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To Our Readers

A message from the Executive Editor

The *Journal of Interdisciplinary Teacher Leadership* (JoITL) is a peer-reviewed publication featuring original work on educational topics from research to pedagogy to policy and beyond. It is grounded in the belief that education benefits from diversity of thought and the crossing of disciplinary boundaries. With this in mind, JoITL is designed to engage the scholarship of a wide cross-section of education professionals and provide a space for sharing both research and practice. Educators who seek an intellectual community with whom to share work, explore ideas, and advance teaching and learning are encouraged to become part of the JoITL community.

JoITL was founded in response to a group of Teacher Leaders (Kenan Fellowship awardees) who were seeking a new venue for publishing academic work. They envisioned a journal that would hold to high standards, reflect multiple perspectives, and appeal to the kind of educators who choose to lead the profession from the classroom rather than from administrative positions. They also wanted a journal that would be open to multiple types of articles including, but not limited to, literature reviews, research articles, well-constructed essays, and book reviews.

The five articles in this inaugural edition well reflect the vision of diversity and inclusion in which JoITL is grounded. Among the authors are seasoned K-12 teachers, doctoral candidates, and professors from colleges of education, textiles, and engineering. Although no theme was identified in the call for submissions, several arise from the five articles. The most prominent being one of education's classic dichotomies—the tension between experience and reflection. In the first article, Brian Cartiff argues for more explicit instruction regarding the nature of science (NOS). He notes that inquiry lessons alone are not sufficient to convey the characteristics of scientific knowledge or scientific ways of knowing. He posits that an understanding of the nature of science is better developed when inquiry lessons are coupled with guided reflection. Cartiff asserts that a broader, reflective view of scientific work across time, in the form of the history and philosophy of science, would help learners see science as a creative, collaborative endeavor and reveal the dynamic nature of scientific knowledge.

In their article, Rebecca Hite, Gail Jones and Jesse Jur demonstrate the significance of research experiences for teachers. They make the observation that teachers who have not had the opportunity to experience the processes of scientific investigation or engineering design are more likely to believe that science is a passive, codified body of facts. Sarah Carrier, Valerie Faulkner, and Laura Bottomley's article focuses on the experiences of undergraduate pre-service teachers (PST) as they develop and implement integrated STEM investigations for grades K-2. The PSTs in their study saw a high level of engagement among their young students, but they did not feel that the students made connections between what they were doing and why they were doing it. As observed by the authors, the PSTs were learning the challenge of balancing engagement with conceptual understanding.

While experience and reflection (thought) may not have been the primary focus for these authors, their work well illustrates how important both are to learning. The inadequacy of either experience or thought alone to result in learning has long been acknowledged, but the reality of that understanding is continually made fresh in the act of educating others. As noted by John Dewey in *Democracy and Education* (1916), learning is about seeing connections and understanding relationships, and relationships cannot be established when experience and thought are disconnected. He believed that understanding born out of thought alone was an impoverished kind of knowing, and that activity separated from thought served to make an act mechanical.

The final two articles in this edition, by Katherine Baker and Cynthia Bullard, are abbreviated literature reviews that explore alternative pedagogies for engaging students and causing them to become both constructors and generators of knowledge. Baker's thoughts on culturally relevant mathematics pedagogy and Bullard's on gamification and game-based instruction emphasize the agency of the learner and stress the need for authentic experiences in which students can find relevance and meaning.

It is exciting to see the vision that grew from a small group of Teacher Leaders come into fruition in the form of this first edition of the *Journal of Interdisciplinary Teacher Leadership*. Our goal is to publish twice yearly (January and July) and provide a space for ideas and discourse from an ever-growing interdisciplinary community of educators.

Elaine Franklin, Ph.D.
Director, Kenan Fellows Program

The Case for Explicit Instruction

of the Nature of Science in Secondary Science Education
through the Incorporation of the History and Philosophy of Science

Brian Cartiff

Abstract: *Richard Feynman, the celebrated physicist, is frequently attributed as saying that "philosophy of science is about as useful to scientists as ornithology is to birds."*

Professor Feynman taught at the California Institute of Technology for many years, but perhaps this experience did not afford him the best view of the general level scientific literacy of most people.

The inventive Feynman would likely be disappointed in the rigid nature of much pre-college science instruction, and he would definitely be disappointed in the lack of student understanding of the nature of science.

The Next Generation Science Standards emphasize the nature of science as one of their standards, but currently most pre-college science instructors do not address this learning target or only do so through the indirect approach of using inquiry lessons.

There is strong evidential support for including the explicit instruction of the philosophy of science and the history of science in pre-college science classrooms as a way of augmenting scientific literacy and enhancing student views on the nature of science.

The Scientific Method is taught in almost every science class from elementary grades through high school. From a pedagogic standpoint this repetition is desirable – reiteration will aid student memory and familiarity. The most frequently emphasized ideas about the scientific method are Francis Bacon's inductive method, originally proposed in the 1600s, and Karl Popper's falsifiability, tracing back to the 1960s (Lederman et al., 2002, p. 501). For many years, though, scientists and philosophers of science alike have recognized there is no set scientific method (Lederman, Abd-El-Khalick, Bell, & Schwartz, 2002, p. 501). The instruction of these views of the scientific method would not be problematic if they were taught as conflicting views about the nature of science (NOS), each with weaknesses and strengths, but they generally are not – they are presented as procedures that scientists follow when they practice science. This rigid interpretation of NOS leads students down false pathways in their conceptualization of science.

Understanding the Nature of Science

Misinformed views of NOS have many negative consequences. Two recent related concerns are the decline in scientific literacy and the dearth of young adults pursuing STEM degrees in the United States (Hossain & Robinson 444). These issues may be linked to a fragmented understanding of NOS and correlated to misconceptions about the tentative state of scientific knowledge. These fallacies can be readily evinced through student (and teacher) misunderstandings of basic ideas like hypotheses, theories and laws (Abd-El-Khalick & Lederman, 2000, p.1076). Poorly developed understandings of the cautious nature of scientific language have contributed to alarming societal trends. Fad diets are espoused by nutritionists; vaccines are condemned by celebrities and shunned by parents for fear of their inefficacy and "potential" link to autism; and homeopathic remedies garner followers because they are phrased in terms of absolutes, whereas doctors and scientists couch their descriptions in probabilities. The fact that students graduating from high school and college (even with science degrees) do not understand the tentative nature of scientific knowledge makes it difficult for them to navigate through the sensationalized science and pseudoscience presented by the media.

The Future of STEM

STEM fields are likely having difficulties recruiting and retaining qualified candidates for related reasons. According to the National Math & Science Initiative, in 2013 only 36% of high school graduates in the U.S. were ready for college science ("STEM Education Statistics"). Even some of these "prepared" students potentially avoid pursuing STEM degrees because they see science as staid, logical, and fixed – the antithesis of the collaborative, creative, and evolving process that it truly is. Others who do originally pursue these degrees expecting this inventive process find themselves wading through rigid, stagnant introductory college classes in which there is also little NOS instruction. Students initially enrolled in STEM programs have an alarming attrition rate – a recent study found that "a total of 48 percent of bachelor's degree students and 69 percent of associate's degree students who entered STEM fields between 2003 and 2009 had left these fields by spring 2009" (Chen & Soldner, 2013). There are different causative factors of these disturbing trends, but it is a reasonable speculation that a lack of a developed sense about NOS and the intricacies of the scientific process contribute significantly.

Since scientists, educational leaders, and pedagogic organizations have long recognized that it is desirable to help students "develop informed conceptions of science," it is surprising that so little instruction about NOS seems to take place (Lederman et al., 2002, p. 498). Even though guidelines like the Next Generation Science Standards emphasize its importance, popular curricula like the Common Core do not (NGSS, 2013, Appendix H). There also seems to be a disconnect with science teachers. Claims that a majority of these pre-college instructors view science merely as an "established body of knowledge and techniques that require minimal justification" (Monk & Osborne, 1997, p. 407) may not sound particularly generous to educators, but multiple studies have reached these conclusions. The recent emphases on teacher accountability and standardized tests used to evaluate teacher effectiveness have likely exacerbated this problem, as these exams generally are not designed to assess NOS. Creating a valid assessment to gauge students' conceptions about NOS has been an issue in education for decades, but the instruction is critical even if there is disagreement over how, or if, to evaluate it.

Using History & Philosophy in Science

Not all science teachers have eschewed the instruction of NOS, but many who do address it approach it indirectly. Some science educators have even suggested that NOS "cannot be taught directly, rather it is learned, like language, by being part of a culture" (Abd-El-Khalick, 2012, p. 2089). This has led many to assume that just using inquiry methods helps students develop NOS understandings, but Sandoval and Morrison found that inquiry has little impact on comprehension of NOS without explicit attention being concentrated on epistemological ideas (2003, p. 384). Exacerbating the issue is that "even when they (teachers) hold clear and coherent views about science and scientific inquiry, teachers do not plan laboratory-based lessons consistently or carefully in relation to those views" (Monk & Osborne, 1997, p. 407).

This is not to contend the importance of inquiry lessons. These lessons lend themselves to helping students understand some of the processes of science. However, they must be carefully planned and include guided reflection about how they relate to NOS. Even then, they are limited in their possible impacts on student comprehension. The explicit teaching of NOS should also be employed through the inclusion of the history and philosophy of science (HPS). Many studies have found this to be "an effective way to reach the goal of enhancing science literacy for all citizens" (Wang & Schmidt, 2001, p. 52). Using the history of science as an instructional tool has been promoted since William Whewell published "History of the Inductive Sciences, from the Earliest to the Present Times" in 1855 (Niaz, 2015, p. 176). Some history has traditionally been taught in science classes, though there is little evidence that this instruction has been well-designed or appropriately connected to NOS concepts. Gallagher found in a 1992 study that when teachers did try to include the history of science, that it was merely to "humanize science" and "foster positive attitudes" rather than enhancing an understanding of NOS (Monk & Osborne, 1997, p. 407).

