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WEB-ASSISTED PROBLEM BASED LEARNING IN NANOTECHNOLOGY AND QUALITY OF STUDENT LEARNING IN ELEMENTARY SCIENCE

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ABSTRACT

A study of the effects of web-assisted instruction in Problem-Based Learning (PBL) in nanotechnology on the Quality of Student Learning in Science (Science Conceptual Understanding, the Attitude Towards Science, and the Perception of Science in Society) among elementary students (N=46) is reported. The PBL in nanotechnology involved a web-assisted instructional tool in nanotechnology, *Catching the Rays* a PBL with sunscreen selection. Results indicated a significant ($p < .05$) paired *t* – test gains for Science Conceptual Understanding and Attitude Towards Science. Results of post-interview of a systematic sample (N=6) of participating students to Perception of Science in Society questions indicated two emerging themes: "Risks and Benefits" suggesting students have a positive perception that nanotechnology comes with risks and benefits to society, and "Solves Problems" suggesting students have a positive perception that nanotechnology is governed by society's needs and is used to help solve society's problems. The study findings suggest that PBL with web-assisted instruction in nanotechnology had a positive effect on students' Overall Quality of Student Learning in Science as defined by Science Conceptual Understanding, Attitude Towards Science, and Perception of Science in Society.

Key Words: *Nanotechnology, Web-Assisted Instruction, Problem Based Learning (PBL), Sunscreen, Quality of Student Learning, Conceptual Understanding, Attitudes Toward Science, Perception of Science in Society*

(See Appendix 1 for a **Glossary of Acronyms** used in this manuscript.)

INTRODUCTION

Calls for aligning science education with society's workforce needs are coming from various sectors of society such as businesses, non-profits, and governments. The Committee on STEM Education of the National Science and Technology Council[2] calls for more evidence-based STEM instruction and authentic STEM experiences. According to Andrew Liveris of The Dow Chemical Company, "we need courageous fixes for the long term [work force] pipeline issue" (cited in Camera[3], no page number). Science and technology developments of the 21st Century exceed the innovation and discoveries of the 19th and 20th Centuries. This presents an alarming situation, as America is falling short of its competitive edge in the global economic market and American students are performing poorly on science achievement tests compared to their international counterparts[4, 5, 6, 7]. How to improve the quality of student learning remains a challenge facing educators in the kindergarten through university pipeline.

In a test driven educational environment, most instructional practices used in science classrooms today lack the means to adequately achieve the quality of student learning in science required to succeed in the twenty-first century workforce. "We must help citizens [e.g., educators, policy makers, leaders] understand that the anachronistic nature of most schooling today does not have the type of instruction, level of rigor, or expectations needed to address the challenges they [students] will inherit, or to imagine and create the future."[7] Often, effective pedagogical approaches such as discovery learning, mastery learning, assisted instruction, and PBL known to improve the quality of learning have been overlooked to make room for coaching students as young as elementary graders for achievement tests. It is a critical period of time in history to stop and evaluate the quality of student learning in science and, as a result, it is imperative to identify the instructional practices needed to achieve it. The quality of student learning in science may be operationally conceptualized into three distinct dimensions: Science Conceptual Understanding, Attitude Towards Science, and Perception of Science in Society[8, 9, 10, 11, 12, 13]. As science educators make every effort to make classroom science cognitively engaging, interesting and relevant to Science in Society, science by itself is advancing at rapid pace.

Research and development in fields such as materials science are catapulting unprecedented advancements in science and its technological applications in society. For example, developments in nanoscale science have given way to nanotechnology applications ranging from fibers made of carbon nanotubes that are stronger than steel to smaller and smaller semiconductors with more rapid computing speed that make communication devices faster, smaller and economical (e.g., iPhone)[14]. In this context, this study explored the effects of PBL with web-assisted instruction in nano-technology on the Science Conceptual Understanding, the Attitude Towards Science, and the Perception of Science in Society of elementary students.

Elementary schools play a vital role in the education pipeline endeavoring to improve the quality of student learning in science. Science experiences at the elementary years form lasting attitudes towards science that govern the development of scientific literacy well into adulthood [12, 13]. Students form long-lasting Science Conceptual Understanding foundations, attitudes towards science, and perceptions of Science in Society that relate to the interest they show in science at the middle and secondary levels[15, 16]. According to Ana Mari Cause of Washington University, to promote under-represented groups in the STEM education pipeline, it is necessary to think about it "from cradle to college" (cited in Camera [17], no page number). In this context, science at the elementary grades is critical to give the needed "scaffolding" essential for enhancing the quality of learning[12, 13]. Exploring the effects of instructional practices at the elementary level will help to identify those practices capable of achieving what is meant by the quality of student learning in science in 21st -century society.

The study results may provide valuable insight into Quality of Student Learning in Science in terms of Science Conceptual Understanding, Attitude Towards Science, and Perception of Science in Society essential for evaluating innovative educational interventions in science education. The study addressed the following questions: What is the effect of PBL with web-assisted instruction in nanotechnology on the Science Conceptual Understanding of elementary students? What is the effect of PBL with web-assisted instruction in nano-technology on the Attitude Towards Science of elementary students? Lastly, what is the effect of PBL with web-assisted instruction in nanotechnology on the Perception of Science in Society of elementary students?

LITERATURE REVIEW

The literature review will lay a foundation for the Quality of Student Learning in Science with respect to the intervention web-assisted PBL in nanotechnology. First, an attempt will be made to lay a foundation for the Quality of Student Learning in Science in terms of Science Conceptual Understanding, Attitude Towards Science, and Perception of Science in Society. Second, the review will provide a base for the web-assisted PBL in nanotechnology intervention in terms of nanotechnology, PBL, and web-assisted instruction. Each is explored to provide a rationale for choosing nanotechnology over other science disciplines, and PBL and web-assisted PBL over other instructional practices for nanotechnology instruction to improve the Quality of Student Learning in Science.

Quality of Student Learning in Science

The National Research Council and the American Association for the Advancement of Science provide frameworks for what students should know and be able to do in science, and serve as complementary standards and benchmarks for envisioning the Quality of Student Learning in Science. The NRC published *National Science Education Standards* (NSES) in 1996 that outlines a set of standards for the teaching and learning of science. According to NRC[12], to be scientifically literate implies that a person has (in varying degrees) positive attitudes and values towards science, science concept understanding, inquiry abilities, and the ability to read and evaluate scientific information, and pose, debate, or defend an argument using scientific terminology. AAAS identifies 12 benchmarks in Science for all Americans (SFAA) that provide a roadmap for achieving scientific literacy. According to AAAS[4], to be scientifically literate means to understand the nature of science, nature of mathematics, nature of technology, physical setting, living environment, human organism, human society, designed world, mathematical world, historical perspectives, common themes, and habits of mind.

Despite organizational differences and variations in terms (benchmarks versus standards), three distinct themes emerge: Science Conceptual Understanding (e.g., NRC-earth and space, SFAA-living environment), Attitude Towards Science (e.g., NRC-inquiry skills, SFAA Habits of Mind), and a Perception of Science in Society (e.g., NRC science in personal and social perspectives, SFAA historical perspectives and human society). Drawing from these three themes, the Quality of Student Learning in Science can be operationally conceptualized as having three key dimensions: Science Conceptual Understanding, Attitude Towards Science, and Perception of Science in Society. In this multi-dimensional perspective, each dimension has equal value in the Quality of Student Learning in Science.

Science Conceptual Understanding

Science Conceptual Understanding refers to the grasping of science concepts with an awareness of the relationship among them with a level of confidence to act with them beyond memorization[8, 18, 19, 20, 21]. A concept may be defined as a "mental construct represented by a word or phrase[20] (p. 340). As Novak[22] posits, concepts are what one thinks with and can be abstract (e.g., discovery, observation) or tangible (e.g., cat, table).

According to Konicek-Moran and Keeley[8] "when students understand a [science] concept, they can (a) think with it, (b) use it in areas other than that in which they learned it, (c) state it in their own words, (d) find a metaphor or an analogy for it, or (e) build a mental or physical model of it. In other words, the students have made the concept their own, and this is what we call "[science] conceptual understanding" (p. 6). They provide the following example: students who have learned the concept of evaporation by memorization can answer standardized tests and recreate a drawing on the water cycle, but when faced with a question as simple as what happens to the water in a wet bed sheet on a clothesline "many students do not understand conceptually that when water evaporates it goes into the air around us in a form we cannot see called water vapor" (cited in[19, 8], p. 2-3). As Keeley, Eberle, and Dorsey[23] suggest, "taking the time to elicit and examine student thinking is one of the most effective ways to support instruction that leads to conceptual change and enduring understanding" (p. ix).

Konicek-Morn and Keeley[8], Lederman and Abell[18], Miller[24], Weinstein[10], and Wong and Hobson[11] offer similar interpretations of what is meant by Quality of Student Learning in Science. For example, Miller[24] extracted three themes because of an empirical review of SFAA's description of scientific literacy: grasping of concepts, understanding of nature of science, and impact of science and technology in society.

