are losing interest in it, the task of teaching them becomes doubly difficult. Though the dwindling interest in reading is problematic, it begs the question: If students are not reading in their free time, what are they spending that time on? Asking this question can produce some interesting answers that can help teachers re-evaluate the ways in which they attempt to teach their students the topics covered in the curriculum.

These students are filling their free time with their popular culture, and with the advances in technology in the world today, students have a wealth of it available at their fingertips at all times. They are interested in it, they spend massive amounts of their own free time on it, and they understand and identify with it. It is clearly a great interest- provoking tool in the classroom. However, teachers struggle with identifying with student culture and incorporating it into their classroom in an effective way because they have a difficult time understanding its potential educational value. This comes from a lack of understanding of student culture and training on how to use it effectively (Xu, 2005). However, when students interact with popular culture it shows that they are capable of understanding complex ideas. They do it every day when they appreciate the lyrics of a song, laugh at intelligent jokes in TV shows, and follow the structure and point of view of a film. These things have tremendous educational value and they can serve as tools to get students pulled back into the classroom. Traditional texts have great value and what is being taught in the language arts classroom is necessary for students to learn – but students have lost interest in text and what is going on in the English classroom. If we can use popular culture to bring some students back into the fold of the classroom, teach them something with it and thereby improve their self-efficacy as learners, we can perhaps create more students who are inspired and believe they are capable of learning material through text in the language arts classroom. Students can learn valuable elements of curriculum through popular culture, and that culture can be an effective tool with which to motivate students to learn and become more interested in reading. (Ruday, 2008 & Xu, 2005). (This previous paragraph has a couple too many 'in the English classroom.' If you can rephrase and delete at least one of them, it would sound better.)

Viewing Popular Culture as a Viable Teaching Tool

If students can apply higher order thinking skills to analyze popular culture texts, they will then be able to apply those skills to other texts in the classroom (Ruday, 2008). These critical thinking and analysis skills that students need to able to use throughout the educational process can be taught in many different ways. Over the last few decades, teachers have been under the impression that these popular culture texts do not have any value in the traditional classroom, but this is not true (Xu, 2005). Many students hit a wall during their classroom experience that has to do with a lack of interest in the topic. For instance, "When will it ever matter if I know what a metaphor is?" Students have trouble seeing the relevance of topics in the curriculum today. In the study by Ruday (2008), students used popular culture texts to reinforce ideas learned in the classroom. They used popular song lyrics to discuss literary devices like metaphor, simile, and hyperbole. One student responded, "I've learned about making inferences before, but I've never had a teacher use things that I do on my own time to teach me about them. This helped me remember what I learned in class, and made me more interested in doing it," (Ruday, 2008, p.9). While this is only one student's opinion, it speaks to his idea that when students are engaged with popular text, they are more apt to learn and be enthusiastic about the material. This relevance gives them power over their own education, something many students do not perceive that they have, and allows them to be more engaged with the material being taught.

Self-Efficacy and Popular Culture

Ruday (2008) also mentions the effect that beliefs about self-efficacy can have on learning in the classroom, and how popular culture texts can improve these beliefs about one's own ability to learn through text in the language arts. Too often in the classroom students feel overwhelmed and unconnected to the material that they are being taught. Then when they do not learn the material, they begin to believe that they are incapable of doing so. This infinite loop can provoke students to feel like they are stupid and unable to pick up on concepts addressed in the classroom. Their self-efficacy has deteriorated, and this defeated attitude can lead to lower test scores. However, when popular culture is used in the classroom, students are engaged with topics that they may have knowledge of beforehand. When students have this kind of prerequisite knowledge they can feel much more up to the task of learning information based upon it. Building this self-confidence about learning with popular culture can be very beneficial in the language arts, because many underachieving readers have lost this confidence (Alvermann, Hagood, Heron-Hruby, Hughes, Williams, & Yoon, 2007).

Once students understand that they are capable of learning the material from one type of text, they may be able to take that confidence into other areas and become more capable readers and learners. It is possible in this type of environment that students may even know more about the topic than the teacher. For instance, if the teacher decides to bring an episode of, "The Big Bang Theory," into the classroom to study point of view, students may know more about the show and its characters and structure than the teacher does. This is not the problem that it may be viewed to be, as research has shown that discourse about popular culture can lead to learning (Wiliams, 2007). Talking to the students about what they know and filtering that through what the teacher knows, can lead to great strides in understanding.

Talking about popular culture in the classroom can produce some interesting results. In one study by Williams (2007), students were exposed to stereotypes in the media of readers and writers. They discussed images of great writers and poor writers. Stereotypes of the great writers included William Shakespeare from the film, *Shakespeare in Love*. The poor writers were depicted in the movie, Office Space. Teachers talked about how we view great writers as people who are inspired to write and have very little difficulty sitting down and creating a work of genius. Then we have the characters in, Office Space, who struggle with writing and sit at computers every day struggling to power through every single word until they meet the minimum requirement. These pop culture characters are great ways to get students to talk about how they feel about reading and writing. Most students feel that these are accurate interpretations of types of writers, and students are very discouraged when they find that they are not Shakespeare. The media does not portray accurate representations of literate people, and it is important to discuss some of those issues so that students can have a better understanding of what they are capable of. The media does the same with action heroes, showing these people to be very literate and very capable of understanding and interpreting text and situations with very little problems if any. Then, there is usually some type of sidekick who does nothing but sit in a library or school and pore over books all day. Learning for them is very involved and takes massive amounts of time in order for them to be useful. Again, these are not accurate representations of the learning process and they can really discourage students. It is important to discuss with adolescents what these representations really mean and what is not accurate about them. Literacy will take work for students, but it is not as strenuous and terrible as they may believe from what they have seen in the media. If we can correct some of these misunderstandings about literacy, it is possible that we can increase students' feelings about their own self-efficacy.

Improving students' feeling about self-efficacy as readers in the classroom is crucial, and it relates to Paulo Freire's powerful theory of social reconstructivism. Many students do not understand the value of their own education and what it can do for them. They do not understand the power that they have over their own lives and the ways that becoming a better reader can help them change their path. It is so easy for students to become uninterested in reading and learning because they do not fully understand its value (Freire, 1970). For this reason, it is important to show students the relevance of their learning and build their self-confidence in their own capabilities so that they leave the classroom more informed and well-rounded students. If this relevance and self-confidence can be given through popular culture, why on Earth wouldn't more teachers incorporate it into their curriculum? The answer is the lack of pre-service training that teachers receive in using student culture (Xu, 2005).

Pre-Service Training in Popular Culture for Teachers

As mentioned earlier in the study by Xu (2005), teachers sometimes make an effort to keep popular culture out of the classroom. The teachers are not informed of its benefits and they do not know how to use it as a learning tool. They also do not know much about student popular culture. The age gap only widens as teachers gain experience in their field, and keeping up with student popular culture can be difficult. However, a study by Xu's study (2005) has showed that overcoming this obstacle can be done easily, and when it is done, it is very beneficial to the students in the classroom. In this study, a group of teachers was given pre-service training on using popular culture in the classroom as part of a master's degree program in education. The teachers then brainstormed lists of their popular culture, student popular culture, and ideas to integrate the two together in the classroom. After implementing their ideas, they then wrote reflective papers on their experience.

One of the most universal thoughts in the reflections of the teachers can be summed up in the thoughts of one, "I used to think that only children and young children experience popular culture. Now I realize that I have such an experience, too. It is just the matter of different types of popular culture and how often I experience it," (Xu, 2005, p.725). Most adults view themselves in a way that does not relate to children; however, when they were forced to evaluate the situation they found that they did in fact have a connection through popular culture. Teachers were surprised to not only gain a better understanding of student popular culture and their own, but they were also surprised to find that students could be very useful in coming up with successful lesson plan ideas to teach literary devices. Students were passionate about incorporating their culture into the classroom and actually came up with effective and appropriate ideas.

Conclusion

The research shows that students are engaged with popular culture all of the time and that they are interested in picking it up and spending their own free time on it. (Alvermann, Hagood, Heron-Hruby, Hughes, Williams, & Yoon, 2007). The number of students who wander into a library to pick up a copy of War and Peace to read in their free time is abysmally small, so why are teachers still trying to beat those traditional texts over students' heads? That is not to say that these traditional texts do not have value, because they do. The language arts curriculum does not need a complete and total reconstruction – but students have lost interest in it. They cannot see the relevance and value that the information we give them has – and that is what needs to be corrected. Bringing student popular culture into the classroom can accommodate this need to provoke interest, but it is not a topic on which we should completely base curriculum.

The goal of this article is not to convince others that traditional texts are useless. That is in no way, shape or form true. The goal, after all, is for students to become more interested in reading, not watching more television and playing more video games. If we can get students to understand the relevance of language arts to popular culture, if we can engage them long enough to be successful in learning concepts, we might be able to provoke more adolescents into becoming readers. If students can feel successful in the language arts classroom and improve their self-efficacy as readers, they may be more motivated to read for their own enjoyment and become more active participants in their own education.

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Biography

Jennifer Greenlese is a 7th grade language arts teacher at Taylor Secondary School. She received her Master's degree in education from the University of Toledo as well as Bachelor of Arts degrees in English and psychology. Her research interests include methods for literacy enhancement, and cognitive skills development through adolescence.

Mathematics

Illuminating Mathematics
Using Math to Develop Well-Rounded and Productive Members of Society

Callie S. Goyer

Abstract: A misconception among students and their parents is that mathematics will never be utilized outside of the classroom. While it is true that some of the concepts will not be used directly, those ideas are still important because of what they inherently teach. Important qualities of a well-rounded and productive citizen such as critical thinking, logical reasoning, collaboration, and even effective communication are a few examples. Mathematics illuminates the mind to new ways of thinking, and this is the message that needs to be made clear to both students and their parents. By making some changes to the way teachers present material, this can be accomplished and students will more easily realize how mathematics will benefit them in the future.

Introduction

You teach high school geometry. It is your first year, and you are incredibly excited to share your passion and knowledge of a subject that you hold dear to your heart. You just finished a unit on triangle proofs, and not surprisingly, your students expressed their frustrations and concerns that the material they are learning is "stupid," and they will "never use it outside of your classroom." Then, the time comes for parent teacher conferences. Again, this is your first year so your emotions are a mixture of fear and excitement -you want to share the wonderful things you are doing in the classroom and brag to some of the parents about the great work their students are doing. In walks the first set of parents. You approach them and introduce yourself as their student's geometry teacher. You shake hands, and then the father leans in and says one of the most gut wrenching and harmful things a parent could say, "Be honest with me, are they *really* ever going to use this 'stuff' again?"

Like the father from the scenario above, a common misconception among parents and students about mathematics courses is that the material they are learning serves them no purpose beyond the classroom (Güner, 2012). We can argue that math is functional. For example, you need math to make correct change at the grocery store. But what about geometric proofs or synthetic division? When *are* they going to use either of those concepts again, and if they will not, then why do we bother teaching those ideas? Teachers and students need to know the answer to these questions because "students who understand the value and applicability of learning mathematics are more likely to be successfully engaged" (Howard & Whitaker, 2011, p. 3).

Every subject taught in school has a purpose (Roman, 2004). The content intended to be learned is important, but the subjects we learn are more than just content—they are tools that help us in our day-to-day lives. For example, we learn science as a way to understand the physical world, history we study as a way to learn from successes and failures of people in the past, and language arts we study as a tool for communication. Then there is math—why do we study math? What purpose does it serve in our daily lives? According to Roman (2004), we study math as a tool "to quantify our world--to bound it, if you will, to give it perspective" (p.16). It is a very practical subject, but it is also a tool for illuminating minds. Far too often, this idea is overlooked or ignored, which is incredibly unfortunate because it is arguably the *most* important aspect of mathematics.

Illuminating Aspect

First, a clarification of what is meant by "illuminating" is necessary. For these purposes, I use the term illuminating as in "enlightening with knowledge". Some of the mathematics taught in schools is not taught to be functional, but rather to be enlightening or illuminating. I think of this as being comparable to a weight coach of a sports team. In soccer, for example, no one is going to go out on the field and start lifting weights because it is not part of the game. However, lifting weights for a sport is important because it makes the players stronger physically and also mentally because they become used to pain. The same can be said for mathematics. Are students going to use everything directly that they learn in the math classroom? The answer is no; however, what they are doing and practicing serves the same purpose that lifting weights does for a sports team, only in this case, students are strengthening their minds and not their muscles.

Math as Mental Training

As previously stated, there is some mathematical content taught in schools that many students will not use directly once they leave the classroom. For example, most people will not have to know how to divide 1 ¾ by ⅔, and "even mathematics teachers have a hard time imagining authentic problems that require these exotic calculations" (Steen, 2007, p.9). So why do we make our students study these topics in school? The reason is that solving complex mathematical problems illuminates our students' minds to think in many different ways, one of which is critically.

Critical thinking

Critical thinking is defined in many different ways, but probably the most revealing and applicable definition comes from Sezer (2008) who describes it as "skillful, responsible thinking facilitating good judgment because it 1) relies upon criteria [at hand], 2) is self- correcting, and 3) is sensitive to context" (p. 349). In order to solve a problem in mathematics, one must do each of those things. When students are presented with a word problem, the first question the teacher asks is, "What information are you given?" This demonstrates relying upon the criteria. Every problem students solve presents a different situation, and the approach they take to find the answer depends on this criteria—actions based on information is being sensitive to context. Finally, when students reach a conclusion, they must ask themselves if the answer makes sense based on the given context, or self-correct. In some cases, such as solving proportions, students can work backwards to check whether or not they have found the actual solution, but in other instances, they must check for context clues. For example, does it make sense for the solution to be negative if the question asked for a distance or a length? Similarly, to reach a conclusion on whether or not to support a major political campaign, one must collect information and decipher whether or not it is valid. Critical thinking is not something that can be taught by a lecture or by telling a student how it is done, rather it is a skill that is learned through doing, and mathematical problem solving is one way for students to practice (Huckstep, 1999).

Logical reasoning

In addition to critical thinking skills, mathematics teaches various types of reasoning skills, another quality important for informed and productive citizens (Xin, 2007). There are two main reasons for solving mathematical problems. One is the ability to calculate, and the other is knowing how to interpret the questions being asked (Steen, 2007). Research has shown that when students solve multiple problems with different contexts but similar structure, they develop general reasoning skills. Güner (2012) adds that the cause and effect relationship of the problems students solve in mathematics "enhances everyday problem solving skills" (p. 39). Math illuminates minds to logical reasoning—it teaches people to think for themselves and to not just blindly accept what they are told (Huckstep, 1999).

In addition to teaching our students how to think for themselves, logical reasoning can help our students perform at higher levels to succeed in the work force. But mathematics is not only relevant to people working white-collar jobs. When consumers go to a movie theater, for example, they are seeking fast and quality service. Often people are running late to their shows, and do not want to wait in a long line for their concessions. If someone were to acquire a position as a cashier in the concession stand, knowing mathematics and specifically logical reasoning, would be extremely beneficial to keeping those customers on a time schedule satisfied. A person who can think logically will recognize that when given multiple tasks, such as making a pizza, getting popcorn with butter, and filling up two sodas, the order in which these tasks are completed is important. Making a pizza for example takes more time than filling up a soda drink, so logically speaking it would make sense to start cooking the pizza, and then in the meantime, fill up the sodas and bag of popcorn. This way, completing an order only takes as long as the most time consuming task, which in this example is making the pizza. Without logical thinking skills the task could take much longer, customers will end up getting upset, will likely complain, and ultimately the employee will be less likely to receive any promotions within the company, or may not be able to maintain the job at all.

Collaboration

Depending on the way the subject is taught, an intangible quality the student learns by studying math is how to collaborate effectively with peers, and how to form and defend a logical argument (Perso, 2003; Ball, Goffney, & Bass, 2005). This contributes to the development of good and productive citizens. Proofs are taught in geometry classes, but the reason they are taught or thought to be important is not necessarily because our students are ever going to have a need to prove two triangles congruent, for example. Instead, the value comes from the idea that learning to write mathematical proofs will illuminate our students in the art of forming an argument. Ball, Goffney, and Bass (2005) make the claim that "mathematics instruction can deliberately help young people learn the value of others' perspectives and ideas, as well as how to engage in and reconcile disagreements" (p. 5). Arguments are not solved effectively through loud bantering, but by logical and reasonable defenses. In addition to learning how to defend arguments, by working on mathematical problems in a group setting, students "learn to respect the opinions, skills and differences of others and themselves" (Perso, 2003, p. 8).

Communication skills

Math and communication may not seem too obviously related, but research has indicated that people who have good problem solving and reasoning skills are also effective communicators (Xin, 2007). Acquiring communication skills is actually one of the key advantages to learning how to solve problems effectively. This is incredibly important because such skills are imperative to multiple aspects of day-to-day living (Steen, 2007). For example, communication skills are valuable in the pursuit of higher education or any kind of employment because both colleges and employers expect that students and employees can communicate effectively with people from different backgrounds (Perso, 2003).

Implications: What to Do With This Information

Students need to see and understand the relevance of the material they are learning, and this can be achieved in a number of ways. In the past, math has been taught through direct instruction. It was an "I do, we do, you do" approach where the teacher demonstrated how to solve a problem, then the class tried a similar problem as a whole group, and finally, usually through completing homework assignments, each individual student attempted more of the same problems on their own. For about a quarter of a century, people have argued over whether or not this is the best and most effective approach for teaching mathematics (Klein, 2007). For a while, people argued that our students needed strong "paper and pencil" skills, but then educators felt like they were spending too much time focusing on the calculations when they should be utilizing available technology. They began to push the use of the calculator in mathematics classrooms as a way to focus more on the actual problem solving—they called the calculator the "electronic pencil of today's world" (2007, p. 25). Most recently, the importance has shifted yet again to an approach called problem-based learning (PBL) - a strategy that, if utilized, will aid teachers in the use of mathematics as a tool for illuminating our students' ways of thinking.

This concept has been misinterpreted by some who believe that if we give our students word problems, then they are practicing PBL, but this is not the case (Gasser, 2011). For example, posing a situation where there are 27 heads and 78 legs in a barnyard, and then asking our students to decipher how many chickens versus cows there are is problem solving, however, students can use a formula to find the solution. Furthermore, most of them will not care about the answer - the question is not worthwhile or meaningful for our students, especially those that do not live on a farm! The key to PBL is presenting a complex, rather than simple, issue that will have meaning for our students and engage them in the learning process. According to research, for PBL to be effective, the questions posed should "create interest-driven investigation[s]" and "encourage the active processing of information in the construction of knowledge" (Gasser, 2011, p.110). This approach demonstrates to students that what they are learning has a purpose, is meaningful, and therefore might be something of importance to them - hopefully and potentially getting more students interested in the subject.

Another way that we, as a community of educators, can convince our students of the importance of mathematics is by integrating the subject into other areas of study (Steen, 2007). We must demonstrate how math is applicable to every field and every walk of life. This could mean a study of statistics in a health class to determine how advances in medicine have been made, or even bringing in a professional to talk about how they use math in their careers - if students think they will never use math once they leave school because they do not know anyone else who does, let's make some introductions! For example, have an air traffic control officer come into the classroom and explain how planes can fly without crashing when they cannot see through the clouds.