Employing HPS as an Instructional Tool

This stance needs to be addressed. Michael Matthews, an education professor at the University of New South Wales, has long been a proponent of teaching HPS and sees tremendous opportunities in using it (Yalaki & Cakmakci, 2010, p. 291). Physicist and Nobel laureate Kenneth Wilson and his collaborator Constance Barsky have conducted over ten years of research and argue that "exposure to the history of science helps students consider science as a career to think, ask questions, and explore the concepts and ramifications of broad topics, enabling them to grasp what science is about and how it is concluded" (Gooday, Lynch, Wilson, & Barsky, 2008, p. 323). While the resultant evidence from the few studies that have been conducted into an HPS approach is ambiguous or inconclusive, this is likely because there have been so few investigations and those generally have been conducted over short time periods and with small sample sizes.

Wandersee has found that many student misconceptions are similar to past societal views; students "often harbor misconceptions which were similar to views held at one time or another during historical development of that science concept – thus making the history of science a useful heuristic device for anticipating some students' conceptual difficulties" (Monk & Osborne, 1997, p. 413). Employing HPS as an instructional tool allows students to see how scientists disagree with each other and how they interpret their evidence, thus giving a more appropriate view of science as a creative, collaborative, and, at times, combative practice. Students can also see how scientific ideas change over time with new evidence, shifting paradigms, and developing technologies. HPS can also convey the important interrelationship between culture and science (Lederman et al., 2002, p. 501).

Developing Critical & Evaluative Skills

Even past concerns about using history of science would now seem to be mollified. Steven G. Brush, a noted physicist and historian of science writing mostly in the 1960s and 1970s, supported the use of the history of science toward increasing the understanding of science and scientists' roles in society, but also warned that this history could be construed as subversive since it might undermine the notion of objective truth (Monk & Osborne, 1997, p. 414). In current times this might be seen as a positive - not because of the relativism that Brush was opposed to, but because it might convey the ever-evolving state of scientific knowledge. Teaching the philosophy of science along with the history is critical as it could help students understand this tentative nature and should aid in the development of critical and evaluative skills. Matthews stresses that it is key to pair the philosophy and history of science as the combination can lead to "higher-order understanding and valuation of science" (Yalaki & Cakmakci, 2010, p. 291).

The possible benefits for inclusion of HPS towards addressing NOS are considerable, but research is still in its germinal stage and many obstacles to HPS implementation exist. The aforementioned belief that science is simply "a body of knowledge" poses a difficulty in convincing educators to emphasize NOS at all. Overcrowded curricula provide additional hurdles, as teachers struggle to efficiently allocate the necessary time. Standardized tests and established curricula that do not emphasize NOS shift the focus of teachers to other content. Professional learning communities (PLCs) are a new collaborative trend in education, but they may provide obstructions to change – participating teachers may not feel comfortable re-focusing their practices unless everyone in their PLC agrees to do so. Teachers concentrating on classroom management in over-crowded conditions may be loath to head in new directions for fear of losing control (Abd-El-Khalick, 2012, p. 2098). Additionally, it would not be surprising if the research supporting the explicit approach to teaching NOS has not reached many pre-college teachers. Unfortunately, academic research seems to take an inordinate amount of time to get molded into practical applications in schools.

Change Starts with Teacher in Training

Most likely the largest impediment to the use of HPS is the lack of teacher knowledge. Recently, Denmark and Spain have begun to require pre-teachers to take coursework in HPS (Matthews, 1998, p. 984). Some programs in the United States have also started including this training, but a quick survey of programs throughout the U.S. still shows little employment (Matthews, 1998, p. 984). Without this formal training and with little curricular support, teachers likely will not make the systemic switch. Teachers-in-training should take mandated philosophy of science and history of science courses. Incorporating this into their training would enable teachers to be more confident in employing HPS and would deepen their own understandings of NOS. To achieve these ends, though, would require colleges to embrace a major change in their pedagogic philosophies.

Calls for Reforms in Science Education

Calls for reforms in science education are nothing new. Student misconceptions about NOS have been a target of these calls for over a century. Recent initiatives like the American Association for the Advancement of Science's Project 2061 and curriculum development like the Next Generation Science Standards have helped sharpen instructional focus and learning goals in science education.

Inquiry experiences have been touted for a number of years as an authentic way of providing some of this instruction and they should continue to be employed, but they are not sufficient by themselves. One heretofore underutilized methodology that shows great promise is the practice of using the history and philosophy of science.

A knowledgeable and enthusiastic teacher employing explicit instruction of NOS through HPS can have a tremendously positive impact on student perceptions and understanding. This means that pre-service teachers will also need overt training in HPS before they can bring this educational practice into their high school classrooms. Employing direct instruction on the philosophy and history of science will not be a panacea to fix all of the issues in science education, but it can be a valuable tool for helping students to develop scientific literacy and addressing NOS conceptions.

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About the Author

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Engineering Imagination with Ideation

Drs. Rebecca Hite, Gail Jones and Jesse S. Jur

Abstract: *This paper explores the components and efficacy of an engineering-based Research Experience for Teachers (RET) program with a focus on ideation. Leveraging the imaginative and iterative elements of the ideation process, participants engaged in inquiry exploring energy harvesting and novel sensor technology. In modeling the ideation methodology, participants were more engaged in authentic research, which subsequently fostered the creation of novel lesson plans extending beyond the classroom.*

The importance of research-based, STEM-based RET experiences are a critical feature of bolstering teacher content and pedagogical skills while embedding features of student-centered elements such as creativity and imagination. During the following school year, participating teachers created an inter-district competition designing Ebolavirus sensors using the One Health framework introduced in the summer research experience program. An example of a student product is provided. A discussion of alignment to science curriculum standards as well as the need of these programs are also discussed.

As science educators prepare for incorporation of the Next Generation Science Standards (NGSS) (NGSS, 2013), into K-12 classrooms across the country, engineering education awareness has become widespread. However, full integration of engineering principles into the K-12 curriculum remains a puzzle for science teachers. To replicate engineering practices in industry and academia, students need access to authentic experiences where they engage in the engineering design process to solve real world problems. A fundamental construct within engineering design is ideation, where participants employ constructs of imagination and creativity to design systems or products by overcoming mental roadblocks to address a genuine social need (Hernandez, Shah, & Smith, 2010). Engaging students through creativity is not only an engaging pedagogical tool for engineering teachers (Scott, 1990) but the process also replicates best practices within the contemporary STEM workplace (Employee engagement strategies in "STEM", 2014).

According to Haik (2003), a curriculum using engineering design must include "development of student creativity, use of open-ended problems, development and use of modern design theory and methodology, formulation of design problem statement and specifications, production processes, concurrent engineering design, and detailed system description" (p.3). This work describes the experiences of 19 middle and high school teachers in a research experience for teachers (RET) summer program to develop 6-12 math and science curricula based upon the brainstorming process of engineering ideation.

This paper describes how a RET experience, rooted in peer collaboration and pedagogical growth, in an authentic engineering environment led to a successful student-driven engineering competition. An example of curriculum developed from this program that employs the ideation process for middle grade science, the One Health sensor competition, is described in detail.

Addressing the Standards

The Next Generation Science Standards (NGSS, 2013) include elementary, middle and high school standards that mandate use of engineering design principles. In particular, students are tasked to define criteria and constrains of a design problem, determine criteria and constraints of said problem, develop a model for continual testing and modification, and evaluate competing design solutions.

The intent of these engineering standards was neither to encourage nor discourage the creation of stand-alone engineering courses, as many schools have created new courses in robotics, mechanics, or electronics. The engineering design process, as defined by the NGSS, is an iterative process of defining the problem and developing solutions while optimizing and refining the process (2013).

Figure 1. The Engineering Design Process as Defined by the Next Generation Science Standards.

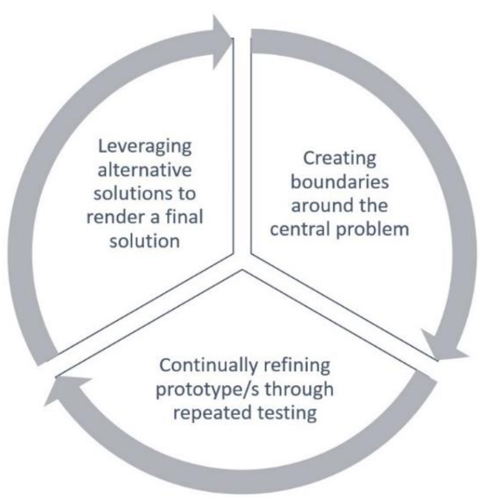

Figure 1. Three pillars of the Engineering Design Process written into the Next Generation Science Standards.

Adapted from APPENDIX I – Engineering Design by Next Generation Science Standards by NGSS Lead States. 2013, Retrieved from http://www.nextgenscience.org/sites/ngss/files/Appendix%20I%20-%20Engineering%20Design%20in%20NGSS%20-%20FINAL_V2.pdf. Copyright (2013) by Achieve.

An integrated STEM approach is necessary for dealing with the societal problems of today, as Roehrig et al. (2012) argued, which are "multidisciplinary, and many require the integration of multiple STEM concepts to solve them." Integrated STEM education is aligned with the interdisciplinary format of new national standards in English and mathematics (Common Core Standards), as well as in science (Next Generation Science Standards) where engineering and technological design are also infused.