According to Gabel[25, 26], decades of research in science teaching has clearly shown the following strategies to improve Science Conceptual Understanding. They are problem solving, discrepant or counterintuitive events[27] collaborative learning, wait-time, context, learning by discovery, problem solving, investigating, concept mapping, real-life situations, connecting science, technology and society, and using valid learning cycles. For example, an analysis of scores from the Colorado Students Assessment Program by Gabel[28] showed student scores of 69.1% in "Standard 1: Scientific Investigation" was higher than the combined scores 61.4% for all the standards combined.

There are several ways teachers can promote learning for understanding in science. Sherwood[29] showed how a water quality analysis simulation using PBL learning among elementary graders could improve conceptual understanding. The learning challenge centered on a river ecosystem augmenting the context of learning. Findings showed significant gains in student conceptual understanding of the presence of macroinvertebrates and dissolved oxygen level, pH, etc.

Attitude Towards Science

Attitude Towards Science refers to an individual's "feelings, beliefs, and values held about an object that may be the enterprise of science, school science, and the impact of science on society or scientists themselves"[30, 18, 31, 15, 16]. National (e.g., NAEP) and international (e.g., International Assessment of Educational Progress) achievement tests have included test items aimed (at varying degrees) at measuring Attitude Towards Science[15, 30]. The effects that student-centered, hands-on approach to learning science on elementary-aged (ages 6-10 years) students' attitudes toward science is reported by Jalil, Sbeih, Boujettif, and Barakat[32]. The two-year study provides valuable insight into the possibility to initiate a shift in students' Attitude Towards Science through instructional practices. Results of a survey showed that 73% of participants receiving student-centered, hands-on science instruction preferred science when compared to 20% of the control group, who received instruction in the way of lecture and textbook.

The National Space Centre program consists of pre-lessons, visits, and post-lessons. Eighteen percent of boys and twenty-two percent of girls showed a significant shift in attitude immediately following the Posttest[33]. However, 62% of boys and 72% of girls showed a decrease in Attitude Towards Science on the five-month delayed Posttest. The work of Jarvis and Pell suggests that macro-context activities may have a positive impact on students' Attitude Towards Science, but these attitudes may decline without continued exposure to such instructional practices.

Paris, Yambor, and Wai-Ling Packard [34] describe the effects situated learning has on the Attitude Towards Science of elementary students. A total of 184 students from grades 3, 4, and 5 received Hands-On Biology curriculum in a situated learning environment. Participants at each grade level for both genders showed an increase in Attitude Towards Science when comparing the Overall Mean of Pretest to Posttest. It seems students' Attitude Towards Science are formed and internalized at the elementary level, and these long-lasting attitudes towards science govern the quality of student learning in science and interests in science.

Perception of Science in Society

Perception of science in society refers to an awareness of science in the students' world and in themselves[35]. Science is an inextricable part of society because of its rooted connections within human events, as well as its effects on them[18, 36, 37]. It is important to engage students in science education experiences that help them to understand that science is not just a personal endeavor; it is a social enterprise of collaboration aimed at improving the human condition[36, 37, 13, 38]. "For future citizens in a democracy, understanding the interrelations of science, technology, and society may be as important as understanding the concepts and processes of science"[39] (p. 337).

It should be noted that science education reform research that explores the development of students' perception of science in society remains scarce. In fact, there are few research studies that exist relative to the elementary level or even secondary and post-secondary levels that can contribute to this literature review. Knobel, Murriello, Bengtsson, Cascon, and Zysler[40] surveyed elementary, middle, and high school international students to determine their understanding of nanotechnology and nano-science in relation to society. Approximately 60% of students surveyed heard mention of the terms nanotechnology or nanoscience, and only 18% of those students reported they heard the terms through school while 31% reported they heard the terms outside of school (e.g., television). This exploratory study is significant because it draws attention to students' lack of awareness of science and technology, as it relates to their own lives and society. In addition, the study brings attention for the necessity of science education to align with science and technology demands of the 21st century global workforce.

Buldu[41] examined elementary-aged (5-8 years-of-age) students' Perception of scientists. A convenience sample of 30 students suggests that students have already developed preconceived stereotypical images of scientists and science. Sixty-five percent of students' drawings represented a stereotypical type (e.g., male gender scientist, lab table, lab equipment). Further interview analysis revealed that most images drawn did not come from students' school life; they came from television. Students' perceptions were, more than not, being formed from outside-of-school life influences. Similar to Knobel et al.[40], Buldu's[41] work also brings attention to the disconnect between science education and 21st century science in society, and to the influence of technology (e.g., television) on students' perception of science and scientists.

Jarvis and Pell[33] explore the effects that hands-on learning immersed in real world content and culture have on 10- and 11-year-old students' perception of science in society. A total of 293 students learned about space through the U.K. National Space Centre program. The education program consisted of pre-visit lessons, visits to the Space Centre and/or Challenger Centre, and post-lessons. Students were asked questions on the uses of science as it relates to improving human life. The Overall Mean scores taken from a Science in a Social Context scale Pretest, Posttest (2 months after Pretest), and delayed Posttest (5 months after Pretest) indicate a significant increase in boys' scores when compared to girls' scores at the 2-month Posttest mark and the 5-month Posttest mark [33]. The authors warn that effect size was small, but differences in gender data account for the statistical significance. However, research highlights the critical role that early science education plays in students' perception of science in society and suggests that instructional practices capitalizing on the use of macro-contexts influence students' perception of science in society.

Nanotechnology

Rapid advances in science and technology of the 21st century drive the global economy and leave nations scrambling to stay on the cutting edge. The prefix *nano* represents an area of research in science and technology. This explosive new science, nanoscience, refers to the science of structures ranging from 1-100 nanometers in diameter, and nanotechnology refers to technologies used to produce and manipulate structures at the 1-100 nanometer scale[42]. The impact of nanotechnology has already swept the nation's industry and government sectors. In 2005, a new wave of nanomanufacturing called Second Generation active nanostructures (e.g., in drugs, transistors) emerged. A Third Generation, 3D nanosystems and systems of systems (e.g., heterogeneous nanocomponents) quickly followed in 2010. A Fourth Generation— molecular nanosystems— is on the horizon for 2020[43, 44]. U.S. Government Department of Defense has shown special interest "to discover and exploit unique phenomena at 1-100 nanometers dimensions to enable novel applications to enhance war fighter and battle systems capabilities"[45]. Appointed teams (e.g., Naval Working Group on Nanoscience, Air Force Research Laboratory Nanoscience and Technology Strategic Team) are in place to capitalize on nanotechnology breakthroughs to ensure revolutionary advances in war systems. Considering the wide range of applications of nanotechnology and the need for a suitable workforce, there is growing interest in nanotechnology education.

Nanotechnology Education: Nanotechnology has the potential to change some aspect of every trade or post-secondary profession. However, Kumar[46] highlights a lack of knowledge of nanotechnology and perception of nanotechnology in society among future teachers in undergraduate science education. Students (N = 109) were administered a ten-item questionnaire that assessed various aspects of nanoscience and nanotechnology, such as etymology and physical scale. The results indicate that future teachers may not be equipped with 21st century science knowledge to teach contemporary science in a meaningful way in the classroom (Mean score was 6.13)[46]. The study showed that teachers may not be properly equipped with the knowledge to deal with scale of matter at the nanometer level compelling the need for "nanometry education"[43, 74]. Continued education for science teachers becomes paramount in the endeavor to improve the Quality of Student Learning in Science.

Marschalek and Hofer[47], after an elaborate nanotechnology public awareness outreach project which extended to 26 cities in 18 countries and a total of 14,400 participants, including hard to reach groups, arrived at the following reflection: "Through the project we've learnt that to some extent it can be achieved by illustrating nanotechnology applications with real examples from everyday life. In doing so it is vital to communicate a clear message about the aim of the outreach activity and the importance of the feedback from every single participant." (p. 92).

Bowles[48] and Kumar[1] suggest that implications of nanotechnology span many science disciplines such as biology, chemistry, aerospace, physical, and energy and are relevant to NSES providing natural opportunities for integration at all grade levels. For example, elementary-aged students can explore nanosunscreen, a topic relative to elementary-aged students' lives, making it a meaningful and purpose engagement. Upper grades can explore more complex nanotechnology topics such as nanofuel cells that require a more extensive background in chemistry.

Floyd-Smith et al.[49] and Jones, Broadwell, Falvo, Minogue, and Oppewal[50] offer practical examples of how nanotechnology can be taught in elementary, middle, and high school levels; for example, applications such as nanofabric. Out of the 210 high school participants (46) and middle school participants (164), 95% showed an increase in nanotechnology conceptual understanding, and out of a subgroup of 73 middle school participants, 20-52% showed an increase in students' attitudes towards science. Jones et al.[50] provide an example of how the same topic, nanofabric, can be explored at an elementary level and naturally integrated into existing science curriculum. A 5th grade class conducted experiment testing nano-treated fabrics that claim to repel stains and water. The nanotechnology topic of clothing was relevant to students' lives, making the experience meaningful and purposeful, and the innovative application of nanotechnology piqued their interests in science. The experiment correlated to NSES (a) Strand A: The Nature of Matter, (b) Strand B: Energy, and (c) Strand H: The Nature of Science[12, 13].

