Science in the Context of Society through QR Code in Problem Based Learning

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Abstract

Science education in the context of societal applications through QR code in problem-based learning (PBL) is addressed in this paper. An example from an elementary classroom where the students received mentoring by their high school peers to develop QR codes involving the Florida Everglades is presented. Through meaningful guidance it is possible to enhance elementary students knowledge of science in society and awaken their curiosity of science using QR code embedded problem-based learning.

Key Words: QR Code, Problem Based Learning, Science in Society, Mentor

1. Introduction

How to connect classroom science to societal applications in problem-based learning (PBL) through QR code is explored in this paper. We live in a world highly influenced and impacted by science and its technological applications. Science and its application in technology are an integral part of society. One of the goals of science education is preparing students to be critical thinkers and problem solvers who understand the role of science and technology in society [1].

Currently, the US focus has followed a standards-driven model for educating students. One of the main features of the standards model calls for the integration of technology for students (Grades K-12). Students must demonstrate the ability to conduct research, think critically, problem solve, engage in effective decision making, communicate, collaborate and participate in creative and innovative activities. Students must be able to use age-appropriate technologies to conduct real life research including the ability to locate, collect and organize information. They need to be prepared to solve problems by gathering, analyzing, collaborating and communicating and collaborating with their classmates about data collection and analysis [2].

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Students in the twenty-first century are savvy consumers of technology and the presence of mobile and online media is ubiquitous in the lives of children and young adults. The immense popularity of social networking among this age group is the ability to develop and maintain online relationships among participants. Children and young adults use mobile and online media to participate in social networking, download videos and music, send messages, and gather information from a wealth of online resources [3]. Their ability to multitask the myriad online media resources is reflected in their increased time spent mastering these complex skills [4, 5]. Students demand material that is relevant and connected to their lives (Vahlberg), and rely on (mobile app) technology to direct their academic and personal lives.

How to transform content rich science topics with societal implications into teachable lessons is a pedagogical challenge. One of the challenges is a lack of well-defined readily available tools to connect classroom science to real-world applications and situations. Though a few commercially developed software products are available in this venue, they often are not effective in terms of adoption by teachers to meet state standards, individual teaching styles of teachers and learning styles of learners. On the other hand, custom-made tools to enlarge the context of learning developed by teams of educators are available but with very limited circulation. Since early developments in video based anchors to connect classroom science to real world applications by the Cognition and Technology Group at Vanderbilt (CTGV) [6] (e.g., *Jasper Series*) there is a growing but limited production of research based technological tools available in this area. The *Rescue at the Boons Meadows* episode in the *Jasper Series* videos deals with mathematical problem solving built around the efforts to rescue an injured bald eagle from a remote location using an ultra-light aircraft [6]. Kumar and Sherwood [7] reported a simulation of water quality analysis using Isaac Walton's method by school students in problem based learning and the associated episode revolving around pollution in a local river ecosystem.

In the web-based software *Problem-based learning with nanotechnology* students engaged in problem based learning in nanotechnology with societal connections in three modules: *Catching the Rays*, *Going Green* and *Friend or Foe* [8]. The *Catching the Rays* module deals with consumer decision-making in sunscreen selection – between regular sunscreens and those containing nano particles. The *Going Green* deals with the use of nano materials in fuel cells and the related environmental impact. The *Friend or* Foe module engages students to explore

heath issues associated with nano particles. In a separate study the effects of the *Catching the Rays* module on the science conceptual understanding, the attitude towards science, and the perception of science in society of elementary students (N = 46) were explored [9]. Pre- and post-tests were administered followed by a post-interview of six students. Results of pre- post-test data analysis showed a significant gain ($t = -16.27$, $df = 45$, $p < 0.05$) for conceptual understanding (pre-test Mean = 0.42, SD = 0.13; post-test Mean = 0.78, SD = 0.12), and a significant gain ($t = -2.52$, $df = 45$, $p < 0.05$) for attitude towards science (Likert Scale, pre-test Mean = 4.13, SD = 0.68; post-test Mean = 4.29, SD = 0.60). Analysis of interview data suggested, "subjects have an accurate perception that nanotechnology comes with risks and benefits to society," and "have an accurate perception that nanotechnology is governed by society's needs and that nanotechnology is used to help solve society's problems." Thus it is possible to integrate classroom science and societal applications of science meaningfully with the support of technological tools in problem based learning environments. However, how to make this connection practically feasible still remains a challenge. One pedagogical approach to tackle this challenge is to design QR code linked PBL activities within the K-12 classroom.