Conclusion

Math is an incredibly powerful tool that can illuminate our minds to new ways of thinking. It teaches skills necessary in any profession - from engineering to the concessions worker at a movie theater. Through learning mathematics, one also learns how to think critically and to use logical and deductive reasoning to form and articulate an argument. In addition, math enables us to balance checkbooks and sign for mortgages that we know through calculations we can afford. Math can even be entertaining! All of these skills can and will help our students function more productively in society, but only if they are convinced that the information we are providing in the classroom is worth their time and effort to learn. If we do not show our students that what we are teaching them is meaningful and worthwhile, then they will not take the time to learn the material, and will not reap the incredible benefits that the subject has to offer. The first step in reaching our students is shifting their attitudes from their current state of negativity to an attitude of inquiry and intrigue. As teachers, we have the greatest ability and the highest responsibility to facilitate that kind of change in thinking. Thankfully, there are strategies to help us accomplish these goals - the challenge for us as teachers is to implement them!

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Biography

Callie Goyer earned her BS in mathematics from Belmont University in Nashville, Tennessee. She then went on to earn her Master's in Education through the accelerated LAMP program at The University of Toledo. Currently, she is looking forward to "illuminating" minds through the teaching of mathematics at the high school level.

Catching Up with East Asia
A Culture-Conscious Approach to Changing American Mathematics Education

Maria Pultz

Abstract: For decades, American students have lagged behind East Asian students on international mathematics assessments. This paper deals with the role of culture and language in this phenomenon and the task of changing American mathematics education in ways that accommodate cultural and linguistic differences. Research shows that these factors, rather than curriculum alone, are responsible for East Asian mathematics scores. Mathematical success is possible for American students, but will require innovations controlling for the variables of culture and language. Once American educators understand that factors originating outside the classroom have considerable influence upon mathematical learning, they will be able to use these innovations in their classrooms.

Introduction

Imagine that you are an elementary student whose day goes something like this:

> Sitting up straight in your chair at the beginning of math class, you respond to your teacher's greeting of "Hello, students" with a polite, "Hello, teacher." Your teacher proceeds to draw a parallelogram and a trapezoid on the board. "These are called a parallel four-sided figure and a ladder figure," she explains. She then shows you how to find the "surface accumulation," by which she means the area, of each shape. You and several of your classmates are called up to the board to work out various area problems involving each shape, and you spend the rest of class practicing the use of the formulae she gave you.
>
> When you go home at the end of the day, you have about two hours of homework to do, on which you must practice more problems using the two area formulae. When you finish, you do not scamper off to play video games or sports. Instead, your mother presents you with a workbook she bought for you and tells you to complete several pages of area problems. While your math scores are strong, she believes that you should be doing even better and that your teacher is not giving you enough homework.

If this sounded familiar to you, you may be a product of a school in East Asia. If not, this scenario may have seemed quite foreign, or even overwhelming. The differences between East Asian and American mathematics education run deeper than what is deliberately done in the classroom. Yet, it seems that American students are constantly being compared to their East Asian counterparts due to the wide gap between American and East Asian mathematics scores on international assessments.

This is indeed a problem, for the 21st century promises a hazardous job market to those who leave school with insufficient mathematical skills. Careers will require modern, competitive skills, and a large population of East Asians will be ready to fill them for less pay and perhaps with more adeptness (Gasser, 2011). Educators, politicians, and parents have thus begun to look for ways to give American children the ability to compete with East Asians, with some claiming that the best solution is to find out what East Asian educators are doing in their classrooms and transplant those methods into our own. However, East Asian teachers often employ the methods of direct instruction and rote learning (Leung, 2001), while the newest research actually favors the constructivist approach promoted by most Western educators (Chung, 2009). We should turn our attention instead to the cultural assets that give East Asians an advantage. Leung (2001) claims that "It is possible to identify a set of common values shared by East Asian countries, and there seems to be some linkage between the features and identified values" which are "deeply rooted in the traditional East Asian culture and, as such, are relatively prevalent and stable" (p. 46). As evident in the opening story, the differences between American and East Asian mathematics education are not limited to classroom practices, but include other notable differences such as the mathematical language used and the after school activities of students. The best way to borrow successful mathematics education strategies from East Asian schools is not simply to replace our curriculum and teaching strategies with theirs, but rather to make changes to American schools that accommodate the variable of culture.

Four Ideas for Improving American Mathematics Education

Research highlights four major areas upon which American educators should focus in their endeavor to replicate the success of East Asian mathematics education. In each area, East Asian cultures have some asset that helps to account for their students' mathematics achievement. Changes to American mathematics education, therefore, must be implemented in a way that meets the unique needs and experiences of American students. The four areas that should be looked at are attitudes toward mathematics, community support for learning mathematics, students' everyday experiences outside of school, and mathematical language.

Attitudes toward Mathematics

Differences between East Asian and American attitudes and beliefs regarding mathematics make it unadvisable to adopt direct instruction and rote learning in American schools. East Asian students are taught that learning is a grueling process that will bring satisfaction once it has been accomplished. Western students are encouraged to enjoy themselves while learning, not just after (Leung, 2001). Stevenson, Lee and Stigler (1986) studied the mathematics experiences of children in Minneapolis, Minnesota, Sendai, Japan, and Taipei, Taiwan, finding that American children felt it was socially acceptable to dislike school, while Taiwanese and Japanese children did not, given the highly prized status of education in their societies. In East Asian cultures, according to Leung, education has long been viewed as a way to bring honor to one's family. East Asians may also feel a greater sense of urgency to become educated, given the economic development of their countries and the dramatic difference between the standards of living for the educated and uneducated (Leung, 2001). In short, East Asian students are supported by beliefs and expectations that propel them forward even when learning is difficult, while American students live their lives in very different conditions and cannot reasonably be expected to learn by rote as East Asian students do (especially when they dislike their studies).

Another difference lies in the way mathematical ability is viewed. East Asian cultures tend to take an incremental view, encouraging students to believe that the variable of hard work is most often responsible for the quality of performance, while Western cultures tend to promote an entity view, attributing students' performance to the degree of mathematical giftedness with which they are born (Ormrod, 2012). Research by Lee and Ginsburg (2009) found that the East Asian view may be more effective in motivating students to persevere, for while mathematical performance is often "the result of a complex set of factors such as family, linguistic, and cultural experiences" (p. 39), it is not the result of a "mathematical gene." According to their survey of mathematics teachers, however, many teachers believe just that. The researchers caution teachers against this belief, for teacher expectations can influence children to their benefit or detriment. This issue should be addressed in teacher education programs (Lee & Ginsburg, 2009); while practicing teachers should take care not to promote the idea that some students simply lack mathematical ability.

A suggestion from Gasser (2011) for improving American attitudes toward mathematics is to create a culture of risk-taking. According to his research, students in China and Taiwan accept failure as part of the learning process and are accustomed to working through problems in front of their classmates. While changing the way that American students view failure is not an easy task, the key to doing so may lie in the way teachers begin the school year. Having students work through problems on the board and then positively discussing their work may establish a precedent for accepting failure as part of the problem-solving process. Gasser's research indicates that making this adjustment requires more than just saying that failure and risk-taking can be beneficial – this must also be shown to and experienced by students (Gasser, 2011).

Community Support

Stevenson, Lee and Stigler (1986) found that American children spent much less time engaged in academic activities than Japanese and Taiwanese students, who spent a great deal of time outside of school practicing mathematics, often using workbooks purchased for them by their parents. A survey of Korean mathematics teachers by Chung (2009) asked participants to speculate as to why Korean students ranked so highly in assessment studies such as TIMSS (Third International Mathematics and Science Study, 2003), PISA (Program for International Student Assessment, 2003), and OECD (Organization for Economic Cooperation and Development, 2006). Frequent drilling and practice were cited by about 22% of participants, but high expectations from Korean parents and private, after school lessons were also frequently cited. Other reasons revolved around the idea that Korean society greatly values education (Chung, 2009). These studies highlight factors other than classroom practices that could be giving East Asian students a mathematics advantage.

The question of how to compensate for the lack of parental and social expectations experienced by many American students is a difficult one, but one option may be to use students themselves as resources. Wright and

Cleary (2006) conducted a study of a cross-age peer-tutoring program serving as a reading intervention. Participants were elementary school students at an urban school with high student needs relative to resource availability, where staff often found their time limited such that they could not provide interventions for all students who needed them. Tutees experienced significant growth in reading ability, and the program was relatively inexpensive (Wright & Cleary, 2006).

High school students may also be a valuable resource for creating community support. Karcher (2009) examines several small, randomized studies of mentor programs for elementary school students and finds that "mentees have demonstrated or reported improvements in attitudes toward and connectedness to school and peers," academic performance, "social skills…gains in conventional attitudes towards illicit or antisocial behavior," and sometimes even "parent connectedness" (p. 292-299). As possible solutions to the achievement gap, mentoring and tutoring programs merit additional research. Nevertheless, these studies are encouraging.

Bringing Students' Everyday Experiences into the Classroom

Leung (2001) points out that East Asian educators view memorization and drilling as a legitimate path to understanding, and perhaps they are effective in East Asian schools due to the sheer amount of time that East Asian students spend on academic tasks outside of school. American students often do not devote the same amount of time to learning mathematics (Stevenson, Lee & Stigler, 1986; Chung, 2009), so it may be necessary to use classroom methods that do match their after school experiences.

Using neurological research on the link between enjoyment and learning, Gasser (2011) asserts that American students learn more when an element of fun is present. Given the amount of time many American students spend outside of school playing video games – which often require problem-solving skills and teamwork – it may be a sound idea to use students' enjoyment of such activities to the advantage of learning. (Gasser, 2011). A study by Roussou (2009) demonstrates the potential of technology to have an impact on children's mathematical achievement. Child participants solved problems within the "VR Playground," a virtual reality environment combining a physical playground with visual and audio equipment. Simulations, visual representations, and constructivist tasks provided the children with problem-solving challenges and auditory and visual feedback. Results indicated that visual cues and feedback were helpful and that children did improve their problem-solving skills (Roussou, 2009). Since 21st century students tend to use computers extensively outside of school, programs such as the VR Playground may provide a way to connect students' everyday lives with the learning of mathematics.

Art and literature are other interests of many children, which can be incorporated into mathematics classrooms (and tend to be less expensive than technology). Tucker, Boggan, and Harper (2010) found that activities built around literature can help children to see how mathematics is relevant to their everyday lives, help children to generalize concepts to various contexts, bolster conceptual understanding, and foster discussion. In one research project, a group of Australian elementary school teachers used children's literature, combined with hands-on activities, in their classrooms for two years. Children did better explaining and reflecting and seemingly enjoyed the experience of being challenged (Tucker, Boggan, & Harper, 2010). "Think Boards," which are student-made artistic representations of concepts, are also potentially enjoyable. Creative activities such as Think Boards encourage connections between concepts and generalizations of mathematical ideas, setting children free to construct knowledge on their own. The products, in fact, can be used for scaffolding and facilitating further instruction (Gunningham, 2002).

Support for Mathematical Language

Despite the relative lack of attention that language receives in relation to mathematics education, "Language plays a key role in mathematics, everyday mathematical learning, and math education [and is] used to define mathematical concepts and to express mathematical ideas" (Han and Ginsburg, 2001, p. 202). Han and Ginsburg contrast Chinese, English, and "Chinglish" (literal English translations of Chinese) mathematical terms, finding that the definitions of English words are often obscured by their Greek and Latin roots, while Chinese words practically define themselves. For example, the "Chinglish" forms of "quadrilateral" and "circumference" are "four-sided-figure" and "circle perimeter," respectively. Furthermore, Chinese counting number words "perfectly embod[y] the basic ideas of the base-10 system" (p. 202). In reading the opening vignette, you may have noticed that the teacher's mathematical terms were much clearer than the ones you grew up with. A study of about eighty native-Chinese speaking junior high students and about twenty native-English speaking junior high students, all from the New York City area, found evidence of a link between Chinese language proficiency and mathematics performance. A positive correlation was found between reading ability and mathematical ability among the Chinese-speaking students, while no correlation was found between the reading and mathematical abilities of the English-speaking students. (Han & Ginsburg, 2001). These results suggest that for Chinese speakers, being language proficient is not only a requirement for learning mathematics, but also an advantage, while it appears that the same cannot be said for English.

Han and Ginsburg (2001) suggest employing an alternative system of naming numbers during the instruction of young mathematics learners. Such a system was tested on a group of English and Spanish speaking Latino children in a study by Fuson, Smith and Lo Cicero (1997). The children were equipped with an alternative number naming system based upon East Asian languages (the number 53, for example, was called “five tens and three ones”) and given computational tasks, including counting and multiple digit addition, to solve. Subjects found the new words easier to learn than standard words and also displayed gains in multiple digit addition, making few conceptual errors in the course of solving problems. Innovations such as alternative number naming could potentially make English mathematical language more accessible to children.

Conclusion

As educators, researchers, and policy makers approach the mathematics achievement gap between American and East Asian students, they should be wary of simply replacing our current classroom practices with those of East Asia. Research reveals a great many factors, many of which are not visible within the walls of East Asian classrooms, which may be contributing to superior East Asian mathematics scores. East Asian culture and language, including still more factors such as beliefs and family life, may serve as the reasons. This is not to say that nothing can be learned from East Asian countries, as their performance on assessments indicates that something about the way they prepare students for mathematics achievement must be effective. What it does mean is that cultural context must be considered in any comparison of the East and West, and that any ideas that are borrowed from them must be altered in order to accommodate American culture.

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Biography

Maria Pultz recently completed the accelerated LAMP program at University of Toledo, through which she earned a Master of Education degree and teaching license in middle grades mathematics and social studies. She spent the 2012-2013 school year student teaching both subjects in a fourth grade classroom and is pursuing a middle school teaching position for the coming year.

Empowering Students in High-needs Mathematics Classrooms with Problem-based Learning
How Fostering Mathematical Reasoning Improves Motivation and Learning Outcomes

Nicholas Edward Chelmu

Abstract: Problem-based learning is a compelling and effective alternative to traditional mathematics instruction. Research suggests that problem-based learning in mathematics is especially successful at improving outcomes for students from low socioeconomic status backgrounds. The literature proposes a theoretical basis that links problem-based learning to improved motivation to learn mathematics for students from high-needs backgrounds. Moreover, experimental evidence and case studies support the effectiveness of problem-based learning when compared to traditional instruction in high-needs mathematics classrooms. Overcoming the challenges of implementing problem-based mathematics instruction in high-needs schools has the potential to improve outcomes for low-income students, reduce the mathematics achievement gap, and raise overall mathematics performance in the United States.

Introduction

"Will *every* problem be like *that* one?" is a question high school mathematics teachers may often hear from students after introducing a problem from a new unit. Students anxiously hope the teacher will provide a simple procedure they can memorize, practice, and duplicate on a test. Who can blame them? For many students, learning mathematics by mimicking the teacher has been the norm since elementary school. This instructional approach is sometimes referred to as "traditional instruction". It refers to a style of teaching characterized by lectures, guided practice, and independent practice, in which the student memorizes and reproduces the teacher's conceptual and procedural knowledge. At first glance, traditional instruction appears to have immediate benefits for the student. Not only is traditional instruction efficient in developing rote skills, it is reliable and predictable for students who seek the security of a simple routine to memorize.

A closer look reveals a cause for concern. In response to the student question referenced above, it must be acknowledged that not every problem will "be like that one." In career settings, as in everyday life, humans encounter a wide variety of problems, and no procedure or combination of procedures will provide the solution every time. This is especially true in emerging STEM fields as well as business and trade careers. Companies that cannot innovate are replaced by ones that do.

A growing body of literature supports a reform of traditional instruction, with the goal of helping students deepen their mathematical understanding. And for good reason – evidence suggests that U.S. students are falling behind their international peers. Data from the Program for International Assessment (PISA) and the National Assessment for Educational Progress (NAEP) tell two interrelated stories: U.S. schools lag behind international competitors in mathematics performance, and the achievement gap between students from low and high socioeconomic status (SES) backgrounds is widening (Flores, 2007; OECD, 2010). U.S. math educators needs a strategy to guide students of all backgrounds, with a particular emphasis on students from low SES backgrounds, in the direction of deepening their mathematical understanding. Only then will the achievement gap begin to close and the U.S. reverse its downward slide in mathematics performance.

Problem-based Learning Deepens Mathematical Understanding

Given that an instructional emphasis on procedural knowledge is not sufficient for developing mathematical reasoning, instruction needs to emphasize reasoning itself (Alper, Frendel, Fraser, & Resek, 1996). The National Council of Teachers of Mathematics (NCTM) introduced its Curriculum and Evaluation Standards in 1989. Deriving ideas from the educational theories of constructivism and progressivism, which advocate for student-centered, discovery-focused learning, the NCTM standards introduced problem-based learning as a means to help students draw meaningful connections between context, language, visual representations, and symbolic representations (NCTM, 1989).

Problem-based learning focuses on setting up problems that integrate students' existing knowledge with tasks that help students develop new ideas through discovery (Silver, 2013). The teacher provides support by framing questions within students' zone of proximal development – the range of tasks students can accomplish with minimal assistance (Vygotsky, 1978). Students are expected to use the tools they have at their disposal – their existing mathematical understanding – to unpack and analyze a novel task. Such a task, if framed correctly, leads students to the discovery of an important rule or pattern in a mathematical concept, which students can generalize into a property, law, or theorem.

Alper et al. (1996) propose that the goal of problem-based learning is to develop reasoning skills for unpacking, analyzing, and solving mathematical tasks. In addition, Boaler (2006) suggests that problem-based instruction should encourage "good questions, helping others, using different representations, rephrasing problems, explaining ideas, being logical, justifying methods, or bringing a different perspective to a problem" (p. 365). These elements of focus are a clear departure from traditional learning.

The key idea behind problem-based learning is connecting different representations of mathematical ideas. When a student solves a new problem by applying existing knowledge, the student is connecting existing background knowledge to new knowledge (Boaler, 1993). When students generalize the solution of a particular problem to the solution of a broader set of problems, they forge new connections in their minds. When students represent an algebraic function in multiple ways, such as through verbal language, a table of values, a graph, a symbolic representation, and real-world context, they forge even more new connections (Brenner et al., 1997). The promise of problem-based learning is that strong connections between mathematics concepts create deeper understanding.

Traditional learning, in contrast, relies on lectures and note taking, during which it is intended that teachers bestow knowledge upon students. This style emphasizes skills and drills, with the goal of procedural fluency in archetypal problem types. The problems are routine and do not require creativity in developing solutions.

New assessments like the Partnership for Assessment of Readiness for College and Careers (PARCC) Assessment reflect the reality that students must be equipped with reasoning skills. The PARCC Assessment includes items that call for mathematical reasoning, arguments, and justifications, in addition to modeling real world applications (Partnership for Assessment of Readiness for College and Careers, 2012).

There are compelling reasons to believe that students from low SES backgrounds especially benefit from problem-based learning. It will be worthwhile to investigate the theoretical basis that links problem-based learning to improved motivation to learn mathematics for students from high-needs backgrounds. In addition, it will be helpful to consider experimental evidence that supports the effectiveness of problem-based learning when compared to traditional instruction in high-needs mathematics classrooms.