The effect of a two-week teacher professional development on teachers' nanoscale science, engineering and technology (NSET) content knowledge is reported by Bryan, Sederberg, Daly, Sears and Giordanao[51]. Although the study showed "significant growth in their [teachers'] understanding of NSET concepts as a result of participating in the program" (p. 92) no convincing explanation is provided for any apparent experimenter effect[52] since the "project staff travelled to teachers' classrooms to assist with lesson implementation and provide instructional resources that teachers requested" (p. 89). Thus, it is not clear the extent to which the workshop was a success in terms of "development" and "durability" of the NSET content knowledge of participating teachers, and findings of studies such as this one should be interpreted with a degree of caution.

Ghattas and Carver[53] reviewed how nanotechnology is integrated into school curriculum and reported a paucity of meaningful activities due to assessment, time, cognitive and curriculum overload. In another review of nanotechnology teaching and learning at the secondary level Hingant and Albe[54] noticed a lack of emphasis on the socio-scientific aspects of nanotechnologies. On the other hand, Winkelmann, Barnas and Saleh[55] reviewed learning resources in nanotechnology and noticed the availability of a variety of resources for K-12 and college levels. A review of literature of precollege teachers' and students' learning in nanoscale science, engineering and technology education made the following recommendation[56]. A design-based approach to research requiring an "iterative cycle of design, development, and field testing of the learning experiences and instructional materials. Each stage of design, development, and field testing is focused on the goal of building and refining an instructional experience that supports learners in their development of conceptual understanding and skills" (p. 30).

Problem-Based Learning

PBL is an instructional method that draws from the theoretical perspective of Dewey's[57] pragmatism and Vygotsky's[58] sociocultural theory. PBL has two models: problem solving and inquiry-based. Both promote self-directed investigation by capitalizing on decision-making skills, social interaction to enhance individual and group appropriation of knowledge, and the acquisition and refinement of problem-solving skills[18, 59, 60]. In addition, both provide problem-oriented situations that can instill in students an appreciation of the value data. The essential features of PBL are (a) student-centered, self-directed investigative learning occurs within a social, collaborative setting; (b) the focal point of learning is the acquisition of conceptual understanding, problem-solving skills, and inquiry skills to investigate real-world problems; and (c) the teacher serves as a cognitive coach and concept facilitator[1, 61, 62, 75].

PBL can be applied to 21st century technology making possible the reality of cultivating inquiry skills in the classroom[1, 62, 63]. This can be achieved through the web-assisted instruction. In web-assisted instruction it is convenient to present real-life problems in the context of real-world science content and science culture. Students are cognitively engaged in exploring a problem where they must activate and draw upon their knowledge and cognitive skills to generate plausible solutions[1, 64].

One of the major drawbacks in PBL is the practicality of providing authentic problem-solving contexts that cultivate cognitive skills along with conceptual understanding[65]. Coupling PBL with World Wide Web technology creates a hybrid instructional environment capable of bringing real-world science and culture into the classroom. By doing so, science becomes meaningful and relevant to students' lives, thus developing in students an awareness of science in their own lives and, as a result, an awareness of Science in Society. Connecting science, technology, and society is a key element in preparing students for the future[36, 37]. Although any one instructional practice should not be deemed a one-size-fits-all approach to the teaching and learning of nanotechnology, web-assisted instruction has helped to enhance PBL, making it one of the most practical instructional designs to equip students with nanotechnology knowledge and cognitive skills needed to address 21st century challenges.

The focus of PBL research has been at the secondary level. Dochy, Segers, Van den Bossche, and Gijbels[66] conducted a meta-analysis from 43 empirical studies on PBL aimed at addressing effects on knowledge and skills and potential moderators (e.g., methodological, research design, scope of implementation, expertise-level of students). In the review, there was not one reported negative effect of PBL on secondary students' knowledge and skills[66]. Although research on the effects of PBL on secondary students is abundant, few explore effects on elementary students. It should be noted that the current research explores the effects of PBL with web-assisted instruction in nanotechnology on the Science Conceptual Understanding, the attitude towards science, and the perception of science in society of elementary students.

Web-Assisted Instruction

Web assisted instruction adds to PBL in several ways. It capitalizes on technology through the use of the WWW to enrich the context learning. In addition, utilizing the WWW has another advantage; it provides virtually unlimited accessibility for teachers and students. Through the web it is possible to present information-rich video, audio and/or text in real-world context ("macro-context") and create a learner-centered learning environment (e.g., episodes online).

In terms of PBL, it is important to provide students with learning contexts that they can relate to when attempting to bring hard-to-visualize abstract topics such as nanoscience and nanotechnology into the classroom[48, 49, 64]. Sherwood[29] illustrates the effects that a simulation-based instruction has on 5th grade elementary students' conceptual understanding in a problem based learning activity. Sherwood[29] studied 42 students who engaged collaboratively on a river ecosystem project called *River of Life*. The *River of Life* serves as a macro-context because it engages students in real-world science context and culture through an inquiry-based 6-step cycle to solve a posed challenge (problem). Analysis of results suggests a significant increase in students' conceptual understanding; approximately 44% of correct answers on the Pretest increased to approximately 55% on the Posttest[29]. Sherwood's work is significant because it provides data on video assisted instruction on elementary-aged students' conceptual understanding, which is one of the three key dimensions of the Quality of Student Learning in Science.

The conceptual understanding research of Cognition and Technology Group at Vanderbilt[67] provides insight into the effects of video assisted instruction on students' problem-solving skills. Students used a 12-videodisk program called *Jasper Series*. Each disk is a macro-context adventure centered on a mathematical challenge that integrated science concepts (as well as concepts from other disciplines). Analysis of a problem-solving pre-posttest suggests that students in the Jasper groups had significant gains in each of the one, two, and multi-step areas of problem-solving that were measured when compared to that of the control groups[67]. Analysis of a pre-post conceptual understanding test suggests that video assisted instruction does not impede conceptual understanding. There was no significant difference between the control groups and Jasper groups. With the advent of the WWW it is not only possible to make the videos available globally but also convenient to develop meaningful web-assisted instructional tools.

The accessibility features of web instructional resources have the potential to provide instant instructional scaffolding for teachers and instant PBL scaffolding for learners, empowering teachers to make that critical first step towards developing multidimensional pedagogies for the teaching and learning of science. PBL in nanotechnology using web-assisted instruction provides exciting World Wide Web platform to present science problems in nanotechnology in a real-world context to gain student attention and engagement in meaningful science learning. Web-assisted instruction may improve but not impede students' conceptual understanding, and it may improve students' problem-solving skills.

Web-Assisted PBL in Nanotechnology

A study involving the development and field-testing of web-assisted PBL in nanotechnology among elementary students is reported by Kumar[1]. Three custom developed web-based modules *Catching the Rays*, *Going Green*, and *Friend or Foe* provided a platform for PBL in real-world applications of nanotechnology, dealing with consumer decision-making, clean energy, and societal issues, respectively. The context was a science classroom.

The modules included a narrator who helps all transitions between the teacher and students throughout the cycle by providing cues to pause/stop for brainstorming ideas, research, reflection, and testing. Each module was equipped with Navigation Tips to guide the users through step-by-step instruction, and aligned with the National Science Education Standards (NSES). The modules are Closed-Captioned to facilitate students with English as a Second Language. Each module followed a modified version of the "Legacy Cycle". The three modules were field-tested among fifth graders ($N = 40$) and the results showed a significant gain ($t = -17.28$, $df = 39$, $p < 0.05$) in conceptual understanding from pre-test (Mean = 0.42, SD = 0.15) to post-test (Mean = 0.86, SD = 0.11). Computed Cronbach's reliability was 0.73 for the Pre- Post- Science Conceptual Understanding instrument. Analysis of post-interview data indicated that most participants were able to successfully apply the concepts learned in the three modules to selected academic and real-world situations. Findings of this study are encouraging that instruction with web-assisted PBL in nanotechnology seems to have a positive effect on certain aspects (Science Conceptual Understanding and Science in Society perspectives) of the Quality of Student Learning in Science among elementary students.

METHODOLOGY

The study explored the effect of PBL with web-assisted instruction in nanotechnology on the Science Conceptual Understanding, the Attitude

Towards Science, and the Perception of Science in Society of elementary students. A mixed-methods approach was used. The study proceeded as follows[9].

Sample

Fifth grade public elementary school students (N = 46) from the southeastern United States participated in this study. Nearly half of the school population received Free and Reduced Lunch based on household income, and approximately one-quarter of the total school population classified as students with disabilities.

Intervention

A web-assisted instruction in nanotechnology called *Catching the Rays* was used in the study. It is one module out of a 3-module unit developed as part of a research project undertaken by Kumar[1] (2015) and discussed earlier in this paper.

The *Catching the Rays* module was chosen for the study because it explores nanotechnology through hands-on activities involving nanosunscreen, which is a societal-based context relevant to the lives of elementary students.

Catching the Rays is a 5-step, inquiry-based learning cycle that guides teacher and students through a nanotechnology challenge involving nanosunscreen. A narrator navigates the teacher and students through the module by cueing them to pause/stop for brainstorming ideas, research, reflection, testing Science Conceptual Understanding, and so forth. The first step in the module is called the "Challenge." Here, the narrator introduces Mrs. Ablett, an award-winning science teacher, who presents students with a challenge to research nanosunscreen and regular sunscreen and make a recommendation based on their research.