2. QR Codes

Quick Response (QR) codes consist of a two-dimensional, square of black and white pixels that can hold 100 times more data than a traditional barcode. QR codes can be scanned by a smartphone, which then links to an Internet address allowing the user to gain more information about the product or service [10]. QR Codes were first used in Japan in supply chain applications to control automobile manufacturing and keep track of vehicle parts [11,12]. Since then, QR codes have gained popularity beyond the automotive industry and are now viewed as a significant technological benefit to society (see Fig 1).

Figure 1. Sample QR code developed with QRstuff.com

Recently, a team of researchers from the University of South Dakota School of Mines and Technology created a tiny version of the codes that could be used to identify counterfeit money. The invention uses a QR code made of nanoparticles combined with blue and green fluorescent ink that can be sprayed onto surfaces such as glass, plastic film, or pictures. The nano-code remains invisible until placed under a near-infrared laser, making it ideal for helping identify counterfeit currency [13].

QR code technology is also been applied to various products including the transport, food, hospitality and tourism industries. Museums are using QR codes to provide additional information about exhibitions, as well as a means for identifying authentication of its' artistic collections [12, 14].

2.1. QR codes for educational purposes

As QR code technology advances, inroads have been made in the field of education. Educational leaders face ever-increasing demands from stakeholders to ensure that students are prepared to enter the workforce and navigate in a technological era. Research results suggest that computer technology application within the classroom supports students' learning [15]. Educating students to become cognitively complex thinkers will enhance our economic competitiveness against other nations [16].

As computer designers have improved QR code technology applicability to SMART phones, educators are incorporating QR code technology into the school curriculum, as a learning tool, to enhance student knowledge. Instead of remaining constrained by traditional classroom instructional methods, educators and students are beginning to consider the powerful role that technology can play in creating an engaging learning environment. Students are encouraged to become active learners by meaningfully connecting classroom science to societal applications with appealing, hands-on activities. Research results indicate that consistent contact with technology, early in life, motivates students to learn more efficiently. In a study by Yusof et al. [15] students were asked to collect relevant information on plants and animals while creating QR codes**.** Students learned how to design QR code**s** to enhance their knowledge of various plants and animals. The study revealed that QR technology facilitated students**'** motivation and interests

in the learning process. QR technology appeared to successfully increase students' attention and awaken their curiosity on a number of science-related content. Often active learning is implemented through meaningful learning activities such as inquiry learning and problem-based learning.

QR codes can potentially add value to learning activities by encouraging students to create and share learning content [15] and engage students with different learning needs [17]. Crompton et al. [18], Robertson and Green [19], and Pérez-Sanagustín et al. [20] believe that QR codes to have a potential to facilitate active learning inside and outside the classroom.

2.2. Problem-Based Learning

Problem-based learning (PBL) involves problem solving in real world context with the aim of developing higher order thinking and problem solving skills in students [21]. In PBL students are challenged to apply specific disciplinary knowledge to solve a problem in an authentic context. The advantage of a PBL is that it provides highly structured learning experiences for students through a series of steps that move students toward developing a specific set of skills. During the planning process, PBL teachers develop a number of society-based problem solving assignments that are progressively more complex. Each assignment should build on skills mastered in previous assignments. Ultimately, the assignments will provide students with the knowledge and skills to solve an authentic, real-world problem. In PBL students are motivated to think like scientists in developing creative solutions to societal problems involving science and technology [8, 22]. When students are engaged in "doing science" in authentic tasks related to society they gain skills and knowledge that are not only transferable to future situations by equipping themselves with the academic and career tools to succeed, but also enable them to see the interaction between science, technology and society. For details on the theoretical foundations of the use of multimedia anchors to enlarge the context of problem based learning in science by integrating societal/real-world applications see CGTV [6], Kumar and Sherwood [7], and Kumar [23].

2.3. PBL, QR code technology and the instructional environment

PBL can be applied to real world challenges making possible the reality of cultivating inquiry skills in the classroom; this can be achieved through QR code technology instruction. QR code

technology appeals to authentic problems in the context of real-world science content and science culture. Students are cognitively engaged in exploring meaningful problems, which require them to activate their prior knowledge to generate useful solutions to real world challenges.