Problem-based Learning Supports Motivation in High-needs Classrooms

While researchers generally regard problem-based learning as an effective teaching strategy, is it effective in all contexts with all student populations? Do low SES populations, which research shows generally exhibit deficits in mathematics achievement, stand to benefit more, less, or equally from problem-based learning than high SES populations?

A key difference between traditional and problem-based learning of mathematics lies in the mechanism of fostering motivation. Researchers have found that students from high SES backgrounds are more likely to derive extrinsic motivation – motivation from external incentives – from meeting high expectations set by the family (Schultz, 1993). As a result, a student from a high SES background is more likely to buy into the rote learning of a traditional classroom, as the rewards of succeeding within that social framework are reaped at home. Low SES students often do not have this support, and often lack the self-motivation to persevere through a subject that does not seem useful or relevant to them, Schultz notes. A problem-based course, meanwhile, provides intrinsic motivation that may compel students from low SES backgrounds to care about learning math. Can we hook students on problem solving by appealing to their thirst to be original, creative, and capable problem-solvers?

It is widely considered that students from low SES backgrounds are more likely to believe that education and personal development occur not just in school but also outside of school (Gutierrez & Dixon-Roman, 2011). Issues of identity – how students define themselves – and self-expression become even more important to students who do not define themselves only through academic pursuits. There are clear differences in how traditional and problem-based learning environments affect students' ideas of themselves as independent, creative, and empowered individuals.

Rote mimicry of mathematical procedures is hardly interpreted by students to be creative or empowering. Consider Boaler's (2002) three-year investigation of approximately 300 students learning mathematics in two schools in England, in both traditional and problem-based courses. Through assessments, questionnaires, and interviews, Boaler monitored students' performance and beliefs about their mathematics learning. Boaler discovered a peculiar difference between students educated with traditional instruction and problem-based instruction: students with traditional instruction reported lower levels of interest in mathematics. The reason? They reported a desire to be creative and original individuals – not people who carry out repetitive, dull calculations. They also reported a desire to be engaged in social interaction and exercise their freedom of expression and thought. In a sad irony, the reasons students gave for rejecting mathematics reflected not the nature of mathematics, but rather the pedagogical practice of traditional instruction. Problem-based learning, it turns out, emphasizes the very aspects the students claimed were absent in mathematics: creative thinking, individual contribution, and interaction with others.

Given that students from low SES backgrounds are already predisposed to prioritize identity formation over academic success, traditional instruction runs a risk of alienating students with its emphasis on conformity to standard practice. Adolescents interested in becoming creative, confident, and expressive individuals may look to subjects other than traditional lecture-style mathematics for establishing personal, academic, and career interests. Problem-based learning stands a better chance of appealing to high-needs students because the pedagogy emphasizes open-ended thinking, creative use of existing knowledge, and articulation of one's own ideas.

Problem-based learning can also appeal to high-needs students because it personalizes mathematics education. It has been argued that mathematical learning takes place through transformative personal events, in which learners come to a greater understanding of their ability to understand and interact with complex systems (Stables, Morgan, & Jones, 1999). When educators teach mathematics as an amalgam of unrelated facts and procedures, it is unlikely students will draw meaningful connections between themselves and the math they are trying to learn. Instead, the authors argue, a sequence of personally significant events is necessary to gain understanding in mathematics. Such significant events occur when students see the underlying pattern and structure of a mathematical concept.

An example of this type of motivating insight is the connection between the roots of a quadratic equation and its x-intercepts, which is only fully understood when represented graphically, symbolically, verbally, and in table form. Each one of those representations is necessary to gain a full understanding of the concept. When teachers structure learning environments to allow for these moments of insight to blossom, students are most likely to experience these personally significant events (Stables et al., 1999). Given adolescents' aforementioned preference for meaningful learning activities, it is reasonable to assume that adolescent motivation will respond better to inquiry- and problem-based learning environments than to traditional learning environments.

Research has also linked problem-based learning to improved student motivation to learn mathematics, a key predictor of mathematics success. A study of a classroom serving minority students in an urban school suggested that framing mathematics problems and acknowledging student contributions to their solutions had a positive impact on motivation and performance (Battey, 2012). Battey suggests that teaching approaches that foster student participation in mathematical tasks, along with constructive teacher support, maximize student outcomes. The author further asserts that problem-solving, inquiry, and discussion resulted in better outcomes in urban math classrooms than traditional learning.

Evidence of Effectiveness of Problem-based Learning in High-needs Classrooms

The impact of problem-based learning on the mathematics performance of high-needs classrooms is supported not just by theory but also by experimental evidence. Research of the Interactive Mathematics Program (IMP) funded by the National Science Foundation in fulfillment of the goals of the 1989 NCTM standards explored student performance in problem-based learning environments (Alper, Frendel, Fraser, & Resek, 1996). The IMP program was designed to include problem-based learning tasks, such as context-driven tasks requiring connections between multiple representations, as recommended by NCTM. The researchers validated the effectiveness of problem-based learning with students from low SES backgrounds using several key measures, including improved standardized test performance and progression to more advanced mathematics courses.

A second example of evidence supporting the effectiveness of problem-based learning in high-needs mathematics classrooms was a four-year study of 160 students in three California urban high schools by Boaler (2006). This study chronicled the reform of a high school mathematics department from a traditional to a problem-based approach. In comparison to the two other schools, which used a traditional approach, the students in the reformed school performed better on assessments, reported high levels of satisfaction with mathematics, and continued on to more advanced math courses. These results suggest a strong link between an instructional approach characterized as problem-based and improved learning outcomes in urban schools.

Challenges and Implications for Improving Outcomes for Low SES Students

There will no doubt be challenges faced by teachers when implementing problem-based learning activities in high-needs schools. Teachers using problem-based learning will likely encounter resistance from students, teachers, and parents, most likely because the practice is unfamiliar to them. Especially at the outset, problem-based learning activities are likely to put high school mathematics students outside of their comfort zone of rote procedural learning. One study found that students in a high-needs school grew frustrated by unstructured open-ended activities and expressed dissatisfaction with the teacher's lack of direct instruction (Lubienski, 1998).

There is a key takeaway from challenges such as this: the role of the teacher matters. Problem-based learning cannot succeed without teachers accomplishing two important goals. First, the teacher must set up a learning task and frame the driving question in a way that taps into students' existing knowledge. Only then will students have the right initial conditions to attempt a problem and make headway with it. Second, the teacher must find a delicate balance between hovering over students and letting them struggle for too long. In either case, if students are fed clues too generously or if they are left to "discover" the learning with no teacher support, the learning process is stalled. The optimal balance would have the teacher providing minimal support targeted to elicit "breakthroughs" by students.

With mathematics achievement gaps prevalent not just across demographic groups, but entire countries as well, there is a sense of urgency to diagnose the problem and prescribe a solution. A well-known book, *The Teaching Gap*, examines the educational systems of high-performing countries like Japan and Germany and finds that math classrooms in other nations include far more problem-based learning than U.S. classrooms (Stigler & Hiebert, 1999). The success of problem-based learning in deepening understanding and motivating students, it appears, can narrow not one, but two achievement gaps: the low/high SES achievement gap in the U.S., as well as the gap between the U.S. and its global peers. With such a compelling case, it is difficult to imagine why the virtues of problem-based learning are not more widely acknowledged.

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Biography

Nick Chelmu received his Master's Degree in Secondary Education from the University of Toledo and his Bachelor of Science in Applied Physics from Columbia University. After working as an investment-banking analyst in New York City, he changed careers to make a difference through education. His passion is developing students' confidence in mathematics, business, and engineering applications.

Science

Scientific Literacy in the High-needs Secondary Classroom
A Guide for New Teachers

Elizabeth Brockway

Abstract: Scientific literacy is an elusive goal for many new teachers, especially those in high-needs classrooms. Scientific literacy enables students to think critically about the real world and understand everyday phenomena in the context of science. With such broad descriptions provided in literature, one condensed description is used in this paper to help develop obtainable goals for students. Inquiry-based instruction is one method of teaching that helps students obtain the goals necessary to become scientifically literate. Both long-term investigations and the 5-E Model are provided as examples for a first year teacher to use. Scientific literacy is an essential goal for new teachers to have for their students in high-needs classrooms.

Introduction

New teachers have a huge demand placed on them to develop their own personal lesson plans, along with learning how to manage their classroom, and how to stay organized. Ensuring students become scientifically literate sounds good as a state requirement, but may appear a daunting task to new teachers, especially since it is such a broadly described concept. Despite its importance, scientific literacy remains an elusive goal for many new teachers, especially those in high-needs classrooms. These classrooms present unique challenges, such as students' lack of interest, focus, and foundational knowledge. Scientific literacy has the potential to help teachers overcome these challenges. Scientific literacy is an essential goal for new teachers to have for their students in high-needs classrooms.

This paper will focus on one condensed description of scientific literacy, in order to help new teachers develop obtainable goals for their students. Inquiry as a method of teaching will be examined with a goal of helping students become scientifically literate, followed by two curricular examples of how a new teacher can use inquiry in their classroom. The aim is to help new teachers learn how scientific literacy can be a part of their curriculum.

Scientific Literacy

A variety of descriptions of the term scientific literacy exists in research, and this is perhaps because it is so broadly used. The National Research Council (NRC) described scientific literacy on multiple pages of its 1996 publication, *National Science Education Standards* (NSES). While this likely encompasses all that scientific literacy does entail, it does not provide a manageable and measurable description for a new teacher. The American Association for the Advancement of Science (AAAS) noted a scientifically literate person has an understanding of "key concepts and principles of science, is familiar with the natural world and recognizes both its diversity and unity; and uses scientific knowledge and scientific ways of thinking for individual and social purposes," (Rutherford, 1991, Introduction). Thus a year's growth in scientific literacy should include some essential skills; one of which is critical thinking (Chiras, 1992; Yager, 1982; NRC, 1996). Critical thinking involves analysis, interpretation, and evaluation of scientific statements, suggestions, theories, et cetera. A second essential skill is understanding science, in a deeper sense of the word, including understanding "how science works" (Clough & Olson, 2004, p. 28; also DeBoer, 1999; NRC 1996; Flannery, 2007; Rutherford, 1991). "Understanding science requires that an individual integrate a complex structure of many types of knowledge… [including] the ability to use knowledge… and to distinguish between what is and what is not a scientific idea," (NRC, 1996, p. 23). Finally, the description must include a connection between science and society: "the public's understanding of science" (DeBoer, 1999, p. 584; see also Nelson, 2004; Krajcik & Czerniak, 2007; Flannery, 2007; Rutherford, 1991), "how science, technology, and society influence one another" (Pearson, 1990, p. 318), and "the application of [scientific] knowledge to the activities of life," (DeBoer, 1999, p. 584). With such broad descriptions of scientific literacy provided in literature, one condensed description is used to help develop obtainable goals: the ability to think critically about the real world (e.g. interpret, analyze, evaluate) and understand everyday phenomena, all in the context of science.

Inquiry-based Learning Leads to Scientific Literacy

Scientific literacy is not a topic that can be taught just by reading a book or doing a laboratory experiment. Students must build the skills and knowledge that make them scientifically literate. The *National Science Education Standards* (NSES) were developed to promote scientific literacy for all students. Their focus on the minds-on approach involves inquiry-based activities and active learning in which students are asking questions and teachers serve as a guide to assisting students towards discovering their own answers. Through inquiry, "students actively develop their understanding of science by combining scientific knowledge with reasoning and thinking skills," (NRC, 1996, p. 2; see also AAAS, 1993; Rutherford, 1991) which is essential to scientific literacy. Bodzin (2008) agrees with inquiry methods as well, arguing that inquiry helps students "develop a broad understanding of science, along with the critical reasoning and problem-solving skills involved in scientific reasoning" (p. 63). Additionally, the National Science Teacher Association (NSTA) agrees that inquiry helps develop skills essential to scientific literacy, (Windschitl, 2008; see also AAAS, 1993).

In completing inquiry processes, students *do* science – they become participants in what has been referred to in every textbook as the "scientific method." While it is not advocated that students do science in this stringent method (NRC 2005; McComas, 2005), the NSTA and the NSES "both encourage direct involvement of students in all five phases of the scientific experience…formulating questions…offering explanations…testing for validity… communicating results…confirming that results are compatible with established views" (Caskey, Yager, & Akcay, 2008, p. 3; see also NRC, 2005; AAAS, 1993). Science is more "meaningful, exciting, and appropriate," when students are able to do science like real scientists do; when students can create and answer their own questions," (Caskey, Yager, & Akcay, 2008, p. 3-4). These activities build on the skills necessary to become scientifically literate.

Inquiry in the Classroom: Long-Term Investigations

To move ahead from the theoretical to the practical, what has worked must be considered to determine how scientific literacy will be a reachable goal for the students in a high-needs classroom. One of the skills identified in the description of scientific literacy is critical thinking skills. Critical thinking skills can be developed by engaging "students in the design and conduct of scientific research" (Sales et. al., 2006, p. 36). By engaging students in long-term investigations, they develop their own hypotheses and experiments, which improve their understanding of science and deepen critical thinking skills. The process of interpretation enhances student understanding of science concepts, which is part of the description of scientific literacy. Norris, Phillips, and Osborne (2008) suggest a process by which interpretation occurs, involving recognizing lack of understanding, creating alternative interpretations, using evidence, judgment of interpretations, followed by the proposal of new interpretations which begins the process again. Argumentation follows with interpretation, as "any interpretation must be justified with an argument" (p. 90); these are skills that are developed through extended inquiries.

Students *doing* science has been shown to lead to scientific literacy, (Caskey, Yager, & Akcay, 2008, p. 3; see also NRC, 2005; AAAS, 1993). McComas (2005) noted that in order for students to understand what authentic scientific investigation looked like, students needed to conduct long-term investigations. Further, conducting true inquiry investigations where students found not only the answer, but had to determine *how* to find the answer, was more authentic than following a given set of steps in a recipe style experiment. In this case, students tended to "perform better and enjoy the experience more," (p. 27). Thus, this authentic experience in doing science through long-term investigations leads to scientific literacy in the classroom.

Here is an example of a long-term investigation that could be used in the classroom.

> "Today we are going to begin an experiment. We want to determine which method is most effective for killing E. coli. We have three options available…" Overtime, the students notice that one of the antibiotic disks is no longer as effective as it was in the beginning of the experiment. The students begin to question the experiment and their results. "Why do you think antibiotic "A" is no longer killing bacteria? Can you come up with a hypothesis? How could we test that hypothesis?"
>
> Suddenly, what the students believed to be an experiment involving effective bactericides is an experiment explaining natural selection, and they are presented with a problem that they not only need to solve, but are also curious about. From here, the teacher would suggest how to continue.

The 5-E Model as an Example

One way to make inquiry possible for new teachers, with a structured framework, is to use the 5-E model of teaching. This model allows students to construct their own understanding of how the world works, from their direct experiences, (Krajcik and Czerniak, 2007). The five E's are: engagement, exploration, explanation, elaboration, and evaluation. This method of teaching engages students in a primary driving question, and provides concrete experiences with which students could make their own understandings about the phenomenon in question. Bybee and colleagues (2006) reported that use of this model for instruction helped students develop better scientific reasoning skills and abilities than traditional instruction (p. 6; see also Duran, Duran, Haney, and Scheuermann, 2011). This model has been found to promote the skills necessary for students to gain scientific literacy.

Using the 5-E Model begins with engagement – activating prior knowledge. It is suggested that all learning begin with what students already know, and their prior misconceptions, so that these may be addressed in the beginning of the unit (Bybee, et. al., 2006; Ormrod, 2012; NRC, 2005). For the students, this engages their interest in the subject. The next step is exploration, where students complete activities in which they are able to experience the topic. Students learn better when they have direct experience with the material they are learning, rather than just abstract evidence or information (Bybee, et. al., 2006; Ormrod, 2012; NRC, 2005; Krajcik & Czerniak, 2007).

The third step in the 5-E Model is explanation. At this point, students have gained some initial understanding or ideas about the topic – they have some experience with which to base their knowledge. Now the teacher has the opportunity to build on their knowledge and expand their vocabulary with the correct terminology to explain their observations, or perhaps begin introducing the main concepts (Bybee, et. al., 2006). Next is elaboration, during which teachers continue to build on students' knowledge with additional activities that help students build a deeper understanding of the main concepts, including an understanding of how science works – essential to scientific literacy (Clough & Olson, 2004, p. 28; see also DeBoer, 1999; NRC 1996; Flannery, 2007). Students are given opportunities to develop new skills, or to improve on the skills they have already obtained. Finally, the last step is evaluation, during which teachers evaluate whether or not students have achieved the learning goals of the unit, but also where students have an opportunity to place some real-world value on their learning. This real-world value is essential to scientific literacy, for students to understand how to apply their learning to their lives outside of the classroom (DeBoer, 1999; Nelson, 2004; Krajcik & Czerniak, 2007; Flannery, 2007).

> An example of the 5-E Model in action in a high school science classroom could look something like this.
>
> *Engage:* "How many of you have gotten your flu shots? Did you get one last year? Why isn't that one good enough, why do you have to get a new one every year? Who has ever had a flu shot, and still gotten the flu that year? Why do you think that happens?"
>
> *Explore:* "Let's see if we can figure out why we are supposed to get a new flu shot every year. Who has a hypothesis we can begin with?"
>
> *Explanation:* As the students begin to suggest and test hypotheses, they will begin to develop possible explanations while doing science. At this point, the teacher can introduce evolution, natural selection, Charles Darwin, or any other concepts that the students may need to further develop their understanding.
>
> *Elaboration:* "We're going to complete another activity today – as you walk into the classroom, you are all finches, the same species. Some of you are different colors and have different sized and shaped beaks, but ultimately, you are one species. As you enter the classroom, you are separated by some rough weather – some of you land on this island, others land over here…"
>
> The class is separated into islands (lab tables). Each island has a unique food source (beans, marbles, or marshmallows) and each finch has a unique beak (toothpick, fork, spoon, or tweezers). Certain finches will survive and reproduce on certain islands – students can further develop their understanding of evolution through the use of this activity and by answering thought provoking questions.
>
> *Evaluation: S*tudents are asked to explain how the flu virus changes every year, in terms of natural selection. At this point, students' explanations are evaluated as well as their ability to answer the unit's driving question.

Through this example, students should have learned how a concept such as evolution affects their everyday lives with the example of the flu virus and getting a flu shot. Students used scientific reasoning skills to answer the question, "Why do you have to get a new flu shot every year?" They have actually searched for the answers on their own, rather than just being told what the answer is, giving them direct experience, which furthers their learning (Bybee, et. al., 2006; Ormrod, 2012; NRC, 2005; Krajcik & Czerniak, 2007). This experience, along with many others like it, would tend to promote students that are more scientifically literate than simply reading a textbook and listening to lectures. This is just one example of how new teachers can include inquiry in their classroom, towards a goal of scientifically literate students.