The second step in *Catching the Rays* is called "Initial Thoughts." Mrs. Ablett invites students to reflect collaboratively on the key words within the challenge statement to begin an initial thoughts discussion. In addition, Mrs. Ablett introduces a set of questions for students to think about. A few examples are: What are nanoparticles? How does sunscreen protect us from UV rays? These questions are also available by clicking on the Resources link. Students are then asked to pause the module to complete a team Initial Thoughts organizer. When the module resumes, Miguel and Dorri, two students in Mrs. Ablett's science class, share their organizer with the class.

Step 3 is "Perspectives and Research." Here, the narrator invites students to roll up their sleeves as they prepare to research nanosunscreen on the Internet. Mrs. Ablett encourages students to consider various perspectives throughout their research. Miguel clarifies what Mrs. Ablett means by perspective. His uncle is a dermatologist and wondered if his view of sunscreen as a doctor would be considered another perspective. In addition to Internet research, students are invited to conduct some research of their own. Procedures for a sunscreen experiment can be found by clicking on the Resources link. Here, students can explore the UV protection rate of nanosunscreen and the UV protection rate of regular sunscreen using energy beads.

The fourth step is "Assessment." This step engages students in a reflection of the conceptual understanding they constructed during the Perspectives and Research step. Students are asked to test their understanding by responding to the set of questions Mrs. Ablett posed in the Initial Thoughts step. Miguel and Dorri realize that finding gaps in their understanding requires one or two return visits to the Perspectives and Research step. Mrs. Ablett reminds them that revisits to the Perspectives and Research step are a normal process in the learning cycle.

"Wrap Up" is the fifth and final step in *Catching the Rays*. Mrs. Ablett stresses how important it is for scientists to share their findings. Like scientists, students are invited to choose a forum for presentation, prepare the presentation, and share recommendations. Mrs. Ablett commends Miguel and Dorri on their use of scientific evidence from both their Internet research and nanosunscreen activity research to support their recommendation. She thanks her entire class for a Challenge well done.

Instrumentation

Both a quantitative instrument and a qualitative instrument were used to test Science Conceptual Understanding and Attitude Towards Science. A qualitative instrument only was used to test Perception of Science in Society.

Science Conceptual Understanding

The Science Conceptual Understanding Pretest-Posttest quantitative instrument has 25 items. It is an adapted and augmented version of an instrument created by Kumar[1] to measure students' understanding of nanotechnology as it relates to nanosunscreen, nanofuel cells, and nanoethics. This multiple-choice test was adapted by eliminating those items relating to nanofuel cells and nanoethics that do not pertain directly to this study and augmented with items involving nanosunscreen. A few sample question items are: (a) What are nanoparticles? and (b) What are the similarities and differences among sunscreens with nanoparticles and those without nanoparticles?

The Nanotechnology Post-Interview qualitative instrument contains five preset questions pertaining to Science Conceptual Understanding. It is an adapted version of an 8-item instrument created by Kumar[1]. Sample items are: (a) Arrange the following three questions [ant, head of a pin, nano zinc oxide] from smallest to largest, and (b) What did your sunscreen activity teach you about sunscreen containing nanoparticles and regular sunscreen?

Attitude Towards Science

The Attitude Towards Science Pretest-Posttest quantitative instrument contains ten items. It is an adapted and augmented version of the Attitude Towards Science subscale portion of an instrument created by Simpson and Oliver[15] with seven items on the five-point Likert scale (Cronbach's reliability 0.88.) Sample items are: (a) I enjoy science courses, and (b) I would enjoy being a scientist. Three additional items were created and added to the scale for a total of ten items. A sample item is (a) I wish we spent more time in our school day to learn science.

The Nanotechnology Post-Interview qualitative instrument contains one preset question relating to Attitude Towards Science. It is an adapted and augmented version of an instrument created by Pell and Jarvis[68]. Pell and Jarvis created an Attitude to Science scale. The scale was pre-piloted and piloted. The scale has five subscales. Science Enthusiast was the only subscale drawn upon to generate an interview question. The Science Enthusiast subscale has a Cronbach's reliability of 0.74[68]. There are eight items in the Science Enthusiast subscale. One question from the eight was used in the Nanotechnology Post-Interview instrument. The post-interview Attitude Towards Science question is: "How do you feel about science compared to other school subjects? Explain using class examples."

Perception of Science in Society

The Nanotechnology Post-Interview qualitative instrument contains four preset questions relating to the Perception of Science in Society. The questions were guided by the NRC[12] Science Education Standards and the SFAA Benchmarks[4].

Guided by the NRC Science Education Standards[12] Science in Personal and Social Perspectives and by the SFAA[4] Benchmarks Human Society and Nature of Technology four interview items to test Perception of Science in Society were constructed. Students were asked to recall their experience in *Catching the Rays* to respond to interview questions that explored their awareness that (a) nanotechnology is used to solve society's problems; (b) nanotechnology comes with risks and benefits to society; and (c) development of nanotechnology is governed by society's needs. A sample question is "Would you recommend nanosunscreen or regular sunscreen to your neighborhood community, and explain why." This sample question probes students' thoughts on (b) nanotechnology comes with risks and benefits to society.

All the above instruments were subjected to review by an expert panel and revised based on any feedback.

Procedure

Participating students were randomly assigned a number and were identified using only their assigned number. Prior to the intervention, the Science Conceptual Understanding Pretest and Attitude Towards Science Pretest were administered during regular scheduled science class. The Science Conceptual Understanding Pretest took approximately thirty minutes to complete. The Attitude Towards Science Pretest took approximately ten minutes to complete.

The intervention was administered within one week following the administered Pretests. The intervention took approximately two and a half weeks to complete. The intervention was administered to all students approximately one hour a day, five days a week during regular scheduled science instruction time in the regular science classroom for approximately two and a half weeks.

Students were administered the Science Conceptual Understanding Posttest and Attitude Towards Science Posttest within one week after the intervention. The Science Conceptual Understanding Posttest took approximately thirty minutes to complete. The Attitude Towards Science Posttest took approximately ten minutes. The Posttests were administered during regular scheduled science class.

A purposeful selection of six students were administered the Nanotechnology Post-Interview within one week after the intervention and after the Science Conceptual Understanding Posttest and Attitude Towards Science Posttest. Interviewees were purposefully selected based upon students' raw scores on the quantitative instrument, Science Conceptual Understanding Pretest/Posttest. The difference in points between each student's Pretest and Posttest raw score was used to determine each student's learning gain points. Learning gain points were then sorted into one of three learning gains categories: Large Gains (LG), Moderate Gains (MG) and Little-to-no-Gains (LTNG) for interviewee selection purposes. Two students from each category to be audio recorded were selected. The rationale for purposefully selecting interviewees was to gain in-depth insight into the thoughts of students[69] across a learning gains spectrum. Miles and Huberman[70] suggest a purposive approach to sampling when smaller case numbers are involved because applying a random sampling approach with small case numbers can lead to a biased pool of students.

The Nanotechnology Post-Interview was conducted interviewing each of the six students one at a time. Each interview was audio-recorded and it took an average 35 minutes to complete. The Nanotechnology Post-Interviews were audio-recorded and transcribed. Interview responses were independently coded and analyzed by two raters.

Data Analysis

A paired *t* test was used to contrast Means for the Science Conceptual Understanding Pretest and Posttest, and the Attitude Towards Science Pretest and Posttest at 0.05 alpha level. The Nanotechnology Post-Interviews were audio-recorded and transcribed. Interview responses were independently coded and analyzed by two raters to independently code and analyze data : Triangulate, using constant comparative method of data analysis utilizing open-coding, and axial coding and selective looking for positive and negative responses, emerging categories and emerging themes.

Results

Results are presented in three sections: Science Conceptual Understanding, Attitude Towards Science, and Perception of Science in Society. See Table 1 for a summary of reliability results for the Science Conceptual Understanding and the Attitude Towards Science Pretests and Posttests[9].

Table 1. Computed reliability coefficients (Cronbach's Alpha)

Cronbach's Alpha	Pretest	Posttest
Science Conceptual Understanding	0.54	0.64
Attitude Towards Science	0.85	0.85

Science Conceptual Understanding

Science Conceptual Understanding Pretest Posttest. The return of the paired *t* test, post being larger than pre, yielded a *t* = -16.27, p <. 01, *df* = 45. Effect size Cohen's d is 2.76. The Overall Pretest Mean (0.41, SD = 0.13) is significantly lower than the Overall Posttest Mean (0.78, SD = 0.12), returning a Post-Pre paired Mean of +0.37 (SD = 0.15). Analysis of differences in Means of responses by item revealed the following: 24 out of 25 test items returned an increase in Means when comparing students' Overall Pretest Means to Posttest Means. The Overall Mean gain + 0.37.

Eleven out of twenty-five test items were above the Overall Mean (test items #1-4, 9, 10, 12, 13, and 19-21), and sample test items follows. Test item #13: "What is the name of the nanoparticle found in sunscreen"? (Pretest Mean = 0.17, SD = 0.38, Posttest Mean = 0.87, SD = 0.34, Difference in Means = 0.70). Test item #12: "What is nanotechnology"? (Pretest Mean = 0.30, SD = 0.47, Posttest Mean = 0.78, SD = 0.42, Difference in Means = 0.48).