One of the major drawbacks of the PBL instructional strategy is the practicality of providing authentic problem solving contexts that cultivate cognitive skills along with conceptual understanding. Combining PBL with QR code 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.
QR codes have gradually made their way into the classroom. QR code readers permit students to digitally scan images that connect to relevant websites thus establishing engagement in student learning. Students are also able to make their own QR codes using free QR code maker (QR stuff.com) websites [5]. Once students select a research topic, they conduct an internet search to identify appropriate websites, which address and answer their research questions. The students copy the websites URL, paste it into the websites (QR stuff.com) field and a QR code is automatically generated. See Figure 1 for a sample QR code generated using QRstuff.com for a rearch topic: *How LCD projectors work?*

There are significant benefits to using QR codes in the classroom, particularly for students who find academic reading material too overwhelming and cognitively complex, both in terms of vocabulary and content. Teachers are able to differentiate learning by selecting websites geared to students' reading proficiencies (Newsela) or by selecting the most appropriate literacy strategies to enhance and support student learning [5].

2.4. Creating the pedagogical foundation for the QR code project

A QR code generation project was conducted among elementary and high school students in Ohio [5]. The elementary students participated in PBL activities where they engaged in hands-on, learning activities and strategies to facilitate student learning, and the secondary students served as mentors. Prior to meeting with the elementary students the mentors gathered together with a group of teachers to discuss and select elementary learning strategies. The mentors were

eager for the elementary students to participate in problem-based learning activities where they would consider sciences' role in impacting favorable change in society. As a case in point, recently, there had been considerable discussion in the news and other media outlets about the role of invasive plant species in the Everglades National Park and the mentors believed that the elementary students would benefit from learning about some of those invasive plants that have been plaguing native plants in Florida's Everglades National Park. The mentors selected YouTube video clips from the Discovery Channels television series: *Dirty Jobs with Mike Rowe* [24]. The video clips highlight a visit by Mike Rowe to the Loxahatchee wetlands. A team of investigators works within the refuge to remove Melaleuca plants and old world climbing ferns known as Lygodium, which smother other plants native to Florida. The high school mentors believed that it was important for elementary students to recognize the important societal role that science can play in protecting the fragile natural resources found in the Everglades.

The teachers encouraged the mentors to consider the role that state academic standards play in the selection of activities and assignments in K-12 classrooms before designing and creating science activities for the elementary students. The mentors decided that they would like the elementary students to conduct research projects in science that addressed the challenges of exotic, invasive plant species in the Everglades, so they googled science standards for Ohio and found an age-appropriate science strategy that they could align with their project. They selected Ohio State Standard (Ohio Learning Standards: Science: Grade 3: Life Science (LS) Behavior, Growth and Change: Explores life cycles of organisms and the relationship between the natural environment and an organism's (physical and behavioral) traits, which affect its ability to survive and reproduce. According to 3.LS.3: Plants and animals have life cycles that are part of their adaptations for survival in their natural environment. Worldwide, organisms are growing, reproducing, dying and decaying. The details of the life cycle are different for different organisms, which affects their ability to survive and reproduce in their natural environment (http://education.ohio.gov/getattachment/Topics/Learning-in-Ohio/Science/Ohios-Learning-Standards-and-MC/SciFinalStandards121018.pdf.aspx?lang=en-US). The mentors believed that these standards most closely fit with elementary PBL lesson and would allow them to tie in the use of QR codes to enhance the students developing understanding of invasive plant species impacting the Everglades National Park.

In addition to the Ohio standards, the teachers provided the mentors with an overview of the available reading and writing strategies [25], the mentors selected several strategies to engage learners' prediction skills: brainstorming and clustering of ideas, and think aloud and KWL strategies to help students refine their developing ideas, actively explore meaning as they read and organize their new knowledge. During brainstorming strategies mentors suggest a significant word from the text to be read, and the students are encouraged to quickly call out their association with that word. No one is allowed to criticize or challenge a suggestion and each contribution is highly valued. The mentor notes each contribution on the board. Brainstorming strategies help students realize what they already know about a topic, as well as address any misconceptions about a topic or idea. Clustering is used to help learners generate bigger, more developed ideas derived from brainstorming activities by linking ideas together. Clustering helps students discover what they already know about a topic that they will be studying and helps to reduce the anxiety learners feel as they attempt to comprehend new information.