Conclusions

Scientific literacy is an essential goal for new teachers to have for their students in high-needs classrooms. It is these high-needs students that continue to fall behind their economically advantaged peers in all subjects, including the

STEM fields. By helping students to become scientifically literate, they will begin to see the world from a scientific viewpoint. With scientifically literate students and citizens, the American people would have the skills to make better-informed decisions, assessing accuracy and avoiding "illogical thinking" (Chiras, 1992, p. 464). It would strengthen "skills that people use every day, like solving problems creatively, thinking critically, working cooperatively in teams, using technology effectively, and valuing life-long learning," (NRC, 1996, p. ix). Scientific literacy would provide the skills necessary for people to ask questions and to find the answers to solve real-world problems, such as climate change and alternative energy. Science provides people with a way to understand the world and to look at why events occur; it helps people explain natural phenomenon. Ultimately, an understanding of science improves quality of life for all citizens, not just the few. And all citizens deserve to have the ability to understand the world around them.

Setting a goal of scientific literacy for our students comes down to individual teachers and individual classrooms, because what works in one classroom may not work in others. Scientific literacy needs to be a personalized goal for each individual classroom and student – it needs to be tailored to the community, the real-world problems that matter to the students, and the students themselves. Scientific literacy is not a cookie-cutter problem that can be solved the same way in each instance. It is something that must be custom designed by each teacher, for each classroom, every year. We, as a community of educators, know that we must have our students *do* authentic science in order to help them attain scientific literacy. What kind of science they *do* is up to us.

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Biography

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The Power of Success in Urban Science Using Argumentation High School Students Use Their Unique Culture to Participate in Science

Amerah Abed

Abstract: Urban students in high school classrooms are often characterized by their cultures and reprimanded for what teachers assume to be aggressive misbehavior. This paper focuses on how educators can use the culture of urban students to participate in scientific argumentation. Argumentation in science requires students to share ideas and confidently present their viewpoint. In order for argumentation to occur in science classrooms, teachers and students must respect each other. This requires teachers to acknowledge the culture of urban students and encourage them to use their characteristics to be successful in science, particularly through argumentation. Urban secondary students can excel in science by using their unique culture to participate in scientific argumentation, but their teachers must support them.

Introduction

"I broke the law of conservation of mass!" screamed one of my students with great excitement as if he were the first young scientist since the discovery of this concept in the nineteenth century to have disproved the law. The students in my urban freshmen physical science class were instructed to work as a team and design an experiment that would test the law of conservation of mass. Joshua and his group chose a variety of materials and assembled their apparatus in a private corner away from the rest of their peers. "Time's up! I want to hear about your results," I exclaimed to the groups after 30 minutes of testing time. Joshua's group was anxious to present first and tell the class how they have proudly broken the law of conservation of mass. Ebony, an intelligent young girl, argued that this scientific law cannot be broken and Joshua's system must have had an error. Joshua responded, "Nope! We weighed our materials, we documented the weight, we dropped the Alka-Seltzer in the water, we weighed it again, and…the mass changed!" Ebony replied with a series of questions, "What did you include in your before weight? What did you include in your after weight? What kind of reaction occurred? How did you keep it in a closed system?" Full of pride, Joshua refused to answer any questions and was convinced that he should have been photographed for the next edition of Glencoe's Physical Science textbook. It was not until Joshua and his group members listened to their peers in the other groups present their experimental designs that they noticed they did indeed skip a step in their experiment causing the masses of the before and after materials to be profoundly inconsistent. Every group that presented following Ebony and Joshua's intense dialogue reported their actual results, but also included their experimental errors.

What is Argumentation?

Argumentation is a key curricular feature that can assist students in developing literacy from a science perspective (Walker & Sampson, 2013). McDonald and Heck (2012) tell us that it is essential to engage science learners in argumentation because it allows them to make informed decisions about personal and global issues, a key element of scientific literacy. In the vignette above, Joshua and Ebony were both confident about their viewpoints regarding testing the law of conservation of mass. Their argument was not only beneficial to Joshua discovering that he made an error in his design, but it also was advantageous to the entire class. The other students that were not actively participating in the discussion were able to gain critical information that prompted them to rethink their designs, identify any errors they had and report them along with their results during their presentations.

Argumentation also involves students engaging and reflecting on practices to further understand how the scientific community builds knowledge. Arguing with evidence requires a student to first build a foundation of scientific knowledge and identify how to support their claim as well as identify the weaknesses and limitations of an opposing claim (Reiser, Berland, & Kenyon, 2012). Ebony's ability to use the correct scientific terms and use what she had learned in class about chemical reactions in her passionate argument with Joshua caused the entire class to take a second look at their experimental design before presenting their results to the class.

Also, the idea of students coming together to discuss their similar viewpoints reflects how groups of scientists work together to argue a common goal, allowing argumentation to offer an authentic science experience for students. All of the above features of scientific argumentation assist students in becoming more successful while participating in science.

Promoting Participation in Science

Today, many times, the model of a science classroom is structured in a hyper-rigid, didactic manner in which the teacher is the all-knowing expert that bestows knowledge upon the student. On the contrary, Emdin (2008) states that learning should be a reciprocal manner, expertise should be shared and the presentation of new information supports a continuous process of teaching and learning. While students are learning from the teacher, the teacher has the opportunity to also learn from the students. Emdin (2007) gives the example of a student that uses his sports knowledge to understand distance and displacement in physics class while concurrently, the teacher is gaining ideas from the student about how to teach the topics they are discussing. The teacher in this situation is open to learning from his or her students. Teachers can continuously learn from their students and use what they learn to continuously teach using different methods. In the case that the teacher does not allow an exchange of knowledge with the students, the student tends to feel irrelevant and unvalued in the classroom (Emdin, 2007).

The nature of schooling bureaucracies marginalizes the urban youth by disassociating them from ever being the knower or the full participant in the classroom. As young individuals, they have thoughts and ideas but their opinions are silenced and are not valued in the science classroom. Urban high school students want to learn science, but the science classroom has too often become a space where they experience a daily loss of their power as an individual, which creates the opportunity for agency-limiting social phenomena, like racism or classism, to fester (Emdin, 2008). Additionally, there is an on-going misunderstanding of African American males in science and a misplaced focus on symptoms of their non-achievement such as a lack of motivation and participation in the science classroom (Kahle, Meece, & Scantlebury, 2000; Seiler, 2001). It is possible they are not paying attention in class because they do not feel important or acknowledged, but the teacher may perceive this as a lack of participation and reprimand the behavior. When a student from an urban school is ignored in the classroom and forced to resort to a pre-mapped out future or when their expression of their cultural characteristics is disregarded, they are left to feel that they cannot rewrite their future. At this point, they are robbed of their ability to author their own life and any belief of hope they once had gradually starts to fade (Emdin, 2008).

It is suggested by Emdin (2008) that the only way to break away from the science classroom that makes urban students feel defeated, overlooked and ignored, and to allow students to offer all their ideas and participate, would be to change the framework of the current classroom. This can be achieved by offering new possibilities for stepping outside of the box from the “normal” didactic and bureaucratic structures of these classrooms. In an effort to demystify what occurs in the world of our urban youth, it is necessary to know how the structures within science classrooms can affect the extent to which students’ power and ability to actively engage within the science classroom and their belief in their ability to succeed in science. They need to be aware that they can create new possibilities for participating in real science (Emdin, 2008). Once again, this must begin with the mindset of the teacher in the classroom.

By establishing a comfortable learning environment for the students that is conducive to exploration, students will be more successful because they can be themselves in this designated space. Teachers should not chastise, scold, talk down to, or belittle students, especially in front of the class. With science being a more difficult subject, students need to feel comfortable to express their confusion or suggest their wacky ideas. At this point, teachers should be understanding and willing to listen to the students’ viewpoints. The path toward learning science is through successful interactions involving high-energy enthusiasm, making it possible for students to get involved and stay involved in science-related activities (Miranda, 2012).

When students feel comfortable enough in their learning environment, they will be more likely to take part in using their voice to speak their minds, particularly through argumentation (Miranda, 2012). This technique of argumentation can be facilitated by a teacher’s foundational knowledge of a student’s culture.

Using Culture as a Tool

The cultural background of a student will have an influence on how that student participates in the classroom. This impact of culture on beliefs about education, value of education, and participation styles cannot be overestimated. For example, in some parts of Asia, it is disrespectful for the students to speak out in class or even look their teacher in the eyes. On the contrary, in most parts of Europe, students are encouraged to be active in classroom discussions and it would be disrespectful if they did not look the teacher directly in their eyes when speaking with him or her (Rosenburg, Westling & McLeskey, 2007).

Due to many differences between teachers and students such as race, socioeconomic status, gender and age, teachers may lack knowledge about the students’ different cultures. This may cause them to sometimes perceive the urban youth to have an absence of the foundation they need to learn science. However, all students enter the classroom with the potential to succeed in science; their culture merely needs to be seen as a tool instead of a handicap.

Teachers who do not recognize the potential learning schema that students develop outside of the classroom will stop them and shut them down, assuming it to be disruptive behavior that does not belong in the classroom (Emdin, 2007; Tobin, 2006). These ongoing shut down procedures suppress the urban youth and the students could experience a build-up of negative emotional energy, frustration, and low interest in science (Tobin, 2006). A science teacher should impress a feeling of belonging upon the students to promote an interest in the content and acknowledge their intelligence, but first they must accept and allow their culture to be used in the classroom. A part of a teacher's preparation to teach urban youth should be to familiarize themselves with the students' culture and utilize the information gained in delivering their lessons.

Literature shows that an urban science teacher has to be professional, respectful, enthusiastic, energetic, passionate about teaching the content and passionate about wanting the students to succeed (Miranda, 2012). Students in urban schools are unique individuals, often times living a completely different and difficult lifestyle than their educator or their counterparts in non-urban schools. It is important for the teacher to recognize this disconnect and be open to learn about the culture of the students. The students should be encouraged, rather than discouraged, to bring their lifestyle and unique cultural mannerisms into the science classroom. If science teachers can inspire students to be themselves and convince them that they can be successful in science, the students will respect the teacher and they will be more open to participate in the classroom. This sense of cultural competency will help the teacher manage the classroom because the students will feel respected and will be engaged in what the teacher wants them to do.

Culturally responsive teaching can also be described as "using the cultural knowledge, prior experiences, and performance styles of ethnically diverse students to make learning more relevant and effective for them; it teaches to and through the strengths of these students" (Osisioma, Kiluva-ndunda, & Van Sickle, 2008, p.391). Before this can happen, it is essential that teachers are able to identify the cultural characteristics of their students and capitalize on how to use them positively to promote participation in the science classroom. A common instructional tool used in the classroom for learning science signifies an experience that urban youth share: the art of argumentation.

Oftentimes in urban neighborhoods, it is necessary for the youth to earn the respect of their peers on the streets. Through this process, they develop aggressive, fearless behaviors and master the art of persuasion. This cultural characteristic that they share can be manifested in the classroom and applied to scientific argumentation. Not only will students be given the opportunity to discuss what they have learned about science, but they will also be given a voice that is deemed as important by their science educator. The teacher's high demand and interest to hear the students' voices is the support that they need to redeem their empowerment in the science classroom.

This form of participation in the science classroom will not be conquered overnight. In order for students to feel comfortable executing a scientific argument in the midst of their peers, they will need to feel that it is cool or worthwhile in some way. A supportive and enthusiastic teacher can help the students appreciate science and encourage them to participate in scientific argumentation by assuring them that they already have what it takes to get started. Students need to be informed that they can be who they already are in the science classroom. They do not have to imitate an old European male to be recognized as a scientist. If urban students already perceive themselves as "cool" individuals, they can be that same "cool" individual in the science classroom by simply altering the content of their argument to contain science concepts using science terminology and results from evidence they have found. Science success is at their fingertips without them feeling stripped of their identity.

Conclusion

Without scientific argumentation, we would still believe that the Earth is flat and we would not know that the sun is the center of the solar system. Scientific argumentation allows us to draw conclusions from debates around interpretation of evidence. This scientific practice can not only grant you a better understanding of high school science, but it equips you to be a lifelong citizen capable of making a justified claim about the world. Maya Angelou (1970) once said, "Words mean more than what is set down on paper. It takes the human voice to infuse them with deeper meaning" (p.98). Our urban youth have voices to be heard and ideas to be implemented. As a science educator, it is our job to equip them with the proper tools that will promote them to speak up in the classroom and the community about science. This empowerment will motivate students to succeed by giving them a more authentic science experience in the classroom and possibly inspire them to pursue a career in the sciences, which is underrepresented by minorities.

In culmination, students in urban schools *do* want to learn science. They may not be the traditional student and it cannot be assumed that they can be taught in the traditional way of teaching science. Although they may not bring their book, paper and pencil to class with them every day, they do bring their personality and the culture that has been instilled in them. Let us use what they have and build from there. They are awaiting our support; will you accept your mission?

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Biography

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Fearing What We Don't Know
Differentiation for the New Science Teacher

Stephanie Bianchi

Abstract: Many new science teachers fear differentiated instruction (DI) and do not use it in their classrooms. This article outlines the principles of differentiated instruction, provides reasons why new science teachers should use DI, and describes examples of what differentiation can look like in the middle school science classroom. This article argues new science teachers fear DI because they lack a strong understanding of the theory and practice of it, but in today's world of accountability, it is more important than ever for teachers to meet the needs of each student they teach. After reading this article, new science teachers will better understand differentiated instruction in order to alleviate their fear of using it within their classroom.

Introduction

How many times have you, as a new teacher, heard from professors or administrators, "You need to differentiate your lessons"? If you are like me, you have heard this numerous times, wondering each time *what does that really mean? How do I even do that?* You may try to avoid differentiating your lessons because you do not fully understand the concept. However, given we are teaching in an era of accountability, with an emphasis on meeting the needs of each student, new teachers *must* be able to differentiate their instruction. Therefore, this article will help you understand what differentiation is, why you should use it, and what it might look like in middle school science classrooms.

In talking with new teachers, I have found many are unsure of using differentiation in their classrooms. I believe this is true because they do not fully understand what it is, what it looks like, or how to do it. New teachers are not always provided with models of differentiated instruction from which to build their own techniques and strategies. When a professor, interviewer or administrator asks us how we differentiate to meet the needs of our students, what should we say?

What Is Differentiated Instruction?

Before we look at why differentiated instruction (DI) is necessary for our classroom practices and how it can help students achieve in our classrooms, we must understand what exactly differentiated instruction is. First, differentiation is not planning an individual lesson for each student, nor is it lessening the content for some students (Willoughby, n.d.). Differentiation is about providing and offering various learning opportunities and styles of learning as well as the appropriate level of challenge for all students. Differentiation is also founded in viewing each student as an individual, as explained by the following definition of differentiation: "the practice of individualizing instructional methods—and possibly also individualizing specific content and instructional goals—to align with each student's existing knowledge, skills, and needs" (Ormrod, 2012, p.G2). This definition helps us understand that differentiation seeks to meet students where they are, creating better opportunities for growth and learning.

How Do I Actually Differentiate?

This concept of providing the appropriate learning experiences and challenges for individual students requires teachers to understand where their students are in terms of the content. Thus, it follows that for teachers to use differentiation techniques, pre-assessment or pre-testing is necessary in order to understand students' readiness levels for each new unit. Roberts and Inman (2007) suggest teachers ask the essential question, "Who already understands it or can do it?" before beginning a new topic, skill, or concept with students (p. 35). This question helps guide instruction based on the students' readiness levels and prior knowledge. There are numerous ways (most of which are not as intensive as creating a separate pre-test) you can pre-assess your students, including K-W-L charts, mind maps, open-ended questions, informal questioning, among many others (p.38). The information you gain from these pre-assessments is then used to determine the best instructional methods for groups of students.

Once you have determined the readiness levels of your students, three main areas of the curriculum can be differentiated to suit your students' needs: content, process, and product. Content differentiation stems from the question, "What do you want the students to learn?" (Roberts & Inman, 2007, p.50). Process differentiation stems from the question, "What do you want the students to do cognitively?" (p. 50). Finally, product differentiation is based upon the question, "How do you want the students to show or demonstrate what they have learned?" (p.50).

From here you can provide various ways of presenting content, facilitate an assortment of activities that each require different cognitive processes, and vary the types of products students create to show their knowledge. While planning and implementing differentiated instruction may sound like a daunting process, new teachers really must attend to the needs of individual students.

Why DI Is Important and What It Can Do for Our Students

Imagine yourself as a middle school student sitting in science class while the teacher lectures about today's topic, rock and mineral identification. You are totally bored because last summer you spent an entire week at rock camp, learning everything the teacher is saying. Rocks and minerals have interested you ever since you visited a mining sluice on family vacation two years ago. Since then, you have collected every book about rock and mineral identification you could find and studied them with a flashlight under your sheets well past your bedtime.

Now imagine yourself sitting in that same science class without a clue. You have never even heard the word mineral, and the teacher is going so fast your hand keeps cramping as you try to take notes. It is difficult to focus on what the teacher is saying because you want to make sure you have the information written down to study later.

Teachers have a tendency to teach their students in methods similar to how they were taught (Pennington, 2009). Many students enter the teaching profession directly after college courses, which usually involve one lecture to the entire class. Therefore, if most teachers model their instructional methods after their most recent educational experience, new teachers may teach like the science lecture scenario, presenting information to students in one fashion without accounting for their prior knowledge and interests. Now, think back to how you felt as you imagined yourself in the science class described above. Would you not have felt more comfortable had your teacher been aware of your prior knowledge or lack thereof? Would you not have been more engaged if you had been given a learning method that suited your current level of understanding as well as your interests? You probably felt exasperated and antsy as the student who loved rocks and minerals and had already become an expert. And you probably felt disoriented, embarrassed, and anxious as the student with no prior knowledge. As brain research indicates, these feelings impede our ability to learn and process information, and these feelings are what differentiated learning works to alleviate so that real learning and achievement can occur (Tomlinson & Kalbfleish, 1988).

At this point, you may be thinking, *but can DI really help my students learn and achieve?* There are many testimonials, first-hand accounts, and single setting examples of how differentiation has been a successful method for meeting the needs of different students in the same classroom; however, there has not been extensive research conducted to provide data on the influence of differentiated instruction across many disciplines, determine its success rate, and validate this type of instructional model across the board. The lack of research on differentiated instruction is due in part to the method's complexity. However, research has shown that in certain circumstances differentiation does in fact foster student achievement. One particular study does help to shed some light on the effects of differentiation.

Koeze (2007) studied elementary students' scores on the Michigan Educational Assessment Program (MEAP) in relation to differentiated reading instruction. Her study found that when choice charts, options for reading which attended to students' readiness and interest, were used, achievement in student reading increased. This is just one of the few studies conducted on differentiation's impact.

While more definitive research can and should be done, think back to how you felt in the science lecture scenario. If you are still skeptical of why differentiated instruction is important, consider that students need to feel comfortable and appropriately challenged as detailed by Tomlinson and Kalbfleish's (1998) list of three principles from brain research that support the use of differentiated instruction in our classrooms.

1. Learning environments must feel emotionally safe for learning to take place.
2. To learn, students must experience appropriate levels of challenge.
3. Each brain needs to make its own meaning of ideas and skills. (p. 54)

The first principle speaks to the idea that we must understand our students' emotional lives and seek to support them in our classrooms by adapting to various emotional needs. Students who feel threatened, intimidated, rejected or unsafe begin producing chemicals within their brain that cause fight or flight responses, which certainly do not help foster learning. These feelings and chemicals certainly came into play in the lecture scenario, preventing learning.