Creativity fostered by the engineering design process is a fundamental component of the Common Core State Standards which stress interdisciplinary learning through the fusion of engineering and technological design (Johnson, 2013). Creativity is also a critical element of understanding the nature of science. According to the National Research Council (NRC, 2012), students "should come to appreciate that science and the current scientific understanding of the world are the result of many hundreds of years of creative human endeavor" (p. 1-2).

According Katehi, Pearson, & Feder (2009), the "siloed" teaching of STEM has significantly impeded efforts to improve student interest and performance in science and mathematics. They argued that increasing the prominence of engineering education may provide the missing interconnections in STEM teaching and learning vital to holistic understanding. Others have argued that an integrated STEM approach is critical to address the multidisciplinary issues and integrated types of problems students are tasked with in modern society (Roehrig, Moore, Wang, & Park, 2012). For many teachers this new challenge to teach engineering and provide authentic problem solving is daunting.

New forms of professional development that are rooted in the discipline and guided by experts in the field can provide teachers the context and experiences to successfully integrate engineering practices into their classroom. Extant engineering research demonstrates the unique insight gained from team-based work (Donath, Spray, Thompson, Alford, Craig & Matthews, 2005) and illustrates how participants interact with engineering concepts, which shapes their learning outcomes (Koro-Ljungberg & Douglas, 2008).

Research Experiences for Teachers

Research-based experiences can have a significant impact on teachers; a landmark study by Maltese & Tai (2010) found the presence of authentic, inquiry based science classrooms was one, if not the greatest, factor in student STEM persistence to college graduation. However, without proper induction into or experiences within the STEM profession, science teachers are more likely to rely on memorization of science facts and maintain a hierarchical classroom environment (Dresner & Worley, 2006).

These conditions negatively contribute to the student perception that science is a passive, boring, codified body of facts; not imagining themselves as active, creatively engaged participants constructing new knowledge or products based in scientific inquiry and engineering design, respectively.

Engaging teachers in engineering design has shown promise as a fruitful way to integrate engineering into the science curriculum; as an RET program focused in engineering may provide "diverse learning opportunities for teachers tailored to their interests and teaching responsibilities" (Ononye, Husting, Jackson, Srinivasan, Sorial, & Kukreti, 2007, p.3). Based upon research by Pop, Dixon, and Grove (2010), an RET format was chosen to build teacher confidence in developing engineering concepts and practices.

The RET Experience in Ideation

In the summer of 2014, 19 teachers took part in an in-depth exploration of the engineering design process (ideation) to develop engineering-based solutions to real world problems. The RET program was grounded in the context of human-animal interactions relating to human health concerns and sensors, due to the current research and expertise of the engineers and science educators at the university facilitating the program.

Participants were introduced to the One Health Initiative (One Health), an international consortium of medical health professionals, veterinarians, scientists, and epidemiologists striving to develop preventive strategies in global health by advancing research in public medical education, clinical care, and health monitoring of humans and animals.

One Health pronounces that animal-human interactions are an ongoing, critical and global problem, as more than 70 percent of emerging infections are zoonotic in origin (e.g. insects and mammals) affecting 6 major continents (One Health Initiative, n.d.).

In small groups, teacher-participants were tasked with identifying a geographic region and an area of concern where they would model the ideation within engineering design by devising a sensor system that would minimize or monitor interaction to prevent infectious disease.

Figure 2.a. Emerging and Reemerging Infections Due to Global Human-Animal Interaction

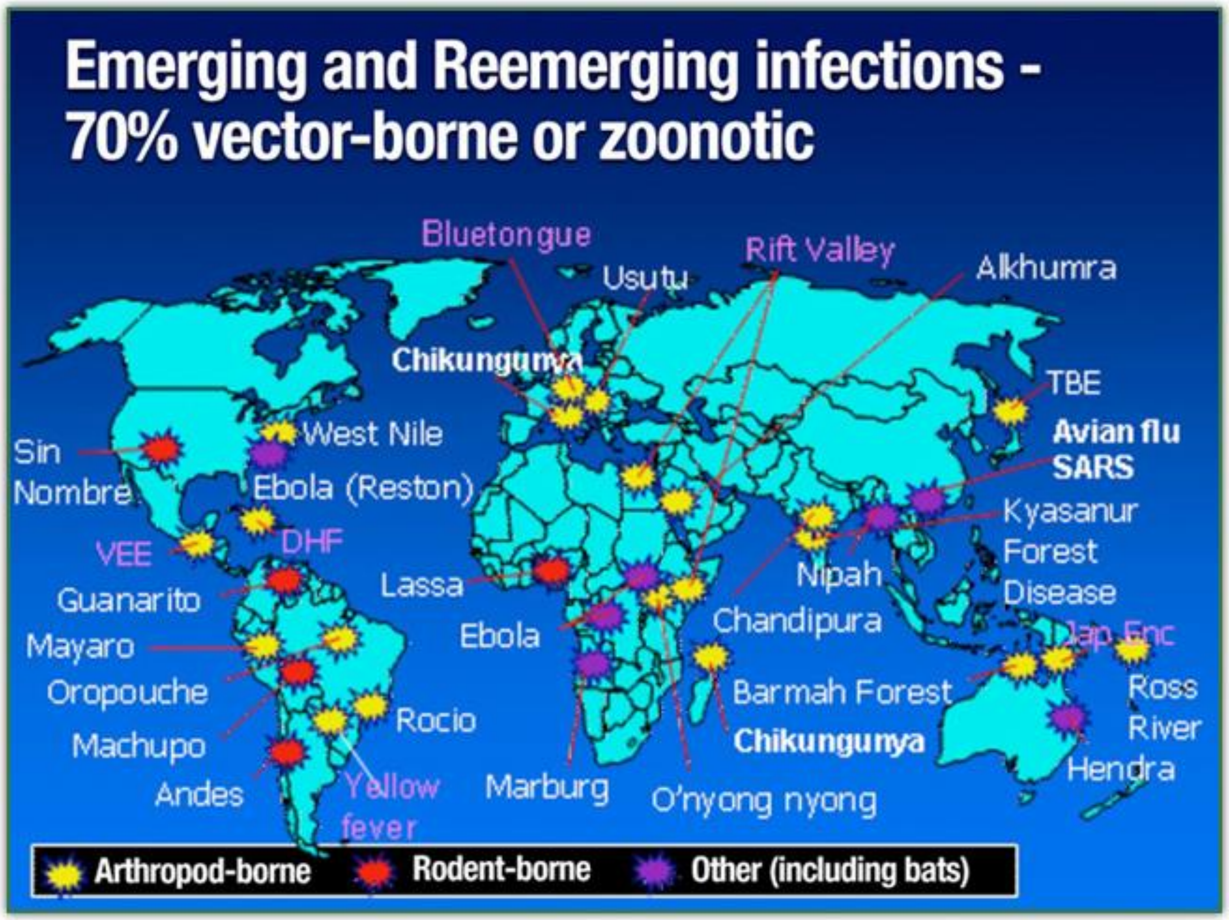

Figure 2.a. A map demonstrating locations of emerging and remerging human infections due to vector-borne and zoonotic disease.

Reprinted from One Health Home Page, by Kahn, L.H., Kaplan, B., Monath, T.P., Woodall, J., & Conti, L.A. In One Health Initiative, n.d. Retrieved June 1, 2015, from http://www.onehealthinitiative.com/. Copyright 2015 by One Health. Reprinted with permission.