To help students organize their ideas, the mentors chose think aloud strategies as they read websites. To be successful, the mentors needed to model the think aloud strategy by selecting a website passage, reading the passage aloud, and stopping repeatedly to make notes about what is being read, and ideas or questions generated from reading the passage. Mentors were taught how to describe their mental processing of the ideas being portrayed to the elementary students and how to record their ideas on paper for future reflection. Finally, the mentors chose the KWL strategy. This strategy would help the mentors recognize the elementary students' prior knowledge about the topic while helping them make connections between new information and the knowledge they already possess. In KWL students list what they already know (**K**) about a topic, next they are asked what (**W**) they would like to learn about a topic and set purposes for reading and finally, after completing the reading, students are asked what they have learned (**L**) about a topic and whether they have achieved the goals they set or reading. Students also realize the misconceptions generated during brainstorming, which the careful reading of a passage clears up [25]. The mentors also learned how to use the software program (QR stuff.com) to generate their own codes from website URLs. Once they had completed several QR codes and

understood how to implement the learning strategies, they were prepared to meet the elementary students.

3. Learning Strategies in the Project

The mentors greeted the elementary students by introducing themselves and describing the project, which they were going to take part in for the day. The mentors showed elementary students a map of the United States and asked if a student could locate the state of Florida. Once the state was identified, the mentors asked the students to brainstorm any physical features of the state. Students volunteered a number of comments: *Florida has a lot of beaches and is near the ocean*. *There are a lot of fish in the ocean*. After additional conversation, the students' attention was redirected to the Everglades and students again were asked to volunteer what they knew about the Everglades including the animals found in the Everglades. Students responded with comments such as plenty of *alligators*. One student mentioned that the landscape looked *brown when flying over it, but it was green with a lot of water, swamps and plants when you were in the Everglades*. All of the student comments were recorded on the white board in the front of the classroom. The mentors then began to ask the students if they were familiar with certain scientific vocabulary terms including*: species, native and non-native (plants), invasive (plants and animals)*, *habitat*. Some of the students recognized the terms, but the majority appeared confused by the terms. The mentors show the YouTube video clips from a television program, *Dirty Jobs with Mike Rowe* [26]. After viewing the video clips, the students added some additional terms to the list on the white board*: conservation efforts, melaleuca trees, airboats, firefighters.*

Once of the mentors believed that they had assembled a sufficient number of vocabulary terms, they began to cluster some of the terms together. Students began to make connections among the terms. Some of the connections included: *Firefighters' jobs: burning melaleuca trees, riding in airboats, protecting native plants.* The mentors created a graphic organizer based on the students' contributions during the clustering strategy (see Fig. 2).

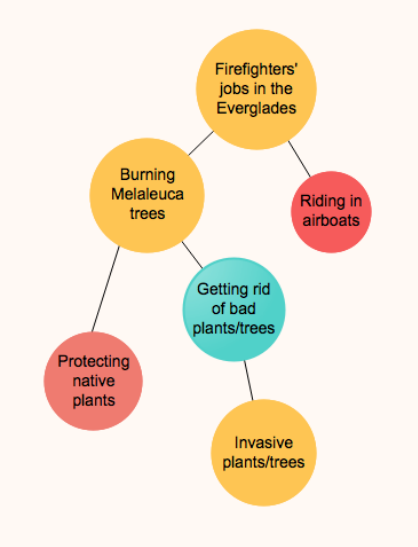

Figure 2. Example of clustering strategy

Next, the mentors told the elementary students that they would spend the rest of the time building on the idea of *getting rid of bad (invasive) plants and trees (in the Everglades)*. The mentors created a KWL chart entitled, *Invasive plants in the Everglades.* Elementary students were asked to volunteer information on what they already *(K) knew* about invasive plants in the Everglades, what they *(W) wanted to know* more about and the mentors promised them that they would be able to fill the column: what they *(L) learned* about invasive plants in the Everglades once they finished the project (see Table 1). Students were told that scientists approached many of their research questions following a very similar format. They were also reminded that many scientists were asking similar questions about invasive plants and trees in the Everglades. Everyone's goal is to make sure that people will be able to enjoy the beauty and wonder of Everglades National Park for many years, but first the big problem of invasive plants and trees must be solved.

Table 1. Invasive plants in the Everglades

What I already know about invasive plants in the Everglades.	What I want to know about invasive plants in the Everglades.	What I have already learned about about invasive plants in the Everglades.

We know that: • Firefighters burn invasive plants and trees to protect the good ones. • Melaleuca trees are invasive trees • Firefighters ride in airboats to burn the trees	We want to know: • What other trees or plants are invasive in the Everglades? • What do these invasive plants and trees look like? • Are good trees damaged when