The second principle speaks to the idea that when content is too challenging, frustration and more neurotransmitters kick in, preventing learning. On the other hand, if content is too easy or repetitive, chemicals within the brain that are optimal for learning are not produced and apathy ensues. Again, the lecture scenario illustrates how these feelings can easily be triggered in a classroom setting and impedes students' ability to learn.

The third principle corresponds to the idea that we cannot make all students understand ideas and skills in the same way, as if we were delivering the content right into their brains. Each student must process the information in his or her own way.

From these principles, we can see that brain research supports the fact that we must work toward instruction that helps all of our students learn in ways that work for them. In working toward differentiated instruction, we must consider where and when differentiation is the most important or necessary.

Middle School Diversity and Differentiation

Tomlinson, Moon, and Callahan argue (1998) that middle school may be the level of school where attention to and instruction centered on student diversity and differences are most crucial. Their argument is based upon three tenets, the first being that the majority of middle schools subscribe to the principle of heterogeneous grouping. The authors state that because of these heterogeneous groupings, schools must guarantee that their instruction is reaching all of the learners as effectively as would occur in a homogenously grouped class. The second tenant, the fact that middle schools "serve a highly diverse clientele with immense variance in readiness, interest, learning profile, culture, and gender (as well as physical development and social maturity)" (p.10), requires educators at the middle school level to address these differences in order to service the clientele effectively.

Differentiation in Middle School Science

So, if middle school is where differentiation may be needed the most, let us look at how differentiation might look in a few middle school classrooms. At the beginning of the school year, Miss Applebottom gave her seventh grade science students surveys to gain insight into their preferred learning modalities, environments, and interests. She uses this information later in the school year to create a Biome Think-Tac-Toe to assess what her students have learned about biomes (Hollas, 2007). Let's see what's happening in her classroom as she assigns this assessment.

> Miss Applebottom: You will notice that you have many different options for how you'll show me what you've learned about biomes over the last several weeks. Take a look at the options and think about what you'd like to complete. You can do any three out of the nine choices, but your choices must form a tic-tac-toe!
>
> Alexis: Oh, oh, oh! I wanna make the Jeopardy game with PowerPoint! I watch that show every night with my brothers.
>
> Heidi: I think I'm going to choose the "Walk a mile in my footsteps" one, where I get to "create footprints to represent a biome. One footprint must contain written information while the other contains only pictorial representations" (p. 480). I can use the new drawing set I got for my birthday!

Here we can see that Miss Applebottom has taken her knowledge about her students—that some are artistic and some love to use the computer— along with their interests, game shows and art, to differentiate the products they will create.

The next unit Mr. McPherson is going to be teaching his sixth grade students is all about cells. At the beginning of the unit, he pre-tests his students using different assessment types. He asks students to draw what they think a cell looks like and gives the students a short-answer quiz about cells. Once he determines each student's prior knowledge and familiarity with cells, he organizes lessons for those who need beginning instruction and those who can delve deeper into the content because they already possess a good foundation of knowledge on the topic.

Halfway through the school year in her eighth grade science classroom, Mrs. Sanderson's lab appears noisy, active, and busy. The students have been studying species and reproduction. Today's focus is cloning in the food industry. A group of students sits around a large table with Mrs. Sanderson as she reviews the scientific concepts necessary to understand how food-cloning works because their assessment showed these students had not yet mastered the concepts. Another group of students stands around the SmartBoard, discussing and arguing some controversial points Mrs. Sanderson has outlined on the board. These students showed through assessment that they understood the concepts, and Mrs. Sanderson's knowledge of their interests led her to provide a debate forum for them. A third group of students, each at their own their computer, is concentrated on researching whether or not cloning in the food industry is a environmentally safe (Ohio Department of Education, 2011, p. 250). This group also showed through assessment they had mastered the concepts of the unit, and Mrs. Sanderson felt these students, who enjoy researching and presenting to the class, would benefit from a research challenge. For some, this nontraditional arrangement of students is frightening and overwhelming—students are in various places throughout the room, working on tasks independently. The debate group may get a little spirited while the research group may get distracted on the internet. But hopefully you have come to understand that through this differentiated model the students in Mrs. Sanderson's class *are* learning. They are learning because they are each working at an appropriate level of challenge, their interests are engaged, and they feel comfortable within their learning environment. Mrs. Sanderson combined her knowledge of students' interests and readiness to create learning opportunities for her students, successfully implementing the use of differentiated instruction in her classroom.

A Call to Differentiate

Although differentiating our instruction can be a scary and overwhelming notion, it is important for us as new teachers to use differentiated instruction in order to help all of our students learn and achieve within our classrooms. As new teachers, we are still honing our skills and methods of teaching. I hope you will now make further learning about differentiation a part of that honing process so that you are no longer fearful of what you do not know.

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Biography

Stephanie Bianchi is a middle school language arts and science teacher. She currently teaches 7th grade language arts in Oregon, Ohio. Stephanie holds a Master of Education Degree in Middle Childhood Education from the University of Toledo and a Bachelor of Arts degree in English from John Carroll University. When she is not teaching, Stephanie loves to knit, craft, read novels, and travel.

Scaffolding Scientific Inquiry for All Students

Allison M. Bayes

Abstract: With full inclusion in effect in high schools, science teachers must change their teaching to ensure all students are learning the content. Teacher-directed learning, with lectures prominent, is not effective for all students. Inquiry, though, has been found effective for all types of students, including special education students and students from different cultures. Inquiry can be seen as a spectrum, ranging from structured inquiry with teachers in control, to open inquiry where the students are in control. When incorporating inquiry into a science classroom, it is important that students are prepared and capable of the inquiry level. When inquiry is scaffolded in the science classroom, from teacher-directed to completely student-directed, every student will learn more effectively.

Introduction

Tom is straining to sit through yet another lecture on physics, listening to his teacher yammer on and on about some person named Newton and what he thought about the way objects moved. A fellow classmate is tapping her pencil. *Tap. Tap. Tap*. Trying to ignore this particular distraction, Tom looks to the other side of his classroom, only to find his gaze fixed on the students passing by the open doorway on their way to lunch. Suddenly, his teacher calls on him, searching for an answer which he cannot find anywhere in his mind. This frustrates Tom. It is not his teacher's fault that he cannot answer the question; she is a great teacher. It is all because he cannot force himself to focus on the lecture while there is so much movement and so many noises assaulting his senses.

Tom may just be one student out of 24 students in Mrs. Jones' regular science classroom, but that does not mean every one of these students learns the same way, or possesses the same skills. These students have gone through full inclusion to participate regular classrooms. Tom has Attention Deficit Hyperactivity Disorder (ADHD) and it is evident that he did not learn much, if anything, during class.

Students in special education are now being signed up for regular education classes in the efforts of including these students fully in the regular high school curriculum. Full inclusion is changing not only the types of learners present in regular science classrooms nationwide, but it is also changing how teachers must present the information. Full inclusion demands that teachers change their strategies to ensure every student is learning science effectively. This presents the problem of one person teaching all of these students, who have different learning styles and needs.

The answer to this problem can be found in inquiry. There is no set definition for inquiry, but there is a common idea behind them all: inquiry seeks to solve a problem. The specifics of what the problem is or how to solve a problem are fluid in that, depending on the type or level of inquiry, they may differ. While student-directed inquiry is preferred to create a more complete experience in critical thinking and creativity, this is not possible to implement when the students are not used to this type of learning. Overall, inquiry is the most appropriate strategy for all of the different learners present in a science classroom, including special education students and students from different cultures and socioeconomic statuses. When inquiry is scaffolded in the science classroom, from teacher-directed to completely student-directed, every student will learn more effectively. Before discussing how to scaffold inquiry into the science classroom, the benefits from inquiry on the different types of learners will be examined further.

Types of Learners

Science classrooms today are made up of many different types of learners due to full inclusion and communities full of different cultures. One classroom can contain students with large differences in ability, from cultures around the world, and with socioeconomic statuses on different ends of the spectrum. This mosaic of students all need to learn the science content and feel a part of the classroom family. This is where inquiry comes in. There are many articles and case studies published that describe evidence of these benefits.

Students in Special Education

A case study by Aydeniz, Cihak, Graham, and Retinger (2012) described that by adding inquiry to the classroom, it greatly benefited the students with deeper understanding of the information and that these new skills were still maintained six weeks later, along with improved attitudes towards science. Kaldenberg, Therrien, Watt, Gorsh, and Taylor (2011) published a related article that explains how every student, even those with learning disabilities, are capable of learning science in the regular classroom when inquiry is used. Inquiry-based projects allow all students the chance to learn a topic at their own pace and by whichever technique works best for each individual, whether it is by researching articles, reading textbooks, or conducting experiments (Kaldenberg et al, 2011). On the other side of the special education spectrum, are gifted and talented students. Science teachers need to create lessons to support these students as well as those with learning disabilities. Lim (2006) conducted a study showing how inquiry "nurtures" these students to increase critical thinking, open-mindedness, and respect of other students. All three researchers suggest that inquiry-based learning is best for students with special needs. Inquiry is a good choice for differentiating lessons since every student can complete the activity in a way that suits his or her unique learning style.

Students' Culture

The students' culture is another important piece of the puzzle when creating a science lesson. Culture makes up who the student is as a person; therefore, based on culture, the student may act differently in class or even learn differently. A case study by Kanter (2010) describes how the culture and socioeconomic status of students affect their learning and future involvement in science. Statistics show that African, Hispanic, and Native Americans make up around only 5% of scientists and engineers in the United States due to lack of access to the needed science instruction during their secondary education. Student achievement was increased by incorporating the inquiry-based projects in the classes (Kanter, 2010). Another article also indicates that classrooms in which inquiry was added to the curriculum had higher student achievement than those classrooms that maintained a teacher-directed classroom (Thadani, Cook, Griffis, Wise, & Blakey, 2010).

Whether it is a student in special education, a student from a different culture, or a student with a low socioeconomic status, learning science is a very real possibility when the teacher maintains a positive attitude and creates a positive environment for learning. Inquiry-based learning may be the path to high achievement for every student in a high school science classroom. The key to this success, though, is how inquiry is incorporated into the science classroom.

Scaffolding Inquiry

The core of inquiry is the solving of a question or a problem. There are many types of problems and the paths to solving them are countless. Inquiry is not encased as one technique that can be incorporated in a classroom. Instead, it encompasses a spectrum of different activities with different levels of inquiry.

Spectrum of Inquiry

Inquiry is a spectrum from teacher-directed learning to student-directed learning. While the goal of incorporating inquiry is student-directed inquiry, all of the types are a part of inquiry. Magee and Flessner (2011) explain the levels as including structured, guided, and open inquiry. Structured inquiry is the teacher-directed level of inquiry, with the teacher creating questions and giving the students the path to answer them. Guided inquiry is in the middle of the spectrum, with the teacher and students working together to come up with the questions and path. Finally, open inquiry is on the student-directed inquiry end of the spectrum, with the students creating the questions and paths to answer them (Magee and Flessner, 2011). This spectrum of inquiry shows just how versatile inquiry is in the science classroom. Therefore, whether or not the students are ready to lead their own inquiry projects and the materials available, the teacher can choose the level or type of inquiry that best suits his or her own classroom.

Why Scaffold?

While open inquiry has numerous benefits to students, not all teachers should use this level of inquiry all of the time. Not all inquiry activities require that level of inquiry, nor are all students and teachers ready for open inquiry. Every level of inquiry, from teacher-directed to student-directed can be implemented into a curriculum given that the circumstances are correct such as, student readiness, teacher readiness, type of activity or project, and length of time allotted. By learning more about inquiry, science teachers can better understand how to include inquiry best, according to their students and curriculum. Strategies to implement inquiry range from editing current activities to creating entirely new unit projects. Finally, the inquiry assignment included in a classroom should be consistent with what the students (and teacher) can handle. Students and parents may revolt when presented with a full open inquiry project for the first inquiry assignment. Instead, students need to acclimate slowly to inquiry by starting with smaller inquiry assignments, such as those towards the teacher-directed inquiry end of the spectrum.

Student monitoring is an important part of adopting inquiry. Through the process of moving students along the spectrum of inquiry, it is important to know when the students are capable of increasing the level of inquiry. Vannest, Soares, Smith, and Williams (2012) describe how to monitor what students are learning. They advise using assessments regularly to find out how well the students, especially the special education students, are learning the content (Vannest et al., 2012). When it comes to inquiry-based projects and classrooms, progress monitoring will allow the teacher to keep updated on how well the students are using these opportunities to learn about the different concepts along with whether or not the science standards are being learned effectively. Vannest and colleagues (2012) also note that if students are having trouble, the inquiry can be switched to a more structured inquiry project with the teacher having more control over the starting questions and procedures. Also, when the students are handling the inquiry activities well, then the inquiry can be switched to open inquiry, where the teacher gives the students even more leeway to control the projects and questions themselves (Vannest et al., 2012).

How to Scaffold Inquiry

When first incorporating inquiry into a classroom, student readiness should be tested to ensure they are prepared for this new way of learning. Many, if not most, students are coming from a lecture-based classroom and are used to passive learning. Structured inquiry activities are the starting point for introducing inquiry. This level of inquiry allows the teacher to maintain control over the majority of the activity with only parts of it being open for inquiry. Gooding and Metz (2012) describe a technique for including teacher-directed inquiry into a science classroom. This technique allows teachers to use their current materials and resources and alter them slightly to include inquiry. If this technique was implemented, it would include science teachers taking traditional labs and altering them slightly (Gooding and Metz, 2012). Peters (2005) also suggests using this technique to first implement inquiry into a science classroom. If this technique were implemented, it would involve the lab steps being mixed up, having the students develop the lab from a concept map, or taking turns adding steps to the procedure (Peters, 2005). This method increases students' critical thinking while creating a point to scaffold off of to move towards further inquiry.

After the students have completed enough structured inquiry activities that they are ready and capable of moving along the spectrum, it is time for guided inquiry. Again, progress monitoring of the students should be done to ensure they are ready for an increase in inquiry. Devick-Fry and LeSage (2010) describe the benefits of using interdependent groups of students in inquiry projects. "Science literary circles" put together the ideas of science notebooks and writing everything down, and literature circles where students form groups to discuss a specific book or set of information (Devick-Fry and LeSage, 2010). The teacher may pose the beginning topic, and then let the students take over, or allow the students to create the question they want to answer. Devick-Fry and LeSage suggest that this would allow flexibility between whether the inquiry is more structured or open by how prepared the teacher is for inquiry in the classroom. If this technique were implemented, the students would work in small groups to complete an inquiry project with each student having a specific role and every thought being written down (Devick-Fry and LeSage, 2010). As the school year continues, the students will eventually be ready for open inquiry, where they have authority to decide the questions and how to answer them. This would be at the opposite end of the inquiry spectrum from where the students started. Open inquiry allows for the most critical thinking and independence in students; therefore, it is the ultimate goal when incorporating inquiry into a science classroom.

Conclusion

Evidence shows that when inquiry is scaffolded in the science classroom, from teacher-directed to completely student-directed, every student will learn more effectively. While the goal is student-student inquiry, this cannot be rushed until the students are ready. In this age of teaching, teachers must use strategies to make sure that all of their students are learning science. Inquiry also leads the students to more critical thinking and thinking like scientists. This leads to the students being more prepared for the independence of adulthood and the knowledge that they are fully capable of going into a science related field. Full inclusion is today's reality that is changing up science classrooms nationwide. Every student deserves the best education for their unique learning style and inquiry is just the method to help these students do their best.

> Going back to Tom's classroom, it is evident that inquiry makes all the difference to these students.
> "Today we are going to start a project on Newton's laws of motion. So far, I have picked the topic and led the activity, but this time around *you* are in control," Mrs. Jones announced. Immediately, Tom's thoughts went towards roller coasters. "Roller coasters move, I'm not really sure how, but they do…roller coasters are the best…I can learn more about how they move," Tom's thoughts starting racing at how to begin this new project. Amazingly, he is not thinking about what he should eat for lunch or how everybody else is talking for once; he is actually excited about this learning opportunity and too focused to notice any

distractions. When Mrs. Jones makes it around to Tom, she is able to direct his thoughts to a particular question that will be answered at the end of the inquiry project: How do the trains on a roller coaster not fall off the tracks when going through a vertical loop? Tom quickly gets up and grabs a laptop. “I’ll get to the bottom of this,” he thought as he opened up a search page online, “this is going to be the best project, ever!” This story of Tom does not have to stay a story to you.

Every classroom is full of students just like Tom. The path towards open inquiry and success for every student is right at your feet. What are you waiting for?

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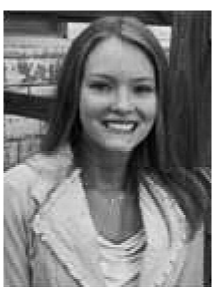

Biography

Allison Bayes graduated from the University of Toledo in 2012 with a Bachelor’s degree in biology and a minor in chemistry. She then stayed there to complete a Master’s degree in secondary science education. Ms. Bayes is currently residing in Maumee, OH and teaching science at Bowsher High School.

Effective Science Assessments
Active Role in Academic Growth

Kayla Gerber

Abstract: Some science teachers struggle with using the most effective assessments in their classrooms to further student academic growth. Assessments are opportunities for students to demonstrate knowledge of the content allowing teachers to use information gained to enhance learning opportunities. This paper describes how assessment feedback encourages academic growth and examines effective assessments, feedback benefits, feedback uses, and ineffective assessments. Research supports that if assessments are used properly they can encourage further learning for students, help teachers teach effectively, and improve student academic skills. Performance assessments are an example of effective science assessments that will be discussed. Effective science assessments provide opportunities for teachers and students to gain insight on students' knowledge to encourage academic growth.

Introduction

Everyone likes taking biology tests, right? Maybe not: remember back to a time when you were sitting in your high school anatomy class. Imagine that you took a test over muscles last week and you were about to receive your graded test back. A couple of things are probably running through your head, like whether or not you did well, and if you did badly how it is going to affect your grade. When the teacher starts passing back the graded test you sink into your seat waiting for the potential bad news, and your confidence instantly drops. The teacher flips your test upside down and places it on your desk; you take one deep breath and flip the test over. On the test, you see your score of 75% at the top of the page, and you take another deep breath because you did not fail the test and it will not hurt your grade in the class. What would you do next? First, you probably would quickly skim through the assessment looking at all the questions you got wrong. The teacher marked all questions wrong that were incorrect, but did not correct most of them. The teacher wrote good job on questions that were answered correctly in the constructed-response section, but only made small comments on the incorrect responses. Sounds like a typical test right?

Were you really concerned with your academic growth in the class after examining your graded test? Probably not, you are probably now more concerned with the new material that the teacher will be discussing for the rest of the period, and not about learning the material you got wrong on the previous assessment. Now that you are a teacher these are serious questions you must consider when giving an assessment to your students. Do you want your students to have this same experience?

The previous situation is a common event for most students that occurs after assessments in science classrooms. Most students have the tendency to forget material right after they take an assessment, and do not want to expand their knowledge of that same material after they have already been assessed. Another common problem in science classrooms is how teachers assess students on inquiry assignments or activities. How is a teacher supposed to actually assess students on an action with multiple-choice or constructed response questions? Some material in science just cannot be tested with a traditional test. Traditional tests normally include a mixture of multiple-choice and constructed-response questions. For example, how are teachers supposed to test their students' knowledge over correct dissecting procedures and muscles of a cat using a traditional test? If a teacher tries to test using a traditional test for the previous actions, is the teacher using the most effective way of assessing?