Figure 2.b. The One Health Medicine Framework

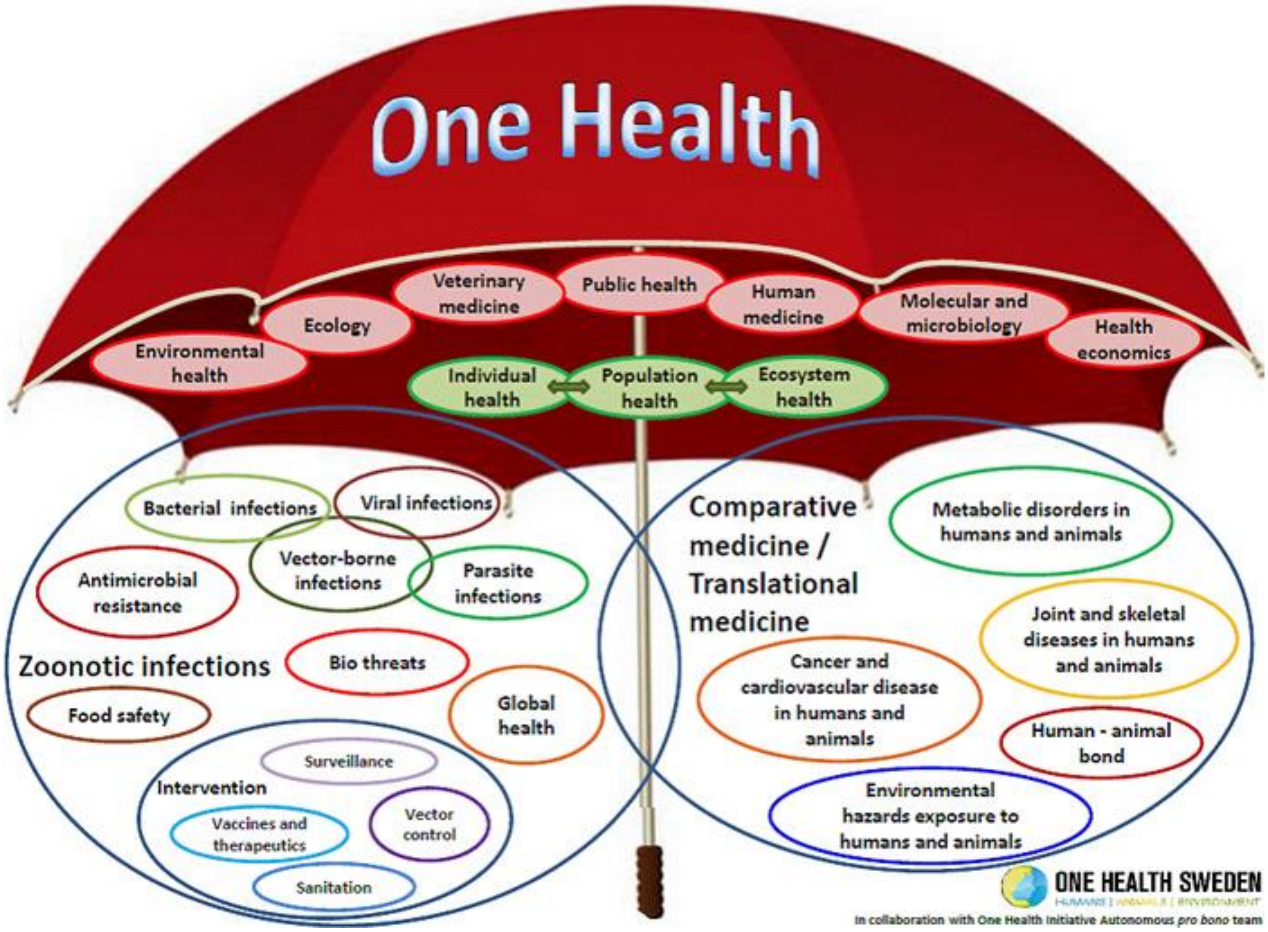

Figure 2b. Reorganizing disease and medicine within a global context as it relates to public, environmental, and economic health.

Reprinted from About One Health, by Kahn, L.H., Kaplan, B., Monath, T.P., Woodall, J., & Conti, L.A. In One Health Initiative, n.d. Retrieved June 1, 2015, from http://www.onehealthinitiative.com/about.php. Copyright 2015 by One Health. Reprinted with permission.

A part of their professional development process involved learning about current research in engineering practices including novel means of energy harvesting and sensor-based technologies and acquiring the skills of the engineering design process to create a new product. For two months, participants tore down wearable sensors to examine their components, shared in lectures from scholars in the field, conducted product comparisons, and learned to use SolidWorks 3-D printing software to generate their prototypes. They were guided through their professional development by faculty in textile engineering and science education.

Ideation was a key part of the iterative process and engaged teachers in the different stages of product development via collaborative refinement of ideas. Once teachers were provided the content background, they formed groups to identify a common problem from the One Health perspective. Participants determined health challenges such as recognizing dehydration in service animals, measuring the quality of life of free range versus caged chickens in poultry farming, and monitoring Rift Valley fever (RVF) in mainland Africa to prevent outbreaks resulting in epidemics.

Figure 3. The Ideation Process Framework

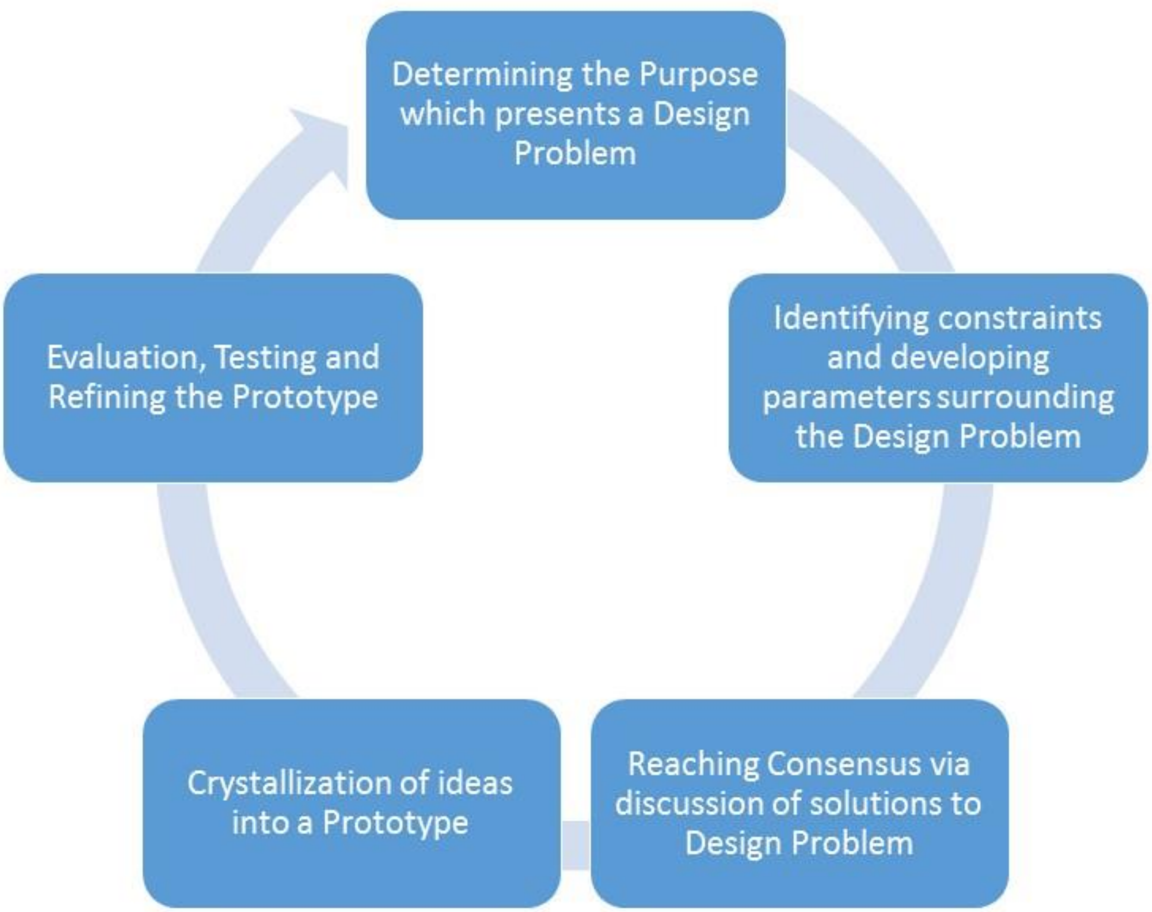

Figure 3. The iterative nature of ideation, a component of the engineering design process. Adapted from Engineering Design Process, Second Edition by Haik, Y, & Shahin, T. 2003, Stamford, Connecticut: Cengage Learning. Copyright 2003, 2011 by Cengage Learning. Adapted with permission.

Using the ideation framework, teams generated specification criteria and design constraints for monitors including but not limited to cost, size, aesthetics, ergonomics, and possible cultural taboos. Participants were encouraged to recommend any plausible idea; all proposals were included and not discarded until there was group discussion and consensus.

During the ideation process, groups outlined their thoughts on white boards to conceptualize and crystallize their product intent and parameters. Design concepts were refined by examination of existing products and reviews of the research literature. Teacher-led groups designed sensor-based products intended to sense hydration levels in search and rescue canines via their sweat, motion detection for chickens as it correlates to physiological effects on poultry health, as well as sensors to detect mosquito movements to trigger interventions to protect people from RVF infection. Participants developed their ideas into collaborative lesson plans addressing mathematics and science standards to be disseminated to teachers throughout the state.

Figure 4.a. The Ideation Process in Action

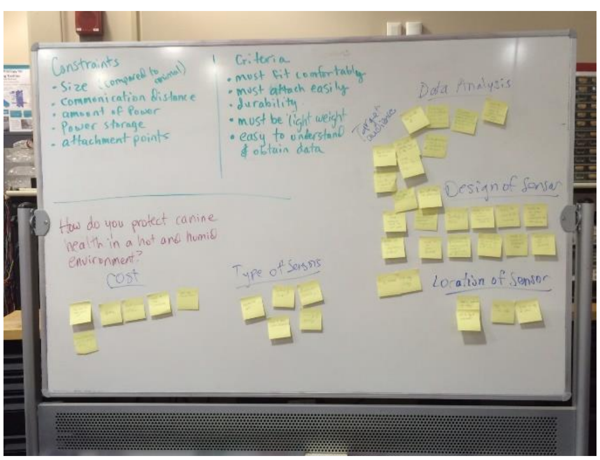

Figure 4a. Participating teachers identifying design constraints and parameters guided by the ideation process.

Figure 4.b. Participating Teachers Engaging in the Ideation Process

Figure 4b. Participating teachers reaching consensus and discussing prototyping guided by the ideation process.

Translating the RET Program to Fostering Ideation in the Classroom

Following the RET program, teachers replicated the ideation process with their students using the curriculum they developed that summer. The following is an example from a teacher, working with the RET facilitators, who developed an inter-district student competition to design a sensor to detect Ebola in the most heavily impacted countries of Western Africa from the 2014 epidemic. This topic was of particular interest since at the height of the outbreak, an estimated 21,000 individuals were affected with the disease and new cases doubled every 20 days (CDC, 2015).