Three out of twenty-five test items were equivalent to the Overall Mean (test items #15, 16, and 18), and sample test items follows. Test item #15: "What is the main cause of skin cancer"? (Pretest Mean = 0.37, SD = 0.48, Posttest Mean = .74, SD = 0.44, Difference in Means = 0.37). Test item #16: "What does SPF stand for"? (Pretest Mean = 0.43, SD = 0.50, Posttest Mean = 0.80, SD = 0.40, Difference in Means = 0.37).

Eleven out of twenty-five test items were below the Overall Mean (test items #5-8, 11, 14, 17, 22-25), and sample test items follows. Test item#14: "Why is the nanoparticle in sunscreen colorless"? (Pretest Mean = 0.26, SD = 0.44, Posttest Mean = 0.52, SD = 0.55, Difference in Means = 0.26). Test item #8: "Are there risks in using nanoparticles"? (Pretest Mean = 0.67, SD = 0.47, Posttest Mean = 0.89, SD = 0.32, Difference in Means = 0.22).

It should be noted that one test item (#23 What does the prefix nano stand for?) showed a negative difference in Mean (-0.90) when comparing students' Overall Pretest Mean (0.13, SD = 0.43) to Posttest Mean (0.04, 0.21), and could be inferred that students might have randomly guessed on the Pretest.

***Science Conceptual Understanding Post-Interview*.** The Nanotechnology Post-Interview Science Conceptual Understanding section contained five questions. See Table 2. The quantitative questions (2/5) (e.g., Question #1) solicited a direct response where the student arranged items in order and/or responded verbally to a multiple-choice question; five out of six students responded positively to this question. The student who responded negatively to this question was from the MG category. Six out of six students responded positively to the second question of this type. The three qualitative questions in this section solicited responses that were open-ended (e.g., Question #2). Responses to these questions were also categorized as positive or negative. Six out of six students responded positively to two out of three questions. Five out of six responded positively on the remaining question. The student who responded negatively to this question was from the LTNG category. Table 2 summarizes response analysis accompanied with sample positive and negative (where applicable) responses.

Table 2. Nanotechnology post-interview: Science Conceptual Understanding responses

Question	Positive Sample	Number Positive	Negative Sample
1. Arrange the following three items from smallest to largest; Ant, Head of a pin, nano zinc oxide	"nano zinc oxide, head of a pin, ant" (LG student)	5/6	"ant, head of a pin, nano zinc oxide" (LTNG student)
2. What did your energy bead activity teach you about sunscreens containing nanoparticles and regular sunscreen?	"The nano energy bead activity taught me nano protects better because it absorbs and it is clear. The regular sunscreen scatters and it's white. But some people have skin problems and are worried nano can get into your bloodstream." (MG student)	5/6	"Nano protects better and is really clear and it absorbs visible light. Regular protects skin and is a little bit clear sometimes absorbs." (LTNG student)
3. A nanometer is about 1,000 times smaller than the size of your classroom, your neighborhood, an ant or a football field	"an ant" (LG student)	6/6	None
4. What did Catching the Rays teach you about learning science?	"Catching the Rays taught me the learning cycle which is a hard challenge so you start with first you do research, perspectives and then you get a recommendation and you're done." (MG student)	6/6	None
5. Is the nanotechnology in sunscreen risk free? Explain.	"Alright the new technology is not recommended for people who that do have skin um skin problems. It might affect the problem they have with their skin. You should probably talk to your doctor about it first before you use nanotechnology, nanosunscreen." (MG Student)	6/6	None

All students interviewed (N=6) responded positively to three out of five Science Conceptual Understanding questions. Five out of six students responded positively to the remaining two questions. In both cases, students responding negatively were from the LTNG category (N=2).

Responses to Question #2 led to two emerging categories: "Nanoproperties" and "Nano Benefits and Risks." Five out of six students demonstrated positive Science Conceptual Understanding through their descriptions of nanoproperties (e.g., one billionth in size, clear, absorbs visible light). The cluster of references to nano particle properties found in sunscreen led to the emergence of the category "Nanoproperties." Five out of six students expressed an understanding of the risks and benefits of nanoparticles in relation to nanosunscreen (e.g., may enter bloodstream, protects against UVA/B better). The repeated mention of risks and benefits led to the emergence of the category "Nano Benefits and Risks."

Two categories emerged from Question #4: "Steps in Scientific Method" and "Science Work Ethic." Five out of six students made accurate mention of process features involved in the scientific method, such as research, perspective, and recommendation. The category "Steps in Scientific Method" emerged from this cluster of words. Two out of six students expressed an awareness and understanding of behavior traits involved as a student scientist (e.g., working together, not jumping right in). This cluster of words led to the emergence of the category "Science Work Ethic."

Table 3. Science Conceptual Understanding: Categories that emerged across responses

Question	Sample Phrases	Categories	Number Positive	Gains Category
2. What did your energy bead activity teach you about sunscreens containing nanoparticles and regular sunscreen?	"Nano… is really clear and it absorbs visible light." (LTNG student) "..nanoparticles are clear and go through and they protect better. Regular sunscreen scatter, are white and bulky…" (LG student)	nano properties	5/6	2/2 LG 1/2 MG 2/2 LTNG
	"…nano can get into your bloodstream." (MG student)	nano risks and benefits	5/6	2/2 LG 2/2 MG 1/2 LTNG
4. What did Catching the Rays teach you about learning science?	"..first you do research, perspectives and then you get a recommendation and your done." (MG student)	steps in scientific method	5/6	2/2 LG 1/2 MG 2/2 LTNG
	"..work together.." (MG student) "You can't just jump in." (LG student)	science work ethic	2/6	1/2 LG 1/2 MG 0/2 LTNG
5. Is the nanotechnology in sunscreen risk free? Explain.	"It might affect the problem they have with their skin." (MG student) "It may get into the bloodstream." (LTNG student)	medical risks	6/6	2/2 LG 2/2 MG 2/2 LTNG
	"I would recommend asking your doctor first before using nanosunscreen." (LTNG Student)	consult alternative perspective	2/6	0/2 LG 1/2 MG 1/2 LTNG

Two categories emerged from Question #5: "Medical Risks' and "Consult Alternative Perspective." Six out of six students demonstrated accurate Science Conceptual Understanding in their description of possible medical risks because of using nanoparticles found in nanosunscreen. The cluster of phrases such as "skin problems" and "organ damage", led to the emergence of the category "Medical Risks." Two out of six students expressed thoughts of pursuing alternative perspectives prior to deciding on if to use nanosunscreen. The category "Alternative Perspective" emerged from a cluster of phrases such "asking your doctor" and "get another perspective." Table 3 summarizes categories that emerged from students' responses to the Science Conceptual Understanding portion of the Nanotechnology Post-Interview.

All LG students (N=2) are represented in 4/6 categories: Nano Properties, Nano Benefits/ Risks, Steps in Scientific Method and Medical Risks. All MG students (N=2) are represented in 2/6 categories and all LTNG (N=2) were represented in 3/6 categories. Students demonstrated accurate Science Conceptual Understanding on 2/3 open-ended Science Conceptual Understanding questions.

A theme of Science Process and a theme of Risks and Benefits emerged from Question #2, Question #4, and Question #5 categories. The theme of Science Process emerged from three categories: "Steps in Scientific Method," "Science Work Ethic," and "Consult Alternative Perspective." These three categories represent some aspect of "Science Process." For example, "Science Work Ethic" represents habits of mind when engaged in the science process. The theme of Risks and Benefits emerged from three categories: Nanoproperties, Nano Benefits, and/or Risks and Medical Risks. These three categories represent some aspect of "Risks and Benefits." For example, an accurate understanding of nanoproperties is necessary to differentiate between which nanoproperties are risks and which are benefits.

The theme of Risks and Benefits and the theme of Science Process suggest that students demonstrated Science Conceptual Understanding of nanotechnology as well as an understanding of the science process, as evident in the categories they emerged from "Nanoproperties," "Nano Risks and Benefits," "Medical," "Consult Alternative Perspective," "Steps in Scientific Process," and "Science Work Ethic." The themes support the quantitative results.

Attitude Towards Science

Attitude Towards Science. Results of a paired *t* test comparing the Means of the Pretest and the Posttest yielded a $t = -2.52$, $p = < .01$, $df = 45$. Effect size Cohen's d is 0.29. The Overall Pretest Mean (4.13, SD = 0.68) is significantly lower than the Overall Posttest Mean (4.29, SD = 0.60) with a Pre-Post paired Mean of -0.15 (SD = 0.40).

Nine out of ten questions showed a gain in the Overall Pretest Mean when compared to the Overall Posttest Mean, suggesting an Overall positive gain in students' Attitude Towards Science. Analysis of difference in Means responses by items showed the following: Nine out of ten test items showed a gain in students' Overall Pretest Means when compared to students' Overall Posttest Means. Sample test items showing the greatest gains in Pretest and Posttest Overall Means follow. Test item #9: "I wish we spent more time in our school day to learn science" (Pretest Mean = 3.96, SD = 1.21, Posttest Mean 4.33, SD = 0.90, Difference in Means = 0.37). Test item #2 "I have good feelings toward science" (Pretest Mean = 3.96, SD = 1.13, Posttest Mean 4.28, SD = 0.89, Difference in Means = 0.32). Test item #4: "I really like doing science activities" (Pretest Mean = 4.70, SD = 0.76; Posttest Mean = 4.87, SD = 0.54, Difference in Means = 0.17). One out of ten items, test item #6 'Everyone should learn science", resulted in a negative gain (-0.15) in students' Overall Pretest Means (3.61, SD = 1.15) when compared to students' Posttest Means (3.46, SD = 1.22).