Teachers need to create effective assessments that provide students with the knowledge and confidence to grow academically. Assessments provide students with opportunities to demonstrate their knowledge of content, allowing teachers to use information gained to enhance learning opportunities for students. Effective science assessments will provide these opportunities for teachers and students to gain insight on students' knowledge to encourage academic growth. Discussion will take place on what makes science assessments effective, how effective assessments benefit students, and examples of effective assessments.

Relationship between Effective Science Assessments and Academic Growth

Effective Science Assessments

Assessments are used in science classrooms to allow students to demonstrate their learning and understanding of the content material, and provide the opportunity for students to improve their learning. According to Khan (2012), the focus of assessments should be to improve student learning rather than to collect information, and should be part of the teaching and learning process. Effective assessments also provide opportunities for teachers to place students in a situation where they can exhibit their true potential.

For example, it would not be the most beneficial for students to take a traditional test over dissecting procedures or cat muscle identification; a different type of assessment would be more effective in providing students with a better opportunity to demonstrate their knowledge. Effective assessments provide information to be used as feedback to modify teaching and learning activities in an education classroom (Bell & Cowie, 2001; Lyon, 2011). Effective assessments produce data that reveal students' strengths and weaknesses, which can be used to adapt and help students learn in the future (Khan, 2012).

Students must know ahead of time what they will be assessed on and the criteria that will be used to judge their success. Cobb (2004) states that corrective instruction must be included in lesson plans after assessments are given, and that effective assessments are only effective if they correspond with both curriculum and instruction. Effective assessments should be short and be incorporated frequently into the classroom (Cobb, 2004). After frequent assessments, teachers must use the information gained to implement instructional strategies that target students' weaknesses with the content material, which will result in academic growth. For example, if it is evident through an assessment that most students do not understand the difference between biceps and triceps then the teacher must incorporate an instructional strategy to help students learn the material better. The complexity of science content can be challenging for students, so effective assessments can be used as scaffolding tools to check for understanding.

Increasing students' confidence in learning and assessments can be a product of effective assessments (Stiggins, 2002). According to Stiggins, when students watch themselves succeed on assessments it boosts their confidence, and shows them that they are in charge of their own learning. How students prepare for a science assessment should be evident by the score received on their assessment. For example, if a student studied for two hours the night before a muscle identification assessment and scored a 19 out of 20 on their test, they will have more confidence than if they scored 14 out of 20. t\Through effective assessments students will see that they have the power to change their results to assessments or they will know what to learn. Once science teachers know what makes assessments effective, they can comprehend the importance of assessment feedback.

Feedback

Good feedback practice is defined by Nicol and Macfarlane-Dick (2006), as "anything that might strengthen the students' capacity to self-regulate their own performance" (p.205). Feedback is information that is communicated to students from their teachers concerning their work. Feedback enhances the quality of teacher-student interactions during learning activities that take place in the classroom, which generates more opportunities for expanding students' understanding (Bell & Cowie, 2001).

Benefits of Feedback

According to Khan (2012), feedback is only effective if teachers share information gathered from an assessment with their students, especially the stronger and weaker areas of students' knowledge. By sharing students' strengths and weaknesses, teachers can guide students to continue to build on the strong academic areas and remove the weaker areas, resulting in higher performances on future assessments. For example a teacher writes "you seem to have a good understanding of the arm muscles, but more work needs to be done learning the lower leg muscles" on a student's muscle identification assessment. In that situation the teacher pointed out both the student's strengths and weaknesses giving the student information to aid learning. The feedback confirmed the strengths of the student, and told them what information they still need to learn.

It is important that teachers provide feedback on all class activities. Feedback is normally communicated in a written or verbal form, and needs to be positive and constructive, encouraging students to continue to work hard to comprehend the material (Khan 2012).

Students' ability to understand feedback given from assessments is a key component to effective assessments. Feedback is only effective if students can understand and interpret the feedback. Hickey, Kruger, and Kindfield (2000), completed a formative assessment study looking at feedback. The study consisted of four teachers that taught a total of 18 life science classes, working at suburban schools. The classrooms were divided into three types of classrooms, and each type of classroom received a different method of feedback to be provided to students for their test over genetics. The three types of feedback classrooms were grade-oriented, standards-oriented, and accountability-oriented classrooms. Students in all classroom types were given their graded assessments back with their given type of feedback. After students received their test and a copy of the key back they were told to either examine their test and feedback provided and correct the test, or move on to the next assignment (Hickey, Kruger, & Kindfield, 2000).

The data collected in the above study showed that most students with all three-feedback types did not use the feedback information to enhance their academic growth. Some of the students in the study stated that they were confused by their feedback that they were given on their assessment. It can be concluded that teachers must guide the students to use the feedback in order for feedback to be used effectively, and feedback must be given to the students in simple methods in order to avoid confusion(Hickey et al., 2000).

Ineffective Assessments

Ineffective science assessments could have negative effects on individual student's learning and their personal mind set towards assessments (Guskey, 2003). According to Guskey (2003), assessments that are effective and meaningful do not surprise students. Guskey states that if a science assessment is surprising to a student who studied, than that student might get the impression that studying does not help for future assessments. Another idea students might think about with surprising assessments is that they cannot trust their teacher to accurately assess their understanding of the material. Assessments should reflect the skills and concepts that were discussed and taught in class. For example, the muscle identification assessment should not contain questions over bones if bones were not covered during class time.

Effective Performance Assessments

How teachers use and create assessments determines their effectiveness in science classrooms. Performance assessments are one assessment tool that can be used effectively in science classrooms. According to Ruiz-Primo and Shavelson (1996), science performance assessments are defined as "an assessment that provides students with laboratory equipment, poses a problem, and allows students to use these resources to generate a solution" (p. 1045).

Performance assessments can be either high-structured or low-structured, and low-structured performance assessments have been proven to be more effective. Low-structured performance assessments force students to come up with the procedure on their own while solving a problem. High-structured performance assessments provide students with the procedure to complete the task, and are more guided throughout the whole assignment. Students tap into their higher-level critical thinking with low-structured performance assessments, because these assessments require students to think and apply more knowledge when dealing with the content. The more effective performance assessments are created, the higher the levels of concepts can be accurately tested (Ruiz-Primo & Shavelson, 1996).

A teacher during a science performance assessment gives students a problem or places them into a certain situation, and students have to solve the problem or issue. An example of a high-structured science performance assessment is a teacher giving each student a non-dissected leg on a cat specimen and telling students they have 40 minutes to use the correct dissecting procedures to clean five muscles, correctly identify them, and answer five constructed-response questions. An example of a low-structured assessment is a teacher telling students to create a representation or model of the different types of muscles in the body using the provided materials. Performance assessments are great ways to assess inquiry activities that students complete in science classrooms.

According to Ruiz-Primo and Shavelson (1996), there are characteristics that make each of the three components of performance assessments effective. An effective task invites students to solve a problem or conduct a scientific investigation, requiring the use of concrete materials that react to the students' actions and provide feedback. An effective response format provides opportunities to record findings, allowing students to decide how to summarize findings, and requiring students to justify their answers. Effective ways to record students' responses are direct observation, notebooks, computer stimulations, constructed response, and multiple choice questions (Ruiz-Primo & Shavelson, 1996).

Ruiz-Primo and Shavelson's (1996) research showed that different measurement methods for performance assessments tap different aspects of science achievement, providing a different insight into what students understand. For example, multiple-choice questions assess different types of knowledge in comparison to constructed-response questions. Unlike constructed-response questions, multiple-choice questions do not measure components of science knowledge that are valued in science education, because students are not given the chance to produce an answer on their own. An effective scoring system within a science performance assessment reflects the goals for which the task was selected, captures the right answer, and provides feedback to the students and teacher (Ruiz-Primo & Shavelson, 1996). Students have been proven to perform better on performance assessments in comparison to other types of assessments (Haydel & Roeser, 2002).

Not Worth the Time?

Some teachers say that they do not have the time to focus on creating effective science assessments or to reteach material after they already have taught it once. But isn't students' academic growth what teachers are aiming for in their classrooms? Teachers can reteach information by using a quick instructional strategy or by going over a few questions concerning the material. Effective assessments do not have to be long but should be incorporated frequently into science classrooms. Not every effective assessment has to be a performance assessment or full of time-consuming, constructed-response questions, but could be as simple as ten multiple-choice questions. Assessments, if created effectively should guide teachers in creating their lesson plans, and provide them with an expansion and abundance of ideas for their classrooms.

Conclusion

Students cannot grow academically from an ineffective assessment, especially when learning science content. Teachers must put the time and effort into providing students with effective assessments. Students must be given feedback on their assessments allowing them to understand what they need to do to improve their learning. Most students will take assessments more seriously if they know that the assessment is meaningful and going to help them academically.

It is important that teachers remember that a traditional test is not always the most effective way of assessing student learning. How can a teacher assess an inquiry action or activity with a traditional test? It is sometimes impossible, so incorporating the most effective assessments for given content information is crucial to students' success in the classroom. For any assessment, teachers should use the information gained from giving assessments to adapt their instruction to provide students with opportunities to further their knowledge of the content material. The evidence that has supported the arguments throughout the paper provides the conclusion that assessments, instruction, and curriculum go hand-in-hand when encouraging student academic growth in a science classroom.

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Biography

Kayla Gerber has a Bachelor's Degree in biology and chemistry from Heidelberg University and a Master's Degree in education with a focus in secondary science from the University of Toledo.

Creating a Problem-based Learning Environment in Science through Service Learning

Araina Johnson

Abstract: Students lose their will to engage in science early–between the ages of 11 and 16. In order to avoid loss of engagement, teachers should implement a problem-based learning environment. Addressing socioscientific issues, participating in explanation and argumentation, and generating scientific models are parts of a problem-based environment. One way to implement a problem-based environment is through service learning. Service learning provides the problems and engagement factor necessary to create a problem-based environment so that students may address socioscientific issues, explain and argue, and engage in model building. The effectiveness of service learning is based upon how much the project integrates with course content, if students work collaboratively, and the status–full-time or part-time–of the students involved.

Introduction

Research shows that students lose their drive to engage in the study of science throughout the ages of eleven to sixteen (Turner & Peck, 2009). When students lose this engagement factor, they are no longer actively participating in the discussion, experimentation, cooperative learning, and data modeling necessary for *doing* science in or outside of the classroom. *Doing* science means that students are exhibiting questioning skills, investigating questions they develop, and "modeling authentic inquiry" (Hanegan, Friden, & Nelson, 2009, p. 79). If teachers do not take the necessary steps to ensure and maintain student engagement in the sciences, the number of students who pursue science, technology, engineering, and mathematics (STEM) careers may decrease (Turner & Peck, 2009). Therefore, it is imperative that science teachers take action to create learning environments that stimulate students' engagement, or reengagement, in order to facilitate science learning and *doing* science in their classrooms.

The traditional lecture-based approach to teaching is unlikely to stimulate the sophisticated engagement necessary for students to reach a state of deep thinking; perhaps due to the "constant stream of information" that "leaves students scrambling to take accurate notes with little time to process questions and concepts" (Gasiewski, Eagan, Garcia, Hurtado, & Chang 2012, p. 230). Pursuing an environment that works to engage students entails moving away from the traditional lecture-based environment and transitioning into one suitable for actively *doing* science, possibly a problem-based learning environment.

Service learning, defined in depth later in the paper, is one way to implement a problem-based teaching approach because it provides the problems and engagement factor necessary to create such a learning environment. However, in order for one to use this approach in the classroom, one must understand the separate entities that problem-based learning and service learning are and then how they fit together. Examples pertaining to life sciences will be provided in order to show how problem-based learning and service learning come together to promote student learning.

Problem-based Teaching Instruction

What is Problem-based Learning?

When teaching with a problem-based approach, students are first given a problem that triggers prior knowledge (Schmidt, Rotgans, & Yew, 2011). After activating this prior knowledge, students are asked to work together in order to build upon what they already know (Schmidt, Rotgans, & Yew, 2011). When working together they may be asked to hypothesize why the problem exists and brainstorm solutions to the problem (Schmidt, Rotgans, & Yew, 2011). As time progresses, students reflect upon and revise the hypothesized models as new evidence presents itself. Through this collaboration, reflection, and revision students should become more aware of their preconceptions concerning the proposed problem, and become better equipped to address the gaps that may exist in their understanding of the proposed problem (Schmidt, Rotgans, & Yew, 2011). Knowing the definition of problem-based learning is not enough. Teachers must also know ways to create a problem-based learning environment in order to implement it into their classroom.

Ways to Create a Problem-based Learning Environment

One way to create a problem-based learning environment is to teach in the context of issues–take an issue-oriented approach to teaching. This may promote students' higher-order thinking and therefore enhance science literacy skills necessary for today's community (Lenz & Willcox, 2012). This type of issue-oriented teaching of science contains socioscientific values at its core. A socioscientific issue can be defined as "a complex social issue with links to science concepts" (Lenz & Willcox, 2012, p. 551). It is important to note that issues are different from topics–issues are derived from topics. In this approach, findings are used to infer and make choices regarding socioscientific issues. An issue-oriented approach allows students to understand the process of assessing scientific data, using data to develop an argument, and assessing how science plays a role in society. Students review issues and the trade-offs, pros, and cons related to the issue. Trade-offs can be defined as "giving up something that is a benefit or advantage, in exchange for something that may be more desirable" (Lenz & Willcox, 2012, p. 553). The choice of a broad issue allows for plasticity when relating the content to the issue because a broad issue can take many different angles. One advantage to this approach is that all students engage in making connections between science, the real world, and everyday life. Another advantage is that this approach may increase students' abilities to argue and use data to back their decisions on socioscientific issues.

Another way to create a problem-based learning environment is through the use of explanation and argumentation in science (Reiser, Berland, & Kenyon, 2012). Explanations are defined as "accounts that link scientific theory with scientific observations or phenomena" (Reiser et al, 2012, p. 6). Explanation recognizes cause and effect relationships, reports for all data obtained, expresses reasoning for the phenomenon occurring, asks *why*, and compares and critiques the phenomenon occurring (Reiser et al, 2012). Argumentation arises when a person is hesitant about a suggested explanation; this hesitation encourages students to defend and contest their explanations and to question others' explanations (Reiser et al, 2012). In order for students to participate in explanation, they also have to participate in argumentation (Reiser et al, 2012). Reiser and colleagues (2012) describe a link between explanation and argumentation. In some cases, explanations, developed through investigation and gathered data, can be tweaked through argumentation. Teachers should integrate explanation and argumentation with science content because it allows students to make arguments that reveal data backing a claim, evaluate the limitations of their arguments, discuss the arguments through reasoning and reflect on their own explanations in order to revise and further develop them in accordance with criticism (Reiser et al, 2012).

A third way to create a problem-based learning environment is to engage students in data modeling (Lesh, Middleton, Caylor, & Gupta, 2008). Models can be defined as "external representations of mental concepts" and may consist of, but are not limited to, "diagrams, three-dimensional physical structures, computer simulations, mathematical formulations, and analogies" (Krajcik & Merritt, 2012, p. 6). This is especially important when training students for today's "technology-based *age of information* society"; being able to understand data, models that represent data, and make judgments about data are key when it comes to quantitative interpretation in real-world situations (Lesh, Middleton, Caylor, & Gupta, 2008, p. 116). Even a task as simple as reading *USA Today* requires the reader to interpret mathematical data in the form of models (Lesh et al, 2008). Though many models could explain one phenomena, it is important to stress that models only estimate and breakdown "how the entities they represent work" (Krajcik & Merritt, 2012, p. 6). It is crucial that models represent evidence consistently and that the appropriate model is chosen depending on the situation and information present. When the model does not relate to the evidence at hand, the model should be thrown out. Even so, models offer a strong means of describing phenomena and engaging students.

Now that a description of problem-based learning has been given, teachers may ask, "How is problem-based learning different from service learning?"

Service Learning

What Is Service Learning?

According to the National Commission on Service-Learning (as cited in Packer, 2009) the term "service learning" can be defined as a "teaching approach that integrates community service with academic study to enrich learning, teach civic responsibility, and strengthen communities" (p. 1). Service learning enhances student learning by increasing understanding of course material and providing students with opportunities to connect information learned in the classroom to real-world scenarios (Lambright, 2009). Service learning gets students *doing* science instead of just thinking about science because it allows for opportunities to question, investigate, reflect, and revise.

Factors That Influence Service-Learning Effectiveness

There are three key factors accumulated through research that influence the extent to which service learning is successful. It is necessary for teachers to take these factors into account when using service learning as a strategy to reach learning goals (Lambright, 2009). Lambright (2009) proposes that the first influential factor is the extent to which the service-learning project is incorporated into the course content. The more the service-learning project integrates with course content, the more positive the outcome. Next, whether or not students work collaboratively throughout the service-learning project influences the successfulness of learning. According to Lambright (2009), “structuring service learning as a group project may increase student perceptions of accountability” (p. 428). Finally, Lambright (2009) states that the third factor that influences the extent of learning during service learning is a student’s status–full-time or part-time. Full-time students benefit more from service learning strategies because they spend more time involved with the project and course material than part-time students (Lambright, 2009). It is necessary to note that secondary science teachers may not encounter students with less than full-time status, and therefore should focus on the first two factors mentioned.

Combining Problem-based Teaching and Service-Learning

Again, service learning provides the problems and engagement factor necessary to create a problem-based learning environment because it is a mechanism for teaching in the context of issues, explanation and argumentation, and scientific modeling. For example, one biology teacher wanted to demonstrate to her class how plants played a role in society (Packer, 2009). To do this, she teamed up with a local farmer to develop problems her students could investigate on the farm in order to develop an understanding of the role that plants play in society. She created a problem-based environment through service learning because she used the service-learning environment (the farm) to develop problems to be explored. By creating the problem-based learning environment through service-learning, she found that students’ attitudes changed to appreciate the hard work and difficulty that comes with farming–the students were better able to empathize. The students also reported having an increased appreciation for the environment. Packer (2009) reported:

> The students all commented on how rewarding it was to taste the asparagus during their final visit to the farm, knowing that their hard work had resulted in an observable, final product. Several students also commented that they learned more from their first-hand experience on the farm than their traditional lecture experience. (p. 12)

Agriculture and Future Farmers of America teacher Stephanie Jolliff provides another example of incorporating service learning into the curriculum to create a problem-based learning environment. During an interview, Jolliff was asked to explain how service learning provides the problems necessary in order to implement a problem-based learning environment in the science classroom. Her response was that when students “engage in problem-based learning that allows them to serve their community, whether it be locally or globally, they truly engage in content and retain that content for years to come” (S. Jolliff, personal communication, June 11, 2013). During the interview, Jolliff also provided a specific example of how she used service learning to promote problem-based learning. Jolliff and her students completed an environmental service-learning project with the goal of discovering how plastic pollution was affecting ecosystems. They specifically targeted finding out how plastic islands were formed in the Pacific Ocean. Addressing this question allowed students to learn how albatross birds, soil, water, and whole ecosystems are impacted by plastic pollution. While exploring these aspects, the students reached out to organizations to see how they were working to solve the issue of reducing waste through recycling. As a result of creating this problem-based learning environment through service learning, Jolliff (personal communication, June 11, 2013) states that:

> Students were so empowered by this project they sought out a $2,000 grant to purchase retrofitted water bottle filling stations to put in the high school and then purchase water bottles for students to utilize to cut down on plastic pollution from our school. In addition, students gave teachers grocery bags that were reusable to reduce plastic waste even further.