Using information and experience from the RET, the teacher scaffolded the ideation process for student teams to design their sensors. Students were tasked with researching epidemiological information regarding signs, symptoms and methods of transmitting Ebolavirus. Student groups were encouraged to use credible online resources to compile information about the disease and discuss best practices of current sensor technology to detect and communicate possible infection to the individual and local health care workers. Each device had to utilize a novel form of energy harvesting and storage, not relying on costly and bulky battery power, derived from the human body. During their research, students were introduced to the concepts of thermoelectrics, piezoelectrics, and supercapacitors. Once student teams decided on the sensor's modality and energy source, they needed to further consider cultural factors and economic impact to encourage its widespread use and ease of construction, upkeep and wear. Using concepts from the NGSS (2013), student teams revised prototypes through testing, consultation with engineers, and discussion in their team meetings.

Student products were evaluated on the criteria of feasibility, aesthetics, wearability and accurately sourced materials and judged on the following rubric. In addition to prototypes, students created an awareness-based advertising campaign to communicate and promote the importance of their sensor system. This additional task is significant as it infuses a largely underrepresented aspect of the nature of science and the NGSS (2013), which not only mandates communication with the public regarding scientific discovery but is also a fundamental aspect of creating scientific knowledge (Nielsen, 2012).

Figure 5. Teacher or Evaluator Scoring Rubric for One Health Sensor Project

One Health Sensor Judging and/or Scoring Rubric

Note: A score point of 0 is only awarded if the element is missing.

Product Aspect	***Description***	***Highly Proficient***	***Proficient***	***Developing Proficiency***
Feasibility	The product designed would work well… • in the chosen environment. • as a sensor on a wearable device. • data is transmitted (if necessary) in a manner conducive to the technological needs, existing infrastructure, and surroundings.	Contains exemplary work within the category. Meets <u>3 or more</u> bulleted points well.	Contains good or average work within the category. Meets <u>1 to 3</u> bulleted points well.	Contains below average work within the category. Meets <u>none</u> of the bulleted points well.
Wearability	The product designed would be able to… • withstand the movements, temperatures, and fluids found in the environment it is placed in. • be made out of a material that is the least obtrusive for the highest percentage of people (i.e. it is not made out of a material that has many known allergens).	Contains exemplary work within the category. Meets <u>3 or more</u> bulleted points well.	Contains good or average work within the category. Meets <u>1 to 3</u> bulleted points well.	Contains below average work within the category. Meets <u>none</u> of the bulleted points well.

	• generally comfortable and not too bulky to wear.			
Aesthetics	The product designed would keep in mind… • cultural sensitivity of the area in which the design will be distributed (e.g. if the color red is taboo in your region you will not design a product with red as the primary color). • stylish considerations including whether or not it is visually appealing. • designs that reflect the target age and gender group OR towards neutrality (e.g. bright colors for children, one-size-fits-all sizes, etc.)	Contains exemplary work within the category. Meets 3 or more bulleted points well.	Contains good or average work within the category. Meets 1 to 3 bulleted points well.	Contains below average work within the category. Meets none of the bulleted points well.
Sensor placement	The product designed would consider… • Body location/s that would collect and transmit the most data (i.e. a hydration sensor would be placed on the inner arm). • Body location/s that maximize comfort and minimize discomfort for the wearer.	Contains exemplary work within the category. Meets 3 or more bulleted points well.	Contains good or average work within the category. Meets 1 to 3 bulleted points well.	Contains below average work within the category. Meets none of the bulleted points well.

	• Body location/s that are minimally invasive unless designed specifically for that location (e.g. a sensor in teeth).			
Power	The product designed would be powered by… • an appropriate type of power (i.e. plutonium for a wearable sensor is too powerful and unsafe). • ubiquitous sources easily sourced in the selected location or desired market. • a method that provides a lengthy lifespan for the product. • a type of power that is preferably renewable.	Contains exemplary work within the category. Meets 3 or more bulleted points well.	Contains good or average work within the category. Meets 1 to 3 bulleted points well.	Contains below average work within the category. Meets none of the bulleted points well.
Ad Campaign	***Description***	***Highly Proficient***	***Proficient***	***Developing Proficiency***
Instructions	The advertising campaign should contain instructions that are… • concise on how to use your device. • written for the targeted audiences (consider literacy levels or age appropriate words and language.) • graphics and designs that aid the user in understanding how to use and maintain the product.	Contains exemplary work within the category. Meets 3 or more bulleted points well.	Contains good or average work within the category. Meets 1 to 3 bulleted points well.	Contains below average work within the category. Meets none of the bulleted points well.

Awareness	The advertising campaign should contain… • specific information about the spread of Ebola, how to prevent transmission, and how your product will help protect against/prevent/or provide early detection of Ebola. • information from vetted and reputable sources (CDC, WHO, University-based research or journal articles). • a call to action that empowers the user in social responsibility and educating others.	Contains exemplary work within the category. Meets 3 or more bulleted points well.	Contains good or average work within the category. Meets 1 to 3 bulleted points well.	Contains below average work within the category. Meets none of the bulleted points well.
Feasibility	The advertising campaign should consider… • advertising rules and laws for this specific geographic location e.g. flyers may be • appropriate to reach the target audience/user e.g. if you have a radio ad make sure it is in a location where a large percentage of the population in the area has access to a radio, if it is a billboard/poster make sure it is written to on the level of the average literacy level for the area). • advertising that is ecologically friendly.	Contains exemplary work within the category. Meets 3 or more bulleted points well.	Contains good or average work within the category. Meets 1 to 3 bulleted points well.	Contains below average work within the category. Meets none of the bulleted points well.

	• planning that includes continued use of the product (e.g. longevity, training in the community) once the initial advertising campaign is complete.			
Group Dynamics	***Description***	***Highly Proficient***	***Proficient***	***Developing Proficiency***
Planning	The product team should contain… • a clear product planning design outline. • a clear advertising campaign plan. • documented opportunities where group members conducted background research (e.g. online, journals, asking engineers, etc.)	Contains exemplary work within the category. Meets 3 or more bulleted points well.	Contains good or average work within the category. Meets 1 to 3 bulleted points well.	Contains below average work within the category. Meets none of the bulleted points well.
Collaboration	The product team should contain… • clear evidence of a group effort where each individual was engaged in the planning and production of the product and advertising campaign.	Contains exemplary work within the category. Meets 3 or more bulleted points well.	Contains good or average work within the category. Meets 1 to 3 bulleted points well.	Contains below average work within the category. Meets none of the bulleted points well.

	• a presentation that engages the audience member/s and provides a coherent outline of the One Health Project. • group members that are able to answer audience questions regarding the product and advertising campaign development and execution.			

Figure 5. Scoring rubric for student ideation projects using the One Health concepts of preventing global health threats.
By Hite, R., 2015. Reprinted with permission.

Team submissions included designs for detecting the virus through non-invasive sources of specimens and the body's natural non-specific immunity reaction. One student project that is highlighted in this paper exemplifies the process of engineering ideation. This group designed a wristband specifically for use in Liberia, a heavily impacted area from the Ebolavirus epidemic.

They decided that their device would be powered by human body heat and solar power, energy sources that are constant and abundant. Using locally sourced hemp and nylon for adjustable sizing, sensor cost and manufacturing would be minimal out of respect for the economically depressed region.

Consisting of a LCD screen and manual touch buttons, users would be educated about the signs and symptoms of the disease and then quizzed regarding their current health status. If their responses indicated probable infection, a GPS locator would direct them to the closest medical facility for treatment. Through their cultural research, this team found the Liberian flag had roots in slavery, so they decided instead on a culturally accepted and relevant pan-African color scheme.

Using the rubric provided, this group earned highly proficient status in the categories of feasibility, wearability and aesthetics due to their acknowledgment of technological limitations of the area, astute use of available materials and awareness of cultural issues, respectively.

It is evident this project submission reflects the collaborative process and critical thinking essential to the ideation process and the defining of boundaries and revising of prototypes recommended by the NGSS (2013).

Figure 6. Student work of an Ebolavirus Sensor

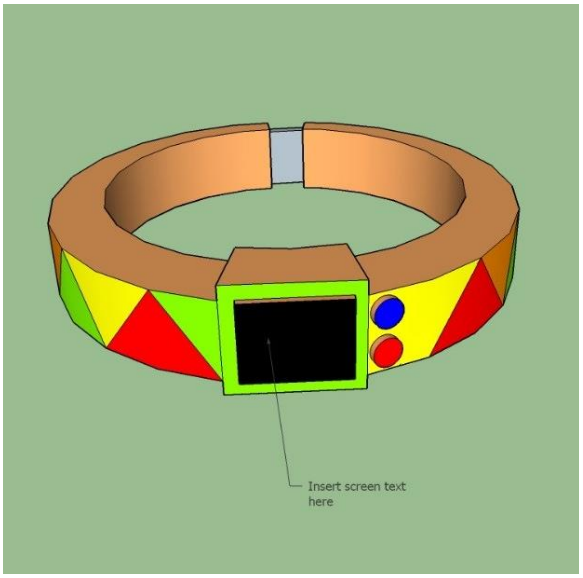

Figure 6. Student work demonstrating the concepts of feasibility, wearability, aesthetics, and sensor placement.
By Maxwell H., 2015. Reprinted with permission.

Conclusion

By participating in their own projects where the ideation process was modeled by engineers in an extended professional development environment (e.g. RET program), this student project provides evidence that a teacher participant was able to construct their own knowledge from the RET experience and develop a vision about how ideation may be used in the classroom (Pop, Dixon, & Grove, 2010). Ideation is a viable classroom tool to engage all students in the engineering design process. Students with different strengths, whether it was technical skills, trend awareness, or sensitivity to ethnical issues, students can all positively contribute to the ideation process (Schweitzer, Gassmann, & Rau, 2014). Cultivation of this type of classroom science environment is particularly important in developing a STEM identity, efficacy, and persistence: critically important in reinforcing the STEM pipeline for under-represented populations including Black, Hispanic (Andersen & Ward, 2013) and female (Hazari, Tai & Sadler, 2007) students. This paper suggests use of RET programs may be a vital component in the ecosystem of teacher professional development to provide educators with the preparation and scaffolding to explore in-depth engineering practices, like ideation. Based upon this teacher-developed project, this paper demonstrates that engineering concepts and ideation may be successfully replicated within middle and high school classrooms, providing a powerful opportunity to embed engineering and critical thinking skills into current science and mathematics courses.