Students' raw scores in Attitude Towards Science were explored. The difference in students' raw Pretest score compared to their raw Posttest score was used to determine each student's gains. Gains ranged from +1 to + 16.

Table 4. Gains in Attitude Towards Science and Learning Gains category

Gains	Point Average	Students	Learning Gains (LG) Category
positive	3.9	24/46	7 from LTNG, 13 from MG and 4 from LG
zero	0	13/46	3 from LTNG, 5 from MG and 5 from LG
negative	-2.4	9/46	1 from LTNG, 7 from MG and 1 from LG

The gain in Mean Attitude Towards Science was 3.9. Thirteen out of forty-six showed no gains in Attitude Towards Science (+0) and 9/46 had a negative gain (-4 to -1). The negative gain was -2.4. Overall, 24/46 students showed a positive gain in Attitude Towards Science. See Table 4 for a summary of students' raw score Attitude Towards Science gains.

Over all more than half of the students (24/46) indicated a positive effect on the Attitude Towards Science. Over half of the LTNG students had positive gains in Attitude Towards Science (7/11). This is contrary to the LG students. Over half (6/10) of the LG students showed a zero or negative effect on Attitude Towards Science. MG students were almost even, with 13/25 showing positive gains and 12/25 showing zero or negative gains in Attitude Towards Science.

The Nanotechnology Post-Interview contained one preset question pertaining to Attitude Towards Science: "How do you feel about science compared to other school subjects? Explain using class examples." All six students responded positively. Responding positively was defined as students who expressed a positive Attitude Towards Science. A sample positive response is

"Science is more, um, science is very extraordinary cause you can learn stuff that you'd never knew before and other things have never that you have never heard of and you can actually conduct experiment to understand. It's fun like when you do projects on, say, when you do projects on UV beads like, we did in this lesson. Rocks, also as in like projects in the rock cycle and etcetera and stuff like that would be classroom projects." This sample is from a MG category student. Phrases such as "Science is extraordinary" and "It's fun like when you do projects…" suggest a positive Attitude Towards Science. All six students responded positively. A sample positive response included phrases such as "Science is very extraordinary," "It's fun," and "You can actually conduct experiments." Response analysis accompanied with sample positive and negative responses (where applicable) are summarized in Table 5.

Table 5. Nanotechnology post-interview: Attitude Towards Science responses

Question	Positive Sample	Number Positive	Negative Sample
6. How do you feel about science compared to other school subjects? Explain using class examples	"Science is more um science is very extraordinary cause you can learn stuff that you'd never knew before and other things have never that you have never heard of and you can actually conduct experiment to understand. It's fun like when you do projects on say when you do projects on UV beads like we did in this lesson. Rocks also as in like projects in the rock cycle and etc and stuff like that would be classroom projects." (MG Student)	6/6	none

All six students spanning across the entire Learning Gains (LG, MG and LTNG) spectrum demonstrated a correct (positive) Attitude Towards Science.

\The category of General and the category of Doing emerged from Question #6. The category of General emerged from positive comments about science in a general nature (e.g., fun). The category of Doing emerged from positive comments about the act of "doing" science (e.g., experiments). All six students demonstrated a positive general Attitude Towards Science through comments such as "science is fun" or "I think everyone should learn science." All six students demonstrated a positive Attitude Towards Science in "doing" science through comments such as "you can actually conduct experiments." Table 6 summarizes categories that emerged from students' responses to the Attitude Towards Science portion of the Nanotechnology Post-Interview.

All six students expressed a "general" positive Attitude Towards Science. All six students expressed a positive Attitude Towards Science about the act of "doing" science.

A theme of Positive Process emerged from the category of General and the category of Doing. A sample phrase such as "I think math and science is really good when it comes with working things out together" (LTNG student) that emerged from the category of General, and phrases such as "involves more experiments" (LTNG student) that emerged from the category of Doing, are representative of the phrases from which the theme of Positive Process emerged.

The theme of Science Process emerged from the General and Doing categories of Question #6. Qualitative data suggest that students expressed a positive Attitude Towards Science in general and in doing science, as evident in the category of General and the category of Doing from which the theme of Science Process emerged. There is congruence between the qualitative results with quantitative results.

Table 6. Attitude Towards Science: Categories that emerged across responses

Question	Sample Phrases	Categories	Number Positive	Gains Category
6. How do you feel about science compared to other school subjects? Explain using class examples.	"Science is fun." (LG student) "I think everyone should learn science." (MG student) "I think math and science is really good when it comes with working things out together." (LTNG student)	general	6/6	2/2 LG 2/2 MG 2/2 LTNG
	"..involves more experiments..." (LTNG student) "..you can actually conduct experiments..." (MG Student)	doing	6/6	2/2 LG 2/2 MG 2/2 LTNG

Perception of Science in Society

Interviewees for the Nanotechnology Post-Interview were purposefully selected based upon students' learning gain points. Learning gain points were determined by calculating the difference between students' raw Science Conceptual Understanding Posttest score and their raw Science Conceptual Understanding Pretest score.

A noticeable gain in the number of students with learning gain points of 8-11 identified this as the MG category. Twenty of the forty-six students fell into this category. Students in this category had an 8 (9 students), 9 (4 students), 10 (5 students), or 11 (7 students) point gain in Science Conceptual Understanding. Ten students fell into the LG category. Students in this category had a 12 (3 students), 13 (2 students), 14 (1 student), 15 (1 student), 16 (1 student), or 17 (2 students) point gain in Science Conceptual Understanding. Eleven students fell into the LTNG category. Students in this category had a 1 (1 student), 2 (1 student), 3 (1 student), 4 (1 student), 5 (3 students), 6 (2 students), or 7 (2 students) point gain in Science Conceptual Understanding. Two interviewees from each learning gain category (LG, MG and LTNG) were selected. Table 7 summarizes learning gains categories that emerged from students' point gains from the Science Conceptual Understanding Pretest and Posttest.

There was a considerable gain in the number of students in the last LTNG of +7 (2/46) compared to the number of students in the first MG of +8 (9/46). The gain from two students to nine students marked a break between learning gains points, distinguishing the LTNG category from the MG category. In addition, the number of students for each point gains in LTNG ranges from 1-3 whereas the students for each point gain in MG ranges from 4-11. A similar break reoccurred, distinguishing the MG and LG categories. The last MG of +11 had seven students whereas the first LG of +12 dropped considerably down to three students and remained lower than three for each point gain thereafter. The Point Range was fairly evenly distributed amongst the three categories, with the LG (5) and LTNG (6) being slightly higher than MG (4).

Table 7. Determination of interviewee selection: Established Learning Gains Categories

Established Category	Point Gains	Student Ratio	Point Range	Number of Students
LG	+17 +16	2/46	5	10/46
	+15	1/46		
	+14	1/46		
	+13	1/46		
	+12	2/46		
		3/46		
MG	+11 +10	7/46	4	25/46
	+9	5/46		
	+8	4/46		
		9/46		
LTNG	+7	2/46	6	11/46
	+6	2/46		
	+5	3/46		
	+4	1/46		
	+3	1/46		
	+2	1/46		
	+1	1/46		

Table 8. Nanotechnology post-interview: Perception of Science in Society responses

Question	Positive Sample	Number Positive	Negative Sample
7. Would you recommend nanosunscreen or regular sunscreen to your neighborhood community? Explain why.	"I would recommend nanosunscreen but I would also have concerns. There also are concerns because for people with skin problems regular sunscreen would be better. Because sunscreens with nanoparticles are small enough to go through cracks or openings in your skin that can go into your bloodstream." (LG student)	5/6	"I would recommend nanosunscreen because some people might have skin like sensitive skin and they don't normally use nanosunscreen." (LTNG Student)
8. Sunscreen existed before nanotechnolog y so why do you think scientists care about changing the ingredients of sunscreen?	"Because people are getting worried about oh I'm getting too tan and maybe they need more protection and they don't need want skin cancer so scientists made better ingredients." (LG Student)	6/6	None
9. Do you think nanotechnology can help solve people's problems in other ways? Explain.	"Yes. Consumers like nanosunscreen because it is clear and it protects their skin more again if you do not have skin conditions. Yes. Scientists are using nanotechnology as tools in the medical industry to help patients with other medical conditions using little nanorobots they put the robot into the body and it travels through the bloodstream to the parts inside the body." (LTNG Student)	4/6	"I don't think there's any other problem to solve with nanotechnology except for the UV projecting technology that's in nanotechnology nanosunscreen. That's something we probably we can protect against is UV, UVA and UVB." (MG Student)
10. Do think there is a relationship between sunscreen manufacturers, nanotechnology, and people? Explain	"Yes, there is a connection because the manufactures since they need products to keep peoples skin to getting more tan and cancer they made nano and that relates to people to help them and keep them safe." (LG Student)	5/6	"No. I believe that manufacturers go out and ask the people what they want in sunscreen and what ingredients and they produce it. The nanotechnology is the object that is put into the product that the manufactures made and the people are the ones who tell the producers and manufactures what they would like around their neighborhood or where they live." (MG Student)

The Nanotechnology Post-Interview contained four preset questions pertaining to Perception of Science in Society. All six students responded positively to 1/4th of the questions. Five out of six of the students responded positively to 2/4 questions. The negative responses are students from the MG and LTNG categories. Four out of six students responded positively to the remaining question. Both negative responses are students from the MG category. Results of students' responses along with a positive and negative sample response (where applicable) are summarized in Table 8.