Conclusion

Students tend to look at science as lacking a big picture of the natural world (Turner & Peck, 2009). Students believe science to be “confusing, trivial, depersonalized, irrelevant, and decidedly uncool” (Turner & Peck, 2009, p. 55). Therefore, it is necessary to target science engagement early to ensure that students continuously build their engagement in science. Schools need to promote science comprehension as part of life and not just knowledge. One way to do this is to create a problem-based learning environment through service learning. Doing so will engage students and promote "active minds, hands-on activity, problem-solving, and argument-making" that will sustain this engagement in science (Turner & Peck, 2009, p. 56). Through this environment, students may experience *true* science.

Connecting scientific content to real-world issues through service learning is key to promoting student learning in science. Building problem-based environments conducive to student engagement must be a teacher priority–this means teaching in the context of issues, giving the freedom to scientifically explain and argue, as well as creating, revising and testing models. Therefore, to advance student learning in science, educators should, (a) target science learning early with a problem-based learning environment encompassing service learning, and (b) strive to ensure that the problem-based learning is appropriate for young learners learning to argue, explain, and model scientifically.

If science educators and districts are able to instill what it means to *do* science in students through service learning, students would further appreciate science and may even choose STEM courses or careers in the future. However, there are struggles that come with striving to promote problem-based learning through service learning. For example, it takes time for educators and districts to build networks between science educators and the community. It may also require teachers to learn new instructional strategies, such as explanation and argumentation that enhance scientific literacy skills. Next, it entails a shift away from the traditional lecture-based environment to a more project-based environment. Finally, for teachers, students, and districts alike it could mean increased courses, time-commitment, and money contribution. Although promoting service learning as a means to problem-based instruction may be challenging, and the resources may be costly, taking this approach can create relevancy, connections to the real-world, engagement, and personal value of scientific content.

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Biography

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Afraid of Evolution?
Confront Your Fears Using Nature of Science

Brandy Tanner

Abstract: Evolution is a unifying theme of the life sciences that, however uncontroversial in the field of science, remains socially controversial. Many teachers, in an effort to maintain a harmonious classroom, avoid evolution controversy using techniques that undermine scientific values. A more scientific approach would see teachers confronting evolution as accepted theory, and using the social controversy that ensues as a tool for teaching students about the nature of science. This article suggests that students would be better served by a proactive curriculum that teaches them about social controversy, and that teachers would be better equipped to defend themselves from non-scientific backlash by using a proactive approach to teach socially controversial content, like evolution.

Introduction

Mrs. Stouffer does not like teaching evolution. As a scientist, she believes in the scientific value of teaching about common ancestry, change over time, and the unifying nature of evolution as a critical content piece. As a teacher, however, she dreads the onslaught of questions from her students that sometimes lead to phone calls from parents, who accuse her of being a soulless scientist who quotes books, and touts theories as fact.

When the end of the year rolls around, Mrs. Stouffer is forced to broach the subject, because it is included in the state standards. She begins the unit cautiously. Today we will talk about the way that a species can change over time. I understand that this is a controversial topic, and I want to make sure you know that you will not be graded on what you believe, but on your knowledge of the main ideas. In order to pass the standardized test, you must memorize all of the 15 vocabulary words the top of page 123 by next Thursday.

By the end of her introduction, we can already see some problems with this scenario. Mrs. Stouffer has inadvertently made several implications about the content she is preparing to teach. The first thing we notice is that she never actually uses the term "evolution", despite the fact that this concept represents the bulk of the content. She refers to change within species, but avoids discussing common ancestry. Mrs. Stouffer also suggests that the material is controversial, making it seem that the theory of evolution is scientifically controversial, that is, a theory about which scientists disagree. She undermines scientific knowledge as something that can be unbelievable, and must only be memorized for the sake of a passing grade. Mrs. Stouffer has set the stage for her students to believe that scientific knowledge is untrustworthy within the first five minutes of class.

We have all heard about science teachers like Mrs. Stouffer. Perhaps we have even considered using a similar strategy to avoid backlash from parents over the teaching of evolution. The fears that teachers harbor of confrontation over evolution lead them to avoid discourse, an essential element of science. Rather than continue on this path, science teachers must seek out the tools they need to help them feel comfortable teaching socially sensitive topics like evolution, and must have the scientific knowledge to defend their decision.

Districts, schools, and teachers who ignore controversial topics due to "discomfort" are doing a great disservice (Hildebrand, Bilica & Capps, 2008). Our educational system is faulty if we allow teachers to downplay the significance of social conflict in science in order to avoid uncomfortable confrontations with parents or difficult discussions with students. We must instead consider strategies that directly address the controversy, expose students to varied viewpoints, and utilize the debate that ensues to help students understand science content, improve their reasoning skills, engage them in scientific core values, and instruct them in the nature of science.

Scientific Values and Nature of Science

Science is not just a body of knowledge, but also a set of understandings and practices that take place in a social context (NRC, 2012). This set of understandings and practices, common to all scientific inquiry and knowledge, is known as the Nature of Science (NOS). The following are some NOS tenets, as defined by the American Association for the Advancement of Science (AAAS, 1990):

- Scientific knowledge relies on empirical evidence.
- Knowledge production in science relies on shared habits of mind.
- Scientific knowledge is tentative but durable.
- Laws and theories are distinct types of knowledge in science.
- Science is influenced by societal factors.
- Science cannot answer all questions.

Engaging students in social controversies like evolution encompasses each of the central NOS components. Using social controversies to teach NOS, and using NOS to define social versus scientific controversy, can help teachers *and* students understand what science is, and what science is not.

Teachers who avoid evolution fail to take advantage of the opportunity that social controversies offer to induce inquiry and instruct the Nature of Science (NOS). As educators, we must instead investigate ways to utilize the scientific controversy as a tool to teach about NOS and scientific ways of knowing. NOS is a central component of science that should be integrated into the curriculum, and social controversies like evolution offer a prime vehicle (Zeidler, Walker, Ackett, & Simmons, 2001).

Approach and Avoidance

In 2012, the National Research Council published The Next Generation Science Standards in *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Disciplinary Core Ideas*. This research-based framework suggests direct instruction in scientific ways of knowing and NOS as part of a science curriculum. These groundbreaking new standards also place great value on evolution, listing evolution as one of four disciplinary core ideas, and as a unifying theme that is common to many topics in the life sciences.

The same year that these game-changing standards (with their heavy focus on evolution) were published, Berkman and Plutzer (2012) surveyed 900 ninth- and tenth-grade biology teachers about their classroom practices for teaching evolution. This comprehensive study included teachers from 49 states and 599 different school districts. Teachers were classified into three categories according to the methods they used when teaching evolutionary theory.

The vast majority of science teachers surveyed by Berkman and Plutzer (2012) admitted that they avoid teaching evolution because of the social controversy that surrounds it. Only 28% of teachers were classified as “strong advocates” who confront the socially controversial topic of evolution as an established, scientifically accepted theory that is uncontroversial in the field of science. Termed the “cautious middle” by Berkman and Plutzer (2012), a shocking 60% of biology content teachers admitted that they did not feel like they had the expertise needed to confidently teach evolutionary biology, and that they used strategies that reduced the likelihood of generating controversy and decreased the likelihood of a confrontation. Teachers described three specific strategies: teaching microevolution versus macroevolution (limiting the treatment of evolution to change within species), teaching to the test (minimalizing evolution as something that must be learned in order to pass a standardized assessment), and lastly encouraging students to make up their own minds (teaching the controversy by offering creationism or intelligent design as scientifically verifiable alternatives to evolution).

The teachers in the Berkman and Plutzer (2012) survey admitted to using techniques that reduce the likelihood of sparking controversy, an approach that devalues the scientific evidence of evolution for the sake of maintaining a non-discordant classroom. Since we cannot and should not avoid the social controversy that surrounds evolution, we must find ways to use it to our advantage.

Pedagogical Approaches

Controversial topics are useful to gain attention, hold interest and maximize retention of material (Johnson, Johnson, & Smith, 2008; Hildebrand, Bilica, & Capps, 2008; Berkman & Plutzer, 2012). Dewey (1933) uses the term reflective thinking to describe the intrinsic motivation that students feel to solve a problem that is personally meaningful. Piaget refers to a similar phenomenon called disequilibrium; the mental discomfort that learners feel when they encounter information that conflicts with what they currently know or believe (Ormrod, 2012). Students become engaged with a topic when a problem is presented that is relatable to their own lives and requires considerable intellectual effort for a solution. Educators must find ways to effectively implement socially controversial topics like evolution into the curriculum in ways that engage students in doing the work of scientists.

Corrosive approaches

In a study of pedagogical approaches, Hildebrand, Bilica and Capps (2008) offer four, divergent treatments of the evolution controversy. The first two approaches are both termed corrosive; one is passive-corrosive and the other dogmatic-corrosive. Avoidance, or passive-corrosive, is an approach where teachers simply deny that any controversy exists. In this strategy, the teacher corrodes the validity of scientific ways of knowing and NOS by encouraging students to learn, but not necessarily believe evolution. Rather than engaging the students in rational deliberation and the search for arguable evidence, passive-corrosive teachers ask the students to memorize facts about evolution for the sake of passing an exam, leaving the decision about the validity of evolutionary theory up to the students.

Avoidance methods do not address the developmental and cognitive needs of adolescent students. Adolescent students are not yet developmentally capable of making decisions based on part-fact. We cannot expect immature, underdeveloped minds to create their own truths from incomplete or extraneous information. Many adolescent minds have not yet achieved the full complement of adult thought patterns (Ormrod, 2012), and therefore require cognitive supports that are not offered by this strategy. Students do not have decades of experience with science content, or access to thousands of peer-reviewed articles, as do most science teachers. It is the task of the teacher to provide students with opportunities to evaluate the subject using scientifically verified evidence, scientific discourse and scientific ways of knowing. The passive-corrosive approach does not offer the necessary supports.

In the dogmatic-corrosive approach, or simply Dogmatism, the teacher emphatically stands in opposition to religious beliefs, and in support of science. Like the avoidance method, this approach also denies the existence of controversy, but has the added detraction of alienating students who seek to reconcile their religion with science. By alienating the students whose families or religion identify with creationism, educators who use dogmatic tactics are defying equal educational opportunity for all. Furthermore, teachers who “take sides” on the issue make it seem that evolution is a matter of one’s opinion, open to interpretation, rather than a scientifically verifiable theory, backed by mounds of evidence. Berkman and Plutzer (2012) expound on this idea.

> If students come to think that science is simply a matter of one’s opinion, and that those opinions come from our values and faith, then it will be impossible for science to provide trusted, unbiased information to citizens and policymakers. (p. 23)

Dogmatism creates a divide between students and content, and does not encourage critical thinking or scientific ways of knowing.

Teaching about controversy

The third approach in the Hildebrand, Bilica and Capps study (2008) is teaching *about* controversy. This research-based strategy, with many proponents in the scientific community, engages students in discourse about their own thoughts and feelings regarding evolution. Advocates argue that this method creates a safe space for students to discuss evolution regardless of their own views, the views of the teacher, or the views of the parents. Detractors point out that, by teaching *about* controversy, we bring unscientific ideas into a science classroom. As scientists and educators, we know that no real controversy over evolution exists. Why, then, would we suggest to our students that controversy remains? Hildebrand, Bilica and Capps (2008) suggest that, because it brings non-science content into the classroom—a method that threatens the validity of science—this is not the most desirable treatment.

Proactive-pro-social

The final approach to teaching evolutionary theory is termed Proactive-Pro-social. This method is recommended by the National Research Council (2012), the National Academy of Sciences (1998) and The National Science Teachers Association, and allows the teacher to acknowledge that controversy exists, but not to teach *about* controversy (Hildebrand, Bilica, & Capps, 2008). Proactive-Pro-social methods work because they acknowledge the difference between ways of knowing in science versus other ways of knowing, such as those in philosophy, history, and religion. Berkman and Plutzer (2012) describe this method as one used by the teachers who chose to confront the social controversy surrounding evolution. Teachers who cited this instructional strategy as a method of teaching evolutionary biology dealt directly with opposition views by: (a) teaching what science is, (b) teaching how science and religion ask different questions, and (c) presenting evidence that science and religion are not in conflict. These teachers were able to address the fact that there is no real, scientific controversy over evolution, and that the controversy that does exist is purely social in nature. By addressing the social controversy while teaching only the science, teachers can avoid alienation of student sensibilities while simultaneously addressing the nature of science as verifiable by evidence.

The Proactive-Pro-social approach most closely aligns with NOS and ways of knowing in science, and does not place the teacher's credentials at risk by introducing non-science content into a science classroom. This management of evolution is the most scientific method of addressing a socially controversial topic that is not controversial in the field of science, and is concluded to be the most pragmatic approach to teaching science in a way that mirrors NOS. Science teaching methods should mirror scientific values regarding the nature of science and scientific inquiry, and this can be accomplished through the Proactive-Pro-social approach to teaching students about evolution.

Conclusion

Teachers who avoid social controversies undermine scientific values and do a great disservice to their students (Berkman & Plutzer, 2012). We should choose, instead, to take advantage of the social controversy surrounding evolution as relevant and authentic, and therefore engaging to our students (Kolsto, 2007). Engaging students in discourse about socially controversial science topics can also promote critical thinking (Bigge, 1964). In this age of information and technology, it is meritorious to promote critical thinking skills in the citizens of the future. Teachers can emphasize scientific ways of knowing and the nature of science by reinforcing the usefulness of argumentation from evidence about controversial science content (NRC, 2000).

Research-based methods such as a Proactive-Pro-social approach to evolution education can be useful to us as educators in our endeavor to educate future citizens and scientists. A Proactive-Pro-social approach to teaching evolution addresses the social controversy by defining what science is and what it is not. This curricular approach helps to engage students, and equip them for eventual participation in the democratic process, while enabling teachers to defend themselves from non-scientific backlash from family and community members. Teachers who choose to proactively teach evolution as a scientifically verifiable, unifying theme in the life sciences take advantage of the opportunity that social controversies offer to teach about the nature of science.

Teachers are not simply imparting knowledge onto their students in a social vacuum, nor are we solely teaching them content; we are preparing them for informed participation in the democratic process. We must teach students not only science content knowledge, but also the ways that social context can affect science (Kolsto, 2007). Many issues in science have social, political and legal considerations that can be used as a tool to assist students in understanding science within its social context (See Haler, 2005). Awareness of the social aspects of science can help students understand the delicate relationship between science and society, and assist them in becoming more informed participants in a democracy (Kolsto, 2007). By teaching our students what science is, how science and religion ask different questions, and by presenting evidence that science and religion are not in conflict, we can proactively teach evolution and other socially controversial theories, while exposing our students to essential science content.

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Biography

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Helping Students Understand Climate Change Scientifically
A Case for Earth Systems Education

James E. Canterbury

Abstract: Climate change education in America is broken. Recent studies reveal students and teachers have a disjointed understanding of the mechanisms that cause climate change. A reason for these misconceptions is that science has been presented as a set of disconnected and unrelated topics; mainly physics, chemistry, computer science, and biology. Earth Systems is a comprehensive, holistic approach that views the planet as a system – where physical processes and matter cycles are irreversibly linked. Viewing the planet as an integrated system will help students deepen their scientific understanding of the cause and effect relationships that generate climate change. Though it is complex, and calls for a science education paradigm shift, Earth Systems Education is necessary to reform American climate change education.

Introduction

We are failing our children. Earth's climate is changing. In the last 40 years, the global mean temperature has risen steadily (Hansen et al., 2011; American Meteorological Society, 2007; Meadows & Wiesenmayer, 1999). Freezing levels are retreating to higher elevations and in lower elevations, rain occurs rather than snow (AMS, 2007). Spring snowpack is decreasing and the pack melts earlier in the year (AMS, 2007). According to the American Meteorological Society, "The spring runoff that supplies over two thirds of the western U.S. stream flow is reduced" (AMS, 2007, p.1). Agriculture growing zones, known as the USDA plants hardiness zones, are shifting north. This means plants that once grew exclusively in southern climates can now be grown outdoors in Kentucky and Ohio. Growing seasons for Great Lakes gardeners are longer, and hard frosts are not occurring until late November. With all of this atmospheric turmoil, perhaps the most shocking reality has been overshadowed: the education our students receive on climate change is deficient.

A complete educational paradigm shift in science education is the most fundamental and critical step to fixing the problem of climate change education. I will discuss student misconceptions of climate science as evidence that our educational model is broken, explore Earth Systems Science (ESS) as an alternative science curriculum paradigm and the logical pedagogical successor to a model that has been largely unchanged since the Cold War, and argue that students' scientific understanding of climate change, and science in general, will be improved through ESS.

Students and Teachers Misunderstand Climate Change

Numerous studies have been conducted that allow scientists to gain a deeper understanding of the public's ideas on climate change. What researchers are finding is school children of all ages and grade levels are carrying misconceptions of science concepts, especially climate change (Boyes & Stanisstreet, 1992; Boyes & Stanisstreet, 1998; Boyes, Chuckran, & Stanisstreet, 1993). I define "misconception" as an idea or notion that is contrary to scientific understanding – in this case – of atmospheric phenomena and the processes, causes and remedies of global climate change.

Greenhouse Gases and Pollution Confusion

Shepardson, Niyogi, Choi, and Charusombat (2009) assessed 91 Midwestern United States, seventh-grade students and their understanding of climate change. Survey results indicated that students think global warming is caused by greenhouse gases and air pollution *in general*, neither of which is true. This led them to conclude that solutions to global warming were to drive less, reduce pollution in general and reduce the numbers of factories that pollute. In reality, scientists understand the main culprit of anthropogenic global warming to be the burning of fossil fuels in the production of electricity (American Meteorological Society, 2007; Greenpeace, 1996 as cited by Bulkeley, 2000, p.319). Therefore, students' suggestions would do nothing to prevent or reverse climate change.

Mechanics of the Greenhouse Effect Misunderstood

Aron, Francek, Nelson, and Bisard (1994) conducted a study to uncover general atmospheric misconceptions among 708 students in grades 7 through 12, as well as undergraduate university students. When asked to explain why the interior of a car is often hotter than the outside, 53 percent of the students could not do so accurately. They incorrectly surmised that while *energy* from the sun can pass through the auto glass into the car without issue, the energy from the interior of the car cannot, thus warming the inside. The correct explanation is sunlight gets in and warms the inside of the car while the cooler outside *air* cannot mix with the warmer inside air. What may even be more significant is that those studying to become physical and Earth science teachers scored the lowest of all student groups with only 32 percent responding correctly. The results of this study concluded two things: (a) misconceptions, once firmly rooted, are difficult to correct and (b) misconceptions harbored by future science teachers were found to be similar to those of college students taking introductory classes, which suggests a general lack of scientific knowledge is problematic throughout the K-12 curriculum and beyond.

Who Contributes to Global Warming?