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Walking the Walk: An Integrated STEM Project for Elementary Teachers

Drs. Sarah J Carrier, Valerie N Faulkner, Laura Bottomley

Abstract: *Preparing effective STEM (science, technology, engineering, mathematics) education teachers has become a priority of national economic importance (National Research Council [NRC], 2007) and this goal depends on teachers who understand content and possess effective teaching practices that impact student learning. True integration of STEM will require significant changes in classroom practices, shifting away from traditional instruction, and begin with teacher preparation.*

The present article originates from an interdisciplinary STEM project within an elementary teacher preparation program that has a stated and explicit STEM focus for undergraduate pre-service elementary teachers, yet this investigation also applies to practicing teachers interested in STEM integration. The investigation aims to blur the rigid boundaries that traditionally separate school subjects. Here we highlight a unified investigation project that spans not only disciplines and courses but also pre-service teachers' (PSTs') mindsets.

Framing of STEM Project

Elementary PSTs enrolled in their junior year in mathematics, science, and engineering design courses completed one STEM project that met requirements for each of the three courses. Here we frame the presentation of our project with leading science education and mathematics education organizations' and researchers' recommendations for content knowledge and integration.

Content Knowledge

The National Research Council (2000) states, "to teach science as portrayed by the standards, teachers must have theoretical and practical knowledge and abilities about science" (p. 28), and the National Council of Teachers of Mathematics (2000) declares, "teachers must know and understand deeply the mathematics they are teaching" (p. 17). While teachers' content knowledge contributes to their effectiveness, teachers must also be able to communicate that knowledge to students.

Integration

The concept of interdisciplinarity implies the process of blending ideas, methods, and theories from multiple disciplines (Repko, 2012). Fink (2013) encourages faculty at universities to provide students with "significant learning experiences" (p. 7) that truly connect to students' lives and experiences, but recognizes the levels of institutional change in higher education and schools that are necessary to blur the boundaries of discipline-specific silos. In 2009 the National Academy of Engineering (NAE, 2009) outlined practical problem solving relating to real world challenges through engineering that increase depth of learning in science, mathematics and other subjects.

The STEM Project

We, the science, mathematics, and engineering education professors who teach elementary methods courses simultaneously in our PSTs' junior year, collaborated to develop a truly integrated STEM project to address content and methods for each of our three courses. As methods professors, we recognized that we needed to "walk the walk" of true integration by modeling our recommendations with one combined assignment that would meet goals for each course's standards.

Our courses were structured to support PSTs' development working in K-2 classrooms with a focus on K-2 standards. We intentionally chose to focus on physical science content standards because elementary school teachers traditionally avoid not only science in general, but especially physical science (Carrier, Tugurian, & Thomson, 2013; Tilgner, 1990; Weiss, Banilower, McMahon, & Smith, 2001). The K-2 physical science content standards focus on forces, motion, and sound energy. Mathematics standards include measurement, number and operations, and shapes. Engineering design standards emphasize the design and revision processes that overlap with both science practices and mathematical practice standards.

The integrated assignment required PSTs to work in pairs to create a series of investigations asking K-2 grade elementary students in their field placement classrooms to design a labyrinth using Unifix® cubes or similar objects to guide the path of a battery-powered mechanical Hexbug®. The project goals were to engage students' integrated thinking as they designed a model that included objectives for science, mathematics, and engineering. The labyrinth path was required to include obstacles for the mechanical bug to encounter and continue in motion, a hill, force the bug's change in motion, and a create a change in sound. The intent was to model physical science concepts of force, motion, and sound to blend with mathematical concepts of measurement, shapes, and operations to encourage problem solving and creative thinking. Further, engineering design steps helped the students plan, create, and adapt the labyrinth path. Here we discuss our struggles as professors in shaping the levels of guidance for our PSTs as they worked to provide young children with opportunities to explore STEM.

There were two sections of classes for a total of 57 PSTs who were assigned to field classrooms in pairs. This partner structure was used throughout the field placements and built PSTs' "critical friends" support (Franzak, 2002, p. 261) by working in the field with a partner. This type of social "critical friend" structure serves as a transition for the PSTs from isolated college student learners to teacher learners who will, as professionals, work on grade level and content area teams.

Integrated Content

While the PSTs in this study were challenged with the depth and nuances of teaching, situating this project early in PSTs' methods coursework allowed PSTs to begin to address the complexities of teaching and integration of STEM instruction. One PST expressed her adaptation to the integrated STEM project, yet still clearly considering the content areas separately. "The areas I felt stronger about teaching were definitely the math compared to the science because the math is a little bit easier to show and demonstrate, whereas the force and the science was a little bit harder to show because I didn't really see that." The logistics of teaching sometimes overwhelmed PSTs' focus on content and instruction as discussed below.

Instructional design

One PST explained that because she herself did not have positive memories of science, she was surprised by her students' engagement. Her expectations were challenged because the students' behaviors surpassed what she remembered as a student of science:

> I didn't think they would be as interested in it as they ended up being…just because I was never very "sciencey" growing up, I didn't really connect with science lessons maybe because they weren't really investigation focused.

Many of the PSTs were challenged to identify content along with the learning process with students. Students *having fun* was their measure of success, but it seemed to come at the cost of conceptual understanding. One PST's comment illustrates this struggle, "They were having a lot of fun with the bug, which was great; I just don't think they quite understood why they were doing it." While we know from studies of the human brain that learning is effective when a classroom culture is positive and engaging (Curran & Stokes, 2003), PSTs at this stage are in the process of learning the balance of marrying engagement with learning, just as they are learning the balance of integrated STEM content instruction.

Coming into methods courses that promote blending STEM content areas often counters PSTs' 14 years of learning in classrooms with separate subject areas divided by time schedules and the functional design of schools. One PST explained her shift in thinking about STEM integration. "We did science with math with engineering all together…It wasn't as hard as I thought it was gonna be. I thought they would be totally separate but they all roll together really easily."

Discussion

Integrated STEM instruction is traditionally poorly represented in schools (Venville, Rennie, & Wallace, 2012). As we asked our PSTs to integrate STEM with younger children, the blurred boundaries challenged the PSTs as much as the children. Having spent many years in schools with subjects presented with separate class periods and mindsets, the PSTs were required to dramatically shift their thinking to prepare children with authentic experiences. Calls for preparing students for the STEM workforce (Bayer, 2010) have been misinterpreted. Many of the PSTs' mentor teachers in field placements, rather than identifying STEM as an acronym, used "STEM" to loosely refer to students' designs (e.g., bridges) without identifying the mathematics, science, or technology that would be part of the bridge design process. According to Feiman-Nemser (2001) "Promoting student learning through discovery is difficult, perhaps too difficult for a novice, but one unsuccessful experience should not lead a teacher to dismiss the whole approach" (p. 176) and rather can encourage analysis and reflection. Building on these realizations, we outline our own reflections.

Supporting PSTs' Content Knowledge

While watching the videos of young students and considering the PSTs' reflections, it became clear that comfort level with content affected their implementation of the content goals and objectives. For instance, all of the PSTs know how to measure and are aware that measurement is a content standard for K-2 grades, yet only four PSTs out of 57 focused on measurement as a goal with their students. Almost all groups chose a number and operations goal to address their mathematics requirement. Length measurement is critical to the work that scientists and engineers do on a regular basis, so creating a measurement component within this assignment seemed not only logical, but critical to successfully integrating math objectives seamlessly into the lesson. In our second iteration the following year, we included lessons specifically designed to build PSTs' understanding of measurement and its connection across the disciplines.

As PSTs prepared to help students learn about the forces of push and pull and changes in motion, their limited understanding of the content was reflected in their instruction designs for students. In the second iteration, we devoted class time for PSTs' guided explorations of Newton's laws of motion. Another exercise that was added in the second iteration required PSTs to document physical science standards from grades K-5 to help them learn the developmental trajectory across elementary grades. Both additions provided PSTs with a broad historical and standards-based picture of the content.

Further, in the launch phase of this assignment, PSTs all understood this was their opportunity to *hook* students and heighten student engagement using the 5E learning cycle model (Bybee et al., 2006), yet virtually all of the PSTs interpreted *the hook* as separate from the content itself. For our second iteration of the project, both the science and mathematics methods professors were more explicit about the value of content enhancement with students and reinforced an understanding that drawing attention to the content itself, for instance through a discrepant event, is in fact 'the hook.'

Conclusion

The disconnect between science content coursework and teachers' self-efficacy in communicating content and practices to children (Morrell & Carroll, 2003) strongly points to the need for both pre-service and in-service teacher professional development to meet the demands of Next Generation Science Standards (NGSS Lead States, 2013) and Common Core (NGA, 2010). Professional development that takes place over an extended period of time and combines content area courses and professional learning communities has the potential to improve teachers' self-efficacy and delivery of reform-based science teaching (Lakshmanan, Heath, Perlmutter, & Elder, 2011; Sandholtz & Ringstaff, 2014). Policies that support teachers' continued professional development in presenting STEM instruction are critical to teachers' self-efficacy and in turn student learning. We recognize we have only begun to plant the seeds of STEM integration with the PSTs in this study, and school redesign from elementary through college is needed to blur content area boundaries and provide students with connections to the many everyday issues that require STEM integration.