All six students responded positively to 1/4 of the questions. Five out of six students responded positively to half of the questions. Negative responses are representative of the MG and LTNG learning gains categories. Four out of six students responded positively to the remaining question. The negative responses are representative of the MG category. Two out of two LG students are represented in all four questions.

Four categories emerged. "Risks and Benefits" emerged from Question #7, "Improve Safety" from Question #8, "Solves Society's Needs" from Question #9, and "Solves Problems" from Question #10. LG (2/2) students are represented in 4/4 of the above categories. MG (2/2) students are represented in 2/4 categories. LTNG (2/2) students were represented in 1/4 categories. Table 9 summarizes students' responses to the Perception of Science in Society portion of the Nanotechnology Post-Interview.

A theme of Risks and Benefits and a theme of Solves Problems emerged from the categories of: "Risks and Benefits," "Improve Safety," "Society's Needs," and "Solves Society's Problems." The theme of Risks and Benefits emerged from the category of Risks and Benefits and the category of Improve Safety. The theme of Solves Problems emerged from the category of Solves Society's Problems and the category of Society's Needs.

Table 9. Perception of Science in Society: Categories that emerged across responses

Question	Sample Phrases	Categories	Number Positive	Gains Category
7. Would you recommend nanosunscreen or regular sunscreen to your neighborhood community? Explain why.	"Nanosunscreen because it protects better but some people shouldn't use it." (MG Student)	risks and benefits	5/6	2/2 LG 2/2 MG 1/2 LTNG
8. Sunscreen existed before nanotechnology so why do you think scientists care about changing the ingredients of sunscreen?	"…it might help protect more." (LTNG Student)	improve safety	6/6	2/2 LG 2/2 MG 2/2 LTNG
9. Do you think nanotechnology can help solve people's problems in other ways? Explain.	"…tools in medical industry to help patients." (LTNG Student)	society's needs	4/6	2/2 LG 1/2 MG 1/2 LTNG
10. Do you think there is a relationship between sunscreen manufacturers, nanotechnology, and people? Explain	"It helps people solve practical problems." (LG Student)	solves society's problems	4/6	2/2 LG 1/2 MG 1/2 LTNG

Two themes of "Risks and Benefits" and "Solves Problems" emerged from students' responses to Perception of Science in Society questions. The emerging theme of "Risks and Benefits" strongly suggests that students have an accurate perception that nanotechnology comes with risks and benefits to society. The emerging theme of "Solves Problems" strongly suggests that students have an accurate perception that nanotechnology is governed by society's needs and is used to help solve society's problems. Qualitative data strongly suggest that students' Perception of Science in Society demonstrates an awareness of the relationship between science and society, as evident in the themes.

Post-Interview Responses: Overarching Themes

Two overarching themes of "Nature of Science" and "Nature of Technology" emerged from themes of "Science Process," "Risks and Benefits," "Positive Process," and "Solves Problems." The overarching theme of Nature of Science emerged from the Science Conceptual Understanding theme "Science Process" and the Attitude Towards Science theme "Positive Process." The overarching theme of Nature of Technology emerged from the Science Conceptual Understanding theme "Risks and Benefits," the Attitude Towards Science theme "Risks and Benefits," and the Perception of Science in Society theme "Solves Problems."

Figure 1 summarizes the two overarching themes that emerged the Science Conceptual Understanding, Attitude Towards Science, and Perception of Science in Society portions of the Nanotechnology Post-Interview.

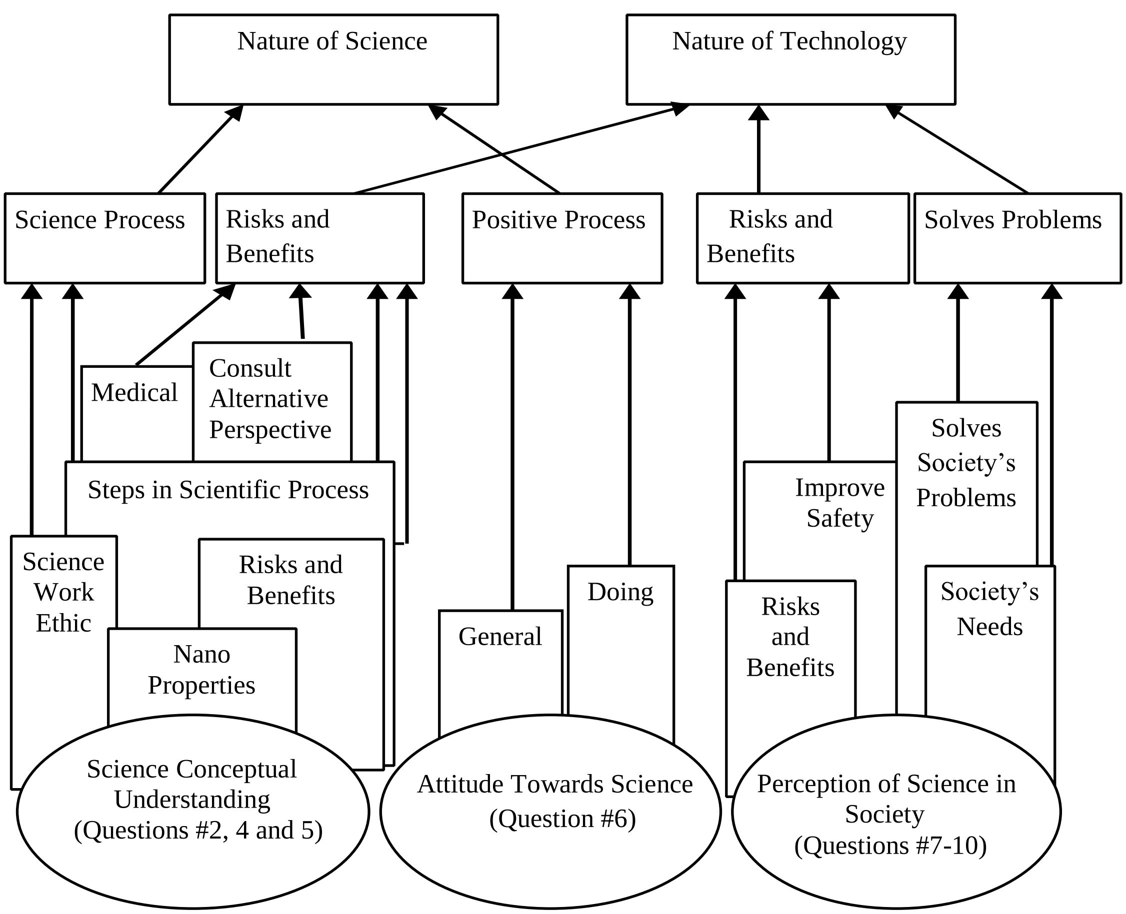

Figure 1. Nanotechnology post-interview: Overarching themes

DISCUSSION

A mixed method study of the effect of web-assisted instruction in PBL in nanotechnology on the Science Conceptual Understanding, Attitude Towards Science, and Perception of Science in Society among elementary students generated interesting findings. A note needs to be added that findings of the study must be interpreted realizing the limitations of the study. The web-assisted instruction which served as the intervention involved Problem Based Learning in sunscreen selection centered on nanotechnology concepts.

Science Conceptual Understanding. Results from pre- to post-test indicated that the intervention had a significant positive effect on participating students Science Conceptual Understanding. There were two quantitative questions in the Nanotechnology Post-Interview. Interview responses suggest that MG and LG students were more successful at responding to verbal quantitative questions than LTNG students. The Nanotechnology Post-Interview contained three qualitative questions, and the findings suggest that MG and LG students were more successful at responding positively to questions than were LTNG students.

Six categories emerged from students' responses: Nanoproperties, Risks and Benefits, Medical, Consult Alternative Perspective, Steps in Scientific Process, and Science Work Ethic. From these categories emerged two themes: Science Process and Risks and Benefits. The Risks and Benefits theme suggests students have an understanding that nanotechnology has risks and benefits to society. The Science Process theme suggests that students understand the science process they applied in the intervention. Theme results suggest that students demonstrated a strong Science Conceptual Understanding of nanotechnology and of the science process.