Bulkeley (2000) conducted a study in Australia in which 242 students, ranging in age from 11 to 18, and their parents were asked to respond to a series of questions concerning climate issues. The study found that nearly 30 percent of responders said they were ‘not sure’ or ‘were sure the greenhouse effect *wasn’t* happening.’ In a second question, 46 percent of respondents said they were ‘not sure’ if individuals contributed to climate change, or said they were ‘sure individuals *do not* contribute’ to climate change. In the same survey, more than 60 percent said that the community ‘*does* contribute’ to the causes of climate change, most significantly by means of automobile traffic. Clearly, the public has a poor understanding of what causes climate change.

Teachers Uninformed – Relate Ozone Layer Depletion to Global Warming

Papadimitriou (2004) conducted a study that investigated the scientific understanding of primary teachers, particularly when it comes to climate change, the greenhouse effect and ozone layer depletion. He found that respondents incorrectly related climate change to air pollution, environmental pollution in general, and acid rain. They also incorrectly related depletion of the ozone layer to rapid climate change. This is a symptom of a much larger inaccuracy these teachers held which is the inability to distinguish between the greenhouse effect and ozone layer depletion - the number one misconception students have about climate change (Choi, Niyogi, Shepardson, & Charusombat, 2010; Shepardson et al., 2009; Gowda, Fox and Magelky, 1997 as cited in Orion & Fortner, 2003, p.100).

Scientific Understanding is Lacking

Through the results of these studies, it is clear that K-12 students, undergraduate college students and even some teachers lack a scientific understanding of climate change. Individuals are either making incorrect process-to-phenomenon connections, or are not making connections at all. This is a systemic problem, and American science education must be reformed to help students make these connections.

Reforming American Science Education

Science Education is Stuck in the Cold War

A likely reason students and teachers are not making scientific connections is that science is presented as a set of disjointed, independent topics (Choi et al., 2010). Orion and Fortner (2003) state that since the Cold War, the paradigm that has dictated American scientific priority has been one that insured military, technological and commercial advantage over communistic societies. Physics, chemistry, computer science and biology have been at the forefront of the collective mind of the scientific community. The educational community took notice and offered a curriculum that has reflected this emphasis ever since. These disciplinary boundaries have relegated many science subjects, including those that explore the workings of our world, like Earth science, to the realm of the least important. Earth science has been deemed so insignificant that only three percent of American high schools offer courses in the subject (Orion & Fortner, 2003). When Earth science is taught, it is also fragmented into seemingly disconnected sub-topics such as meteorology, astronomy, geology, ecology and oceanography (Ruzek, 2010). Orion and Fortner (2003) assert that this curricular approach makes it “impossible” for students to understand how these disciplines interrelate. If subject segmentation makes scientific understanding impossible, changes must be made.

Shifting the Paradigm

Earth Systems Science (ESS) began in 1995 and is far removed from the Cold War mentality. ESS is a holistic pedagogical and curricular approach to Earth science and to science in general. It seeks to teach students to view the Earth as a system--where physical process and matter cycles are intertwined rather than independent. Just as the organ systems of the human body work in concert to maintain homeostasis, so it is that the hydrosphere, lithosphere, biosphere and atmosphere are dependent on one another to sustain the Earth. These spheres are connected; changes in one will bring about changes in another.

For example, rather than presenting El Niño as an occasional weather phenomenon, ESS shows students a cyclical relationship that begins when the Easterly trade winds (atmosphere) in the south Pacific weaken or reverse direction. This leads to the piling up of warm ocean water (hydrosphere) off the coast of Peru. This pool of abnormally warm water (a) disrupts the aquatic Peruvian food chain (biosphere) and (b) becomes fuel for dangerous, flooding rains that negatively impact the southeastern United States (biosphere) (National Oceanic Atmospheric Administration, 2013). This new way of thinking about the Earth will make it easier for students to conceptualize both natural and manmade cause and affect relationships that impact our world.

Implementation of Earth Systems Science

Earth Systems is a modern approach to viewing Earth science but it is also a paradigm shift for science education. It will not work as a stand-alone class; ESS must be integrated across the science curriculum. Physics, chemistry and biology are essential tools used by mankind to understand the planet and its systems. These subjects can easily be taught from the perspective of systems education. Physics teachers can present the energy absorption and reflection mechanisms of the greenhouse effect as a set of interactions between the biosphere and atmosphere. Biology teachers can dissect the carbon cycle to reveal its relationship to the atmosphere, lithosphere, and biosphere. An opportunity presents itself in chemistry to adopt a systems view by investigating natural and manmade compounds, both airborne and dissolved, that impact water quality (hydrosphere). These are areas where students need intervention when it comes to understanding cause and effect relationships.

Mayer and Fortner (1995) approach curriculum implementation by matching students with ability-appropriate content matter. This is accomplished by examining the elementary, middle, and high school curricula in three areas: values, methods, and locales (see Figure 2, p.62). For example, the middle school curriculum would focus on the values of concept clarification and expansion, the methods of investigation, prediction, and application, and research environmental issues at the state and national level. It is also recommended that climate change science enter the curriculum at the middle school level (American Geological Institute, 2010; Fortner, 2001). With this framework set, teachers are free to begin developing and implementing appropriate Earth Systems engagement activities and experiences in inquiry.

Context for Understanding Cause and Effect Relationships

Meadows and Wiesenmayer (1999) state the causes of global warming are confusing to understand because evidence blaming both human actions and natural events can be produced. However, the Earth Systems approach is a way to explain climate change clearly. Hays, Berkman, Hazlett, Richardson, Sykes, and Williams (2012) say the climate can be changed on different timescales by different processes in the Earth system. For example, human-induced changes in atmospheric composition may cause climate change on the 10-100 year timescale; while on the 10,000-100,000 year timescale, changes caused by orbital variations may dominate. On the 100,000-100,000,000 year timescale, changes in the distribution of continents and oceans may be important. On the billion-year timescale, interactions between the biosphere, atmosphere, hydrosphere, cryosphere, and solid Earth have produced major modifications of these subsystems, while feedback among them has resulted in remarkable climatic and environmental stability. The Earth System approach provides the context for understanding the relationships between timescale and system components that result in climate change. (para. 6)

A clear understanding of how each science system is related to each other will lead students to form sound process-to-phenomenon connections in other science disciplines.

Resistance is Possible

A systemic overhaul of science curriculum will be met with resistance by some teachers and administrators due to the sheer size and scope of this endeavor. This is a valid concern and should be met with careful thought and planning. Hoffman and Barstow (2007) report, however, that implementation of the ESS perspective will be helped by demonstrating its value in deepening student understanding of science concepts and critical thinking skills. Most aspects of the physical world can be explained when viewed through the prism of ESS in the same way that evolution can explain most life processes over time (Hays et al., 2012).

Another pitfall may be that a system of integrated processes is a complex way to view the Earth – perhaps too complex. After all, Orion and Fortner (2003) admit that ESS “involves the development of cross-curricular and cross-age programs. It involves interdisciplinary subjects and most of all it involves the teaching and learning about complex interrelated systems and the development of system-cyclic thinking” (p.109). This is also a valid concern but not one that should halt the progress of this modern, 21st century Earth science perspective.

Complexity allows ESS to be as broad in scope and as deep as student knowledge will allow. Using the Earth Systems approach, local community topics will enter the elementary curricular sequence first. This happens because early elementary students build meaning from experiences in what is primarily familiar (Ormrod, 2012). Then, as students develop their cognition and their understanding of the content, larger topics in both scope and impact will enter the curriculum (Orion & Fortner, 2003). The complexity of ESS naturally lends itself to the scaffolding of students' experiences and should be seen as a tool teachers can use to engage students in what they find valuable.

Conclusion

Climate change education in America is broken. Recent studies reveal students and teachers have a disjointed understanding of the mechanisms that cause climate change. A likely reason students have these misconceptions is that classroom science has been presented as a set of disconnected and unrelated topics. Further disciplinary segmentation was perpetuated by the Cold War mentality of gaining military, commercial, and technological advantages over enemy societies. This brought mainly physics, chemistry, computer science, and biology to the forefront of the American educational stage and relegated the remaining sciences (like Earth science) to behind the scenes anonymity.

The Cold War is over. However, like the Titanic guided by her small rudder, America is slow in reacting to the environmental concerns that have become top priority for the general public. The climate is changing, and America's students do not understand how or why. Science education needs reformation, and Earth Systems Science is being presented to kick-start the revolution. Viewing the planet as an integrated system will help students to move from misconception to scientific knowledge. Possessing fundamental scientific knowledge will allow students to dive deeper into more global and abstract topics that are new and engaging.

Taking everything the planet has to offer and trying to conceptualize it as a singularity is a complex job. It will involve developing cross-disciplinary curriculum and instruction methods. Attempting to blend environmental subjects into traditional science classrooms will likely be met with resistance from both teachers and administrators. No one course of study can possibly contain all the information needed to properly understand the Earth and its systems. ESS is too complex to be left alone – it must include all of science. It is a monumental task, but it must be done for the good of the planet and the education of our children.

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Biography

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Social Studies

Role-Play in the Classroom
Accentuate the Positives but Don't Count Out the "Negatives"

Kayli L. McCullough

Abstract: Educators are being encouraged to find new ways to engage their students and get them to learn content in a more meaningful way. In history, some teachers have used role-play and documented their success with the strategy. However, while they have raised valid points in their discussion of the strategy, these educators have ignored the potential "problems" inherent in the strategy, likely for fear that it will discourage the use of the strategy in the classroom. By ignoring the problems, educators have missed opportunities to discuss and explore more meaningful topics in history that are a result of the "problems." This paper aims to address how the "negatives" of role-play are potentially its biggest benefits.

Introduction

Teachers are constantly trying to find ways to engage their students in the content because of apathy on the students' behalf. And while student apathy is apparent in many disciplines, perhaps no teacher experiences it more than the social studies teacher. This apathy is the result of a variety of factors, and is an issue that has been carefully studied over the years, an example being Chiodo and Byford's 2004 study, which found that students truly "dislike" social studies. Scholars have concluded that perhaps the reasons students are disinterested is because of the perceived lack of interest or enthusiasm on behalf of the teacher or the perceived lack of "utilitarian value of the subject matter" (Alazzi, 2007, p. 35). Thus, teachers are trying to find and use methods that communicate the value of the subject to students, while engaging them at the same time.

Instructional methods used vary greatly in terms of scale and creativity, and educators have found role-play to be an especially viable teaching strategy in the history classroom. Supporters of the activity note its many attributes, such as helping students understand the dynamic nature of history, and argue that it should be used more frequently (Gorvine, 1970). Sometimes, educators will use the terms "simulation" or "story-telling" in place of role-play, but the goal and structure is essentially the same, as the point is to get students to act as if they were engaged in a historical setting. Yet, when discussing the positives of the activity, very few educators or scholars highlight the significant issues that role-play may inherently bring to the forefront, or at the very least do not discuss how these "problems" present unique learning opportunities that could help illuminate complicated historical issues for students.

Scholarship

Some academics, including Miner (1977), have addressed the issue of time limits and constraints that make the role-play approach something that needs to be used in moderation and not in place of lectures.Yet, there are more, much larger complications. Beyond the simple issues of time constraints and participation that scholars do discuss, there is the possibility that the role-play will not go as planned and instead will be anachronistic in nature, and bring modern conceptions and ideas to the past. For example, in his work, Gorvine (1970) noted that when engaging in role-play the students could not completely separate themselves from their own modern context, thus their own feelings of patriotism (for example) might have impacted their judgments in the role-play. Therefore, Gorvine suggested that there was a concern of objectivity in the students' acting. Despite this "issue" however, Gorvine saw the strategy as successful.

Instead of downplaying potential negative issues, more educators should bring attention to them. The flaws inherent in role-play could actually be utilized to help students understand complex issues, such as context, bias, and source credibility. Advocates of role-play just might downplay the "problems" within the strategy in hopes of gaining support for their activity, when in fact the problems might actually be the strengths of the role-play. Consider the following scenario, which is very similar to what I have observed as a teacher:

Simulation

The scene is a middle-school history classroom. As the teacher, you have decided that to get your students more engaged in the course material you are going to have the students engage in a role-play about life in late 18th century colonial America. The class has done a lot to prepare; the students have been taught about the basics of the time period and they have also done some research on their own. As the teacher, you have read up on the literature about role-playing in the classroom and followed the guides exactly, in order to ensure maximum learning. The students have written their own play and all students appear to enjoy the activity. Finally, the day comes to act out the role-play and students begin the activity. Everything is going to plan—wait a minute! Is one of your students speaking in Old English? Even worse—is a female student actually taking on the role of governor? All of a sudden, your carefully laid plans seem to be crumbling before you. Students are bringing their own conceptions of the period into the role-play, whether accurate or not. They are also bringing their own contemporary context with them to the 1700s and this is most definitely inaccurate. According to Arnold (1998), who used role-play extensively in his classroom, this role-play may indeed be considered a failure. Arnold contends that a simulation should be as historically accurate as possible in order to be a viable learning strategy. Is Arnold's conclusion fair though? Is this truly a lost cause, or can something be salvaged?

The Benefits of Role-Play

First and foremost, this activity can only be considered a failure if the goal is *only* to get students to learn historical information. Most certainly though, there are some benefits of role-play that go beyond historical learning. Regardless of the amount of material that was actually learned as a result of the role-play, students in the above scenario most likely developed and improved certain skills. For example, as noted in his piece on storytelling, Harris (2007) states that in activities like these, students "build their vocabulary and oral language skills" (p. 112). Regardless of historical knowledge, students in the above scenario surely worked on expanding their language skills as well as their communication skills. Even more importantly, these skills are applicable to all disciplines, and thus perhaps among the most important to build upon. Moreover, because students were working together, they were also building and engaging in a community, which according to Harris (2007) is important to facilitating a successful classroom dynamic. Thus, even though it would be wonderful if all students took away factual, historical knowledge from the activity, role-playing undoubtedly lends itself to helping students learn more about how to effectively communicate with their peers.

Students also learn how to work together and collaborate in order to create something meaningful. These skills will help them in the future, and therefore might communicate to students the validity of the strategy, which is important in order to keep them engaged. Yet, is there an opportunity for students to still learn something about history, even if the role-play was anachronistic in nature? The answer is a firm yes, because of what it can teach students about the nature of writing about, exploring, and engaging with historical events and people.

According to Pratt (1974), the purpose of teaching history is to help illuminate the continuities and discontinuities within the development of man. Thus is not only important to see how we are similar to the past, but more importantly to see in what ways we are different and to think critically about why this is and how events are related to social and cultural changes. A role-play provides the perfect opportunity to illuminate this discontinuity. While in the above example the students were acting in an anachronistic manner, this is not necessarily as much of a problem as Arnold (1998) would suggest. Instead, it provides the educator with an opportunity to discuss with students why they acted in the way they did, even if it seemed contrary to what they learned. For example, why did the female student take on the role of governor when she knew that is was not a role that women would have had during this time period? Likely it is because she has been told (rightly so) that she can be whoever she wants to be. Rather than simply telling her that her decision to act in this way was not historically accurate though, it could be a way for the educator to discuss the change that Pratt (1974) sees as being fundamental in the teaching of history. However, it is something that needs to be talked about and not merely brushed over. This instance is applicable to other ways that students are likely being anachronistic in role-play; their actions are based on their own context and bias. Discussing these issues with them though, may help them better understand that in many ways the people of the past are similar, yet still very different.

The National Center for History in Schools (2013) argues it is important to teach students about "present-mindedness" or "judging the past solely based on the terms of the present-day norms and values." Thus, role-play would be an excellent way of bringing this issue to the forefront, in order to stress to students how their own context may be coloring their view of the past. Instead of simply discussing this issue through a lecture-based format, the role-play provides a real life example that makes the issue more tangible and less abstract for students. Therefore, role-play can show students how to view history in context, which is the task of the historian.

Additionally, role-play could also help students differentiate between facts and interpretation, an issue that is the cornerstone of historical education (National Center for History in the Schools, 2013). The role-play provides the teacher with the opportunity to ask the students what was factual about the play and what were their own ideas based on what they knew or had learned. The goal is to get students to realize that they are recreating history based on what they already know; however, their recreation is not an exact replication of the past, but rather what seems the most logical to them given the evidence. This helps introduce students to the task of the historian. Much like their role-play, the historian has to take evidence and from those sources create his or her own conceptions of the past. The teacher also has the opportunity to ask students how their play might have been different had they read different information. This discussion could lead into a conversation about how historians are motivated or bound by the sources available to them. Their work is widely dependent upon what resources they have at their disposal, much like the students' historical play. The play was based on information, whether it was provided to the students or something they researched. The role-play would have likely been different had the material been presented to them differently.

Finally, the last issue that can be addressed from students' historical anachronisms or misconceptions during their role-play, is the sources they find to be credible. For example, what made the one student in the scenario speak in Old English, when that is not likely something that the teacher discussed or even addressed? The student had to construct or receive their notions about historical events and people from somewhere and that is important to talk about.

Now more than ever, students have a wealth of information at their fingertips and while their source base is widening, that does not mean that it is doing so with accuracy. In fact, according to Woelders (2007), more and more students are "learning" history by watching TV or films. Unfortunately, sources such as these are often lacking in facts. This would be a very likely reason for the student taking on an accent; he heard someone speak this way and decided to mimic it for "authenticity." Instead of simply telling the student that the source was invalid however, this misconception provides an opportunity to ask students where they learn about the past and what sources they consider to be valid and why. With more mature students, it could also help them see what motivations the filmmakers or producers may have had in making the work in the way that they did. This in turn gets back to the issue of bias. Regardless of where they got the information however, it would be fruitful to discuss what students believe is credible and upon what they base their evaluation.

Conclusion

Within this discussion of role-play, it has become evident that the positives of the activities are numerous. However, the benefits go beyond the more traditionally touted examples of helping students learn how to effectively communicate and collaborate with one another. Some scholars, such as Arnold (1998), argue that the best role-play situations are those that are as historically accurate as possible. However, what Arnold and other scholars of his mindset are ignoring are the possibilities that the failure to perfectly recreate the past provide. Students undoubtedly bring their own misconceptions and anachronisms to the history classroom, and cannot be expected to remove or forget them when it comes to role-play. Instead, educators should embrace opportunities such as these to discuss the more complex issues in history, such as context and bias. Admittedly, these concepts are difficult and probably better suited for a more mature student, either at the junior high or high school level. It could be hard to have thoughtful and meaningful discussions such as these with students who cannot yet think abstractly. However, for the maturing thinker, activities such as these could provide an experience or scaffolding to talk about these complex issues at levels that they can understand. Bias might be a hard concept for middle school students to fully appreciate, but when discussed in general terms about how their beliefs influence how they act, most are likely to be able to engage in the discussion. Thus, even though it might not be obvious at first, role-play's flaws could actually provide a meaningful way for the history educator to address larger, complex issues in a way that students can relate to. More generally, this is true of many teaching strategies utilized in the history classroom. While often strategies, activities, or even resources fail to accurately depict the past as it was, this does not negate their usefulness. Instead of a being an accurate portrayal of the past, these "failures" allow the history teacher to go beyond the facts and introduce students to the contested issues in the field. Doing this may also allow students to see value in the field and may help secure history's chance at gaining students' interest in school.

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Biography

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Learning to Teach
Language Arts, Mathematics, Science, and Social Studies
Through Research and Practice

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