From our initial attempt to engage our PSTs in an integrated project, we recognized the challenge and importance of providing future and current teachers the opportunity to explore full integration of STEM. Upon reflection we also learned how we could better support our PSTs in developing lessons that focused on content. In particular we adjusted our own instruction to support the PSTs in deepening their content knowledge related to key content standards (e.g., measurement, force and motion). Elementary schools are an excellent venue to begin framing integrated STEM and to impact these understandings. Therefore, it is important for elementary teachers to *walk the walk* to obscure these boundaries as we work to establish future, and current, teachers' STEM habits of mind.

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Unpacking Culturally Responsive Mathematics Teaching for Young Learners

Katherine Baker

Abstract: *This abbreviated literature review features studies regarding elementary mathematics instruction and the mathematics teachers that act in ways that lend to and further cultural responsiveness. Teachers presented in the review utilized a pedagogical style referred to as responsive teaching (Empson, 2014) and studies were re-read and analyzed with a lens of cultural responsiveness, specifically that of culturally responsive teaching (CRT). The analysis exposed common practices across this vein of mathematics teaching that uphold the tenets of cultural responsiveness. The value that this form of instruction holds for young learners is also presented.*

Introduction

In 1995, Ladson-Billings laid the framework for considering students' cultures in teaching and challenged the deficit conversations around under-performing learners. She used her theory of culturally relevant pedagogy (CRP) to focus on the success of students who were typically seen as the least successful in order to "reveal important pedagogical principles for achieving success for all students" (2014, p. 76). Ladson-Billings found that teachers within the CRP realm attend to the domains of academic success, cultural competence, and sociopolitical consciousness. Adding to the research of cultural implications for the classroom was Gay's (2001) culturally responsive teaching (CRT). Gay defined CRT as utilizing the "cultural characteristics, experiences, and perspectives of ethnically diverse students as conduits for teaching them more effectively" (p. 106).

Specifically in mathematics, Mukhopadhyay, Powell, and Frankenstein (2009) explored subject-matter cultural implications. They believed that "beyond academic mathematics there lies a wealth of human activity that should be acknowledged as mathematical – historical and contemporary mathematical knowledge and practices of all peoples" (p.76). However, Gutiérrez (2009) cautioned against simply replacing traditional mathematics curriculum with a prescribed culturally responsive curriculum. Rather the content of culturally responsive mathematics is dependent upon the learners in the room, and the culturally responsive math teacher is one who seeks to expose all learners' contributions to the mathematics at hand and integrate their identities into the instruction.

Lens and Guiding Question

Lampert's (2001) research foreshadowed what culturally responsive teaching may mean for the elementary context when she explained that while teaching the elementary mathematics content, she simultaneously made and maintained relationships with all students and maintained relationships among their diverse ideas. Lampert explained this type of teaching as, "shaping and being shaped by the evolving intellectual and social networks in which I am acting" (p. 2). It is commonly recognized in the field of culturally responsive education that building relationships matters to student success, however, there is less work around why cultural responsiveness matters specifically to the elementary mathematics classroom. This review addresses that by analyzing across authors with a lens of cultural responsiveness in order to explore how this form of instruction impacts young learners of mathematics. The following question guided this literature review: What does culturally responsive teaching in elementary mathematics entail and how does this teaching contribute to children's learning of mathematics?

Search Methods

Record searches were done with the term "Culturally Responsive Mathematics" in Google Scholar and Article+ for peer-reviewed articles and book chapters to which 211 and 48 records resulted, respectively. Adding "elementary" as a keyword to the search then dropped the results to 139 and 32 records. Author searches were also done around noted social justice mathematics researchers Gutiérrez and Frankenstein, and around mathematics education researchers in the responsive teaching realm such as Lampert and Empson. Records in each database were scanned, noting commonalities. Abstracts were read and records sorted by their relevance of addressing the overarching question. Nine peer-reviewed pieces were selected to cross-analyze for themes of the culturally responsive elementary mathematics classroom. Note that a parameter of publication dates was not used for the records in this review. The purpose of the review was for analysis and integration of key pieces of literature regardless of publication date, in order to shed light on cultural responsive teaching for children's mathematics.

A Review of the Literature

In reviewing these nine touchstone pieces, three overarching themes emerged. The pieces called educators to action, outlined the elements of responsive elementary mathematics classrooms, and/or discussed the impacts of the responsive mathematics classroom.

A Call to Action

Schoenfeld (2002) claimed that the historical context of students' poor achievement in mathematics is a result of traditional instructional approaches and urged for mathematics reform. Schoenfeld heralded Robert Moses' (2001) argument that those in poverty and people of color are affected by a lack of economic access due to a lack of mathematical literacy. A lack of mathematical literacy means a lack of opportunities in higher education or in the work force.

Schoenfeld then referred to the National Council of Teachers of Mathematics (NCTM) Principles and Standards document released in 2000 that made clear the intent for equity in reform-based mathematics instruction. He explained that mathematics equity results in part due to teachers who are prepared to help students learn through quality mathematics curriculum and problem solve in ways related to their worlds outside the classroom. Prescriptive curriculums that give teachers little discretion only serve to suffocate the intuitive mathematics that students bring into the room. Both Schoenfeld and Gay (2001) acknowledged that curriculum design has shown improvement, but Gay noted that the culturally responsive teacher must still evaluate curriculum for components like complexity, context, and authenticity to make the changes that improve its overall quality for all the learners in the room.

In 2013, NCTM furthered its stance on equity with its release of the Mathematics in Early Childhood Learning position statement. The statement echoed past recommendations of curriculum and teaching for young students that are both developmentally appropriate and culturally and linguistically responsive. NCTM asserted that this work must start in pre-kindergarten in order to ensure future success in mathematics for students. The position stated that teaching practices should be built around the mathematics as well as the child's development. Teachers must interact with their children in deep ways in order for the children to interact with the mathematics in deep ways. This view recalled Mukhopadhyay et al.'s (2009) explanation of culturally responsive math instruction that starts "from the points of cultural familiarity, brought out in the curriculum in a deep way connected with the entire context of intellectual activities of the particular culture" (p. 77).

A Look into the Culturally Responsive Elementary Mathematics Classroom

Lampert's (2001) work purported that for students to be successful in mathematics, the teacher must do more than teach the content and find a way to elicit and integrate the various ideas in the classroom into that content. Empson (2014) explained responsive mathematics teaching as "taking into account the evidence provided during instruction about children's thinking and its advancement. To teach in ways that are responsive to children's mathematical thinking, teachers need to elicit children's thinking, interpret this thinking, and then 'respond helpfully'" (p. 24). Analyzing across the work of responsive mathematics classrooms, two subthemes emerged: communication and development of the whole child.

Communication. In the action-research done in her preschool and kindergarten classrooms, Paley (1986) discussed her goal to listen to children with genuine curiosity and intrigue. She became aware of the intuitiveness her students brought to problem solving in the play that was grounded in their real life experiences and began attaching the mathematics to that. By posing questions to students rather than directing them she opened her classroom to discussions that stretched the young learners. She allowed children time to explain, persuade, and justify until they felt satisfied with their reasoning. Paley found that while she was facilitating students in learning math, she was also helping them navigate the question, "What is going on in this place called school, and what role do I play?" (p. 124).

Noddings (1993) specifically cited the use of dialogue in the math classroom as an avenue to culturally responsive teaching. She informed that dialogue could be integrated into math through allowing students to work together, through discussions around word problem contexts, or through a collaborative discussion around the question "How shall we do this problem?" (p. 156). This question allows teachers to draw out student ideas and connect student contributions. Noddings explained that when dialogue is used thoughtfully it allows for students to learn to build upon and appreciate one another's varying ideas. This not only enhances the mathematics at hand, but also enhances the chance at cooperative living outside the classroom.

Lampert (2001) also cited the use of dialogue in the action-research about her elementary classroom. She facilitated communication between students in order to establish a climate in which a student believes that he/she and every other classmate is capable of learning mathematics, no matter their "gender, race, or parents' income" (p.2). Lampert saw the diversity in student ideas and strategies as a rich resource, and deemed it her responsibility to decide how to use this resource to benefit the learners. Responsive mathematics teachers know that their job is not as easy as following a rote curriculum, but they see the value in providing a classroom space that is open to all mathematicians and ground their pedagogy in listening to children for the sake of exposing and integrating diversity of experiences and ideas.

Development of the Whole Child. Similarly to NCTM's 2013 plea for mathematics teachers who teach with both the mathematics and child's development in mind, Noddings (1993) stated that teachers must attend to students' developmental themes such as, "Who am I? Who will I be? How hard should I work and toward what end?" (p. 153). Noddings asserted that while math teachers should promote mathematical growth, their primary aim should be "the growth of students as competent, caring, loving, and lovable people" (p.159).

Gutiérrez (2009) added to this theme of the research through her work on equity in mathematics and proposed four key dimensions of access, achievement, identify, and power. Student identity in mathematics was recognized as providing children “opportunities to draw upon their cultural and linguistic resources (e.g., other languages and dialects, algorithms from other counties, different frames of reference) when doing mathematics” (p. 5). Gutiérrez explained that teachers must also acknowledge that they work within the context of school and a dominant culture, and that many of their children have learned to neglect their personal and cultural selves to be a part of school. The culturally responsive teacher holds this as true and seeks to include those personal aspects that may have been previously silenced in the math classroom for the betterment of the whole child.