Attitude Towards Science. Results suggest that the intervention had a significant positive impact on students' Attitude Towards Science from Pretest to Posttest, post being larger than pre. Overall, raw score gains indicate a gain in Attitude Towards Science of most students. Upon analysis of Students' raw scores, LTNG students returned the most gains in Attitude Towards Science. MG students were split evenly with positive gains and with zero or negative gains. LG students returned the least gains with a zero or negative effect. Response analysis generated two test items with a Mean much higher than the Overall Mean and one test item a Mean much lower than the Overall Mean. The Nanotechnology Post-Interview contained one question pertaining to Attitude Towards Science. All LG, MG, and LTNG students responded correctly to the questions. These findings suggest that the intervention had a positive influence on the Attitude Towards Science across the learning gains categories (LTNG, MG, and LG) spectrum.

Two categories emerged from students' responses: General and Doing. From these categories emerged a theme: Science Process. The Science Process theme suggests that students have a positive Attitude Towards Science when "doing" science and towards the science process experience in general. Theme results suggest that students demonstrated a positive Attitude Towards Science.

Perception of Science in Society. All LG students responded positively to all four Nanotechnology Post-Interview questions, all MG students responded positively to half the questions, and all LTNG students responded positively to three-fourths of questions. These findings suggest that LG students have a stronger accurate Perception of Science in Society compared to MG and LTNG students. LTNG students had a stronger accurate Perception of Science in Society than MG students. Findings indicate that students with the largest Science Conceptual Understanding gains have the strongest accurate Perception of Science in Society.

Four categories emerged from students' responses: Risks and Benefits, Improve Safety, Solves Society's Problems, and Society' Needs.

From these categories emerged two themes: Risks and Benefits, and Solves Problems. The Risks and Benefits theme suggests that students have an accurate perception that nanotechnology comes with risks and benefits to society. The Solves Problems theme suggests that students have an accurate perception that nanotechnology is governed by society's needs and that nanotechnology is used to help solve society's problems.

CONCLUSIONS

Based on the findings of this study, several conclusions can be drawn, however, they must be interpreted realizing the limitations of the study. The use of *Catching the Rays*, a PBL web-assisted macro-context nanotechnology intervention grounded in sound learning theories, in multi-dimensional perspectives seems to have a positive impact on the Quality of Student Learning in Science defined by Science Conceptual Understanding, Attitude Towards Science, and Perception of Science in Society. This study supports previous studies that suggest learning in macro-context having a positive impact on students' Attitude Towards Science[33, 34] and Science Conceptual Understanding[1, 71, 72] and Perception of Science in Society[72]. An instructional design grounded in a multi-dimensional perspective is critical if the Quality of Student Learning in Science is to be improved[16, 73].

The results indicate that the learning of nanotechnology can be achieved in elementary aged students; an age where students develop the knowledge, attitudes, and perception of the role of science in society that govern their academic decision at the secondary and post-secondary levels. Gains in students' Attitude Towards Science, as a result of the intervention, were more prevalent among LTNG students than MG and LG students. The intervention had the least positive effect among LG students. Findings resulting from this study raise awareness that there are many facets of Attitude Towards Science of elementary students that need further investigation. The topic of *Catching the Rays*, nanotechnology in sunscreen, is relevant to the lives of elementary students, thereby providing opportunity for students to experience how nanotechnology relates to their own lives. Providing experiences that connect students with real-world nanotechnology applications can further shape their Perception of Science in Society. Furthermore, this study reinforces previous perspectives that nanotechnology can be fused into science curriculum at the elementary level[48, 49] developing young minds to be successful in the twenty-first century workforce in the future.

Nanotechnology can be fused into science curriculum at the elementary level. The nanomodule, *Catching the Rays*, is correlated to NSES (a) Strand A: Science as Inquiry, (b) Strand B: Physical Science, (c) Strand C: Life Science, (d) Strand E: Science and Technology, (e) Strand F: Science in Personal and Social Perspective, and (f) Strand G: History and Nature of Science[1, 12, 13].

Findings of this study suggest that the intervention is a plausible instructional method to address concerns on disconnect between school science and Science in Society. The findings from this study support the perspective[12, 38] and previous suggestions[18, 36, 37] to engage students in science education experiences that help them to understand science is a personal endeavor as well as social enterprise of collaboration aimed at improving the human condition.

Recommendations and Implications

Based on the findings of this study, the following recommendations are made. Further investigation into the results of the Science Conceptual Understanding response analysis would prove useful in identifying the intervention's effectiveness in promoting student achievement on higher order thinking science tasks.

Follow-up studies are needed to explore variances in gains in Attitude Towards Science of elementary students among the three learning gains categories (LTNG, MG, LG). These studies may identify any possible correlations between Science Conceptual Understanding and Attitude Towards Science that may prove useful in understanding and improving Attitude Towards Science of elementary students.

There is a need to replicate this study on various student populations (e.g., Exceptional Student Education, socio-economic groups). This may identify the intervention's versatility across various populations. Also, studies are needed to further investigate similar research on the effectiveness of PBL with web-assisted instructional tools among various grade levels, preferably among elementary students younger than those tested in this study.

In terms of teacher education, investigation into the effectiveness of the intervention when used by science teachers of varying years of teaching experience and varying degrees of PBL instructional experience are needed. Identifying the effectiveness of the intervention on the Science Conceptual Understanding, Attitude Towards Science, and Perception of Science in Society of elementary students when used by science teachers of varying years of teaching experience with and without PBL should help gain insights for curriculum changes in teacher education programs.

Based on the findings and conclusions of this study, the following implications are drawn. K-12 science instructional methods need to be reevaluated to ensure Quality of Student Learning in Science is being achieved. The traditional one-dimensional lens (Science Conceptual Understanding) to the teaching and learning of science continues to contribute to America's current deficiencies in student performance in science. As a result, teachers need to be educated on nontraditional instructional methods (e.g., PBL with web-assisted instruction) that reflect current cognitive theory (situated cognition). This can be achieved through collaboration between universities and elementary and secondary school systems. Post-secondary science education professors could lead professional development opportunities to share and discuss developments in instructional methods such as PBL with web-assisted instruction.

K-12 science teachers should be provided with professional development opportunities that keep them abreast of nanotechnology and nanoscience. We live in a world that is governed by science, technology, and mathematics. The development of science and technology is happening at rapid speeds and science teachers at all grade levels need to be kept informed and versed in its applications.

Administration needs to support the implementation of nanotechnology instruction in science classrooms. This can be achieved in several ways. First, it is imperative for administrators to support the collaboration between science teachers and science professors to provide K-12 science teachers with the support necessary to teach nanotechnology. Second, administrators need to support the implementation of action research to encourage science teachers to explore multi-dimensional lens instructional tools such as web-assisted instruction.

Nanotechnology and nanoscience need to be integrated into K-12 curriculum. Alignment of curriculum will ensure society's workforce demands can be met. This is imperative if America is to gain a competitive edge in the global market. Instructional modules such as *Catching the Rays* can be an immediate response to nanotechnology integration in K-12. Although any one instructional practice should not be deemed a one-size-fits-all approach to the teaching and learning of nanotechnology, web-assisted instruction has enhanced certain PBL situations making it one of the most practical instructional designs to equip students with nanotechnology knowledge and cognitive skills needed to address 21st century challenges. A lack of sufficient nanotechnology resources in the classroom highlights the importance of developing more web-assisted PBL tools such as the *Catching the Rays*.

Web-assisted instruction has global implications. Teachers across the globe can access *Catching the Rays* simultaneously, creating an opportunity for shared learning and teaching experiences. Students sharing learning experiences with other students outside their communities may contribute to the depth and breadth of students' Perception of Science in Society and an awareness of global issues (e.g., global warming).

The technology platform of tools such as the intervention may help reduce the unequal learning opportunities in the classroom due to socio-economic disparity. Web-assisted instruction tools such as *Catching the Rays* may have the potential to make available to students across the socio-economic spectrum the learning of nanoscience and nanotechnology in the classroom. *Catching the Rays* provides narrator navigation that breaks the learning cycle down into manageable steps so students of all abilities and experience levels have the support to successfully complete the nanoquest.

Policy makers need to make sure there are policies in place that support the teaching and learning of nanotechnology at the elementary and secondary levels. Nanotechnology and nanoscience experiences at this level are imperative because it is at these young ages that long-lasting attitudes towards science are formed, and these conceived attitudes govern the development of scientific literacy well into adulthood (NRC, 2012, 1996). Policies at the secondary level are equally important. Here, policies need to ensure students are provided with opportunities (e.g., courses in nano) that broaden and deepen their scope of nanotechnology and nanoscience applications.

Instructional practices need to provide K-12 students with experiences that establish linkages among personal perspective (e.g., awareness of health, making informed choices) and social perspective (e.g., populations, environments, resources)[12]. Web-assisted instruction may prove essential in this endeavor by providing students with PBL experiences that can inspire an awareness of and nurture a personal and social development of the relation of nanotechnology in society.

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ADDENDUM 1

GLOSSARY OF ACRONYMS

AAAS	American Association for the Advancement of Science
LG	Large Gains
LTNG	Little-to-no-Gains
MG	Moderate Gains
NAEP	National Assessment of Educational Progress
NRC	National Research Council
NSES	National Science Education Standards
NSET	Nanoscale Science, Engineering and Technology
PBL	Problem-Based Learning
SD	Standard Deviation
SFAA	Science for All Americans
STEM	Science, Technology, Engineering and Mathematics
UV	Ultra Violet
WWW	World Wide Web

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