Empson’s 2014 piece closely followed her decision-making with second grade students in a mathematics group and shed light on the attention to whole child. One specific teaching segment highlighted her interactions with a student, Emilio, when he chose not to work on a problem. Rather than jump to deficit thinking about the child, Empson stated,

> I decided I did not want to assume that he was avoiding work. Perhaps it was his way of expressing boredom or confusion, maybe he was preoccupied with a personal problem more important to him than counting candies in a roll (p. 41).

However, she continued to work with Emilio on the problem until he could provide a correct answer. Many teachers have fallen trap to placing the answer above underlying student need, but Empson reflected on her interactions by asking herself, “What did he take away from it? A new understanding of ten as a unit? A feeling of confidence that he can solve problems? A feeling of being forced to do something he did not want to do?” (p. 41). She mused that the answer to “What did he take away from it?” was much more of an important instructional component to consider than Emilio getting the correct answer. For the culturally responsive mathematics teacher, it is crucial that there is reflection and that one admits to judgments and self-motives that may threaten the teaching of the whole child. The responsive math teacher must understand the child first then work towards instilling mathematical goals that build upon this understanding.

The Impact of Culturally Responsive Mathematics

Noddings (1993) explained the efficacy that culturally responsive mathematics can produce for students by noting the empowerment this type of teaching offers. Through a culturally responsive style, teachers can use their personal power to help students acquire power, and thus help them gain control over other aspects of their lives and have efficacy. Noddings asserted that the aim of the classroom teacher should be to promote dialogue “both within mathematics lessons and about mathematics as a potential avenue of self-affirmation” (p. 156). Children deserve to discuss and make sense of the mathematics, and see how their ideas inform the mathematics of the classroom. If this happens from an early age, positive affirmation about mathematics as a subject becomes a part of the child’s discourse, along with that component of self-affirmation.

Beyond just the socio-emotional and developmental needs that culturally responsive mathematics addresses, there is an access issue that culturally responsive mathematics helps to remedy. Schoenfeld (2002) pointed out that mathematics courses are linked to technological literacy and opportunities for higher education. An early foundation in mathematics through high quality mathematics instruction may allow for students to continue on a mathematics coursework path they would have otherwise been denied. Robert Moses (2001), as cited by Schoenfeld, discussed the technological literacy that current and future jobs in the workforce require and that technological literacy is gained through mathematical literacy. Justifying, communicating, and sense-making about mathematics from an early age sets all students up for success in the field that has historically shown that "disproportionate numbers of poor, African-American, Latino, and Native American students drop out of" (Schoenfeld, 2001, p.13).

Implications and Future Studies

In a field that is a product of "the apprenticeship of observation" (Lortie, 1975), a cycle of skill-based, rote mathematics instruction continues. Rather than open the mathematics classroom to a space of students as living generators of knowledge, many teachers continue to stifle them. Teachers treat mathematics as what Freire (1970) referred to as banking education, in which teachers are the bearers of knowledge and deposit it into students. Teacher education programs must address the embedded traditional mathematical beliefs of prospective elementary teachers (PTs) and counteract these with positive experiences that expose them to the openness and cultural obligation of equitable mathematics. University courses that model responsive mathematics teaching with the PTs will be important to future reform movements. This will be crucial to PTs' understandings of how this type of teaching is possible in their future classrooms.

Future research studies are needed around the implementation of culturally responsive elementary mathematics teaching and what it entails for both prospective and practicing teachers. Longitudinal studies that follow young students of culturally responsive mathematics classrooms into future school years would add valuable insight to the research-base in this field. In addition, revealing the opinions and insights from young learners who are a part of a responsive mathematics classroom environment would expose a new perspective not yet seen in research. Interviews and observations specifically focusing on the opinions of children in these classrooms are needed.

If like Schoenfled we believe that mathematics should be democratizing rather than a mechanism for furthering elitism, then we must acknowledge that cultural and racial gaps in achievement exist and that a responsive form of mathematics education is needed. Children need to be able to use mathematics to make sense of the world around them and come to value the contributions of a myriad of different ideals, strategies, viewpoints, and histories. The culturally responsive mathematics teacher must work thoughtfully to ensure that all students have a voice and are able to see themselves reflected in the mathematics of the classroom and the greater world.

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Level Up Intrinsic Motivation Using Gamification and Game-Based Learning

Cynthia Cipriano Bullard

Abstract: *The purpose of this literature review is to compare and contrast gamification and game-based learning (GBL) and examine the benefits of using these strategies to encourage intrinsic motivation.*

In order for intrinsic motivation to occur in the classroom, students need to feel a sense of connectedness to the task, feel they have the ability to master the task, and have the autonomy to direct their own learning (Ryan & Deci, 2000). This literature review will focus on gamification and game-based learning (GBL) and the effect these strategies have on intrinsic motivation.

Defining Gamification and Game-Based Learning

The terms gamification and GBL are sometimes used interchangeably, but they are not the same. Game-based learning combines video games with educational concepts that allow students to apply their knowledge in an augmented reality (Cheng, Kuo, Lou & Shih, 2012), while gamification is defined as a process: "using game thinking and game mechanics to solve problems or engage users." (Miller, 2012). When used in education, gamification provides a game-like learning environment where students have a more active learner role.

Educators may find the benefits of using gamification and GBL far outweigh the risk of moving away from traditional instructional methods when teaching today's students. This shift is supported because today's generation of students view technology as an all-pervasive necessity. According to adults surveyed in the U.S., today's students are twice as likely as previous generations to have played a video game in the past 24 hours (Pew Research Social & Demographic Trends, 2010). Sixty-percent of U.S. children ages 8-18 played video games each day (The Henry J. Kaiser Family Foundation, 2010). This familiarity with the world of gaming makes the transition to using gamification and GBL in the classroom an easy one.

Intrinsic Motivation

Intrinsic motivation is defined as, "The doing of an activity for its inherent satisfactions rather than for some separable consequence." (Ryan & Deci, 2000, pg. 56).

When surveyed about their ideal learning environment, 45 middle school students described a need for intrinsic motivation (Steinberg & McCray, 2012). These students also cited the importance of student-directed learning and active learning environments, including hands-on and role-playing opportunities (Steinberg & McCray, 2012).

Both gamification and GBL address students' desires for an active learning environment, one that also allows students to direct their own educational path (Steinberg & McCray, 2012). Self-directed learning, or learning in which students are motivated to learn for the sake of learning, has been found to occur organically in GBL (Moon, Jahng, & Kim, 2011). Further, the self-directed aspect of gamification and GBL allows students to take ownership of their education, an essential element of intrinsic motivation (Echeverri & Sadler, 2011).

Intrinsic Motivation vs. Extrinsic Rewards

Gamification includes reward systems, competition, and leveling up (Cheng, et al., 2012). A reward system requires students to complete tasks to navigate the game and move to higher levels. "The reward system in digital games is classified as one of the most important elements in game structure responsible for stimulating active and sustained game playing." (Moon et al. , 2011, pg. 3).

However, the use of a reward system has been both praised and criticized with regard to intrinsic motivation. While earlier studies determined extrinsic rewards detrimental to student motivation (Deci, 1971), more recent research contradicts this notion, finding reward systems were not innately detrimental to student learning (Cameron, Banko & Pierce, 2001). Further, gamification has been shown to increase motivation when the experience is a dynamic one that provides opportunities for interaction between players and includes a challenge and reward system. This belief is echoed by students who found game elements such as leaderboards and other representations of their progress and achievements to be intrinsically motivating (Cheong, Cheong & Filippou, 2013).

While educators strive to increase student engagement, there is a fine line between engaging students and meeting the expectations of high scores on end-of-the-year testing, especially when test scores are used to measure not only student growth but also teacher effectiveness. This pressure may cause teachers to be hesitant to shift from traditional to emerging educational methodologies (Barab, Sadler, Heiselt, Hickey & Zuiker, 2007). This hesitation may persist, even when traditional learning environments are defined as stifling experiences based on rules, memorization, and recall of facts in isolation outside of a true context (Gee, 2003). When used in a classroom setting, gamification allows students to move from passive recipients of learning to active leadership roles as they collaborate with their peers, and assume responsibility for their own learning (Bullard, 2015). These types of experiences help foster intrinsic motivation. Students experience authentic learning when learning is participatory and meaningful, rather than traditional experiences that are limited to the acquisition of facts and memorization (Barab, Squire & Dueber, 2000).

Benefits of Gamification and GBL

A gamified classroom fosters creative investigations that sustain learning over a long period and GBL provides learning environments where inquiry spurs creativity in both teacher and students (Frossard, Barajas & Trifonoa, 2012). Students reap the benefits of this creativity as they move to the next level and take charge of their education. This type of learning environment not only enhances, but is also a catalyst for intrinsic motivation (Yien, Hung, Hwang & Lin, 2011).

With the proliferation of social networking, both gamification and GBL speak to today's digitally immersed students, providing them the opportunity for shared learning and socialization, experiences which appeal to and engage learners (Simoes, Redondo & Vilas, 2012). Branching out into social gamification provides both participatory and meaningful learning experiences.

Conclusion and Future Study

Although gamified learning environments have been shown to be intrinsically motivating, additional studies are needed to measure the correlation between gamified learning environments and academic success. Some research questions include the sustainability of a gamified classroom over the entirety of a school year, or whether there is a difference between implementing a gamified environment versus a GBL environment, or if the two are more successful when applied together. Longitudinal studies may not be necessary, but pre and post assessments to measure student growth, and to compare students who participated in gamified environments versus those who did not, may clearly define the effectiveness of gamification and GBL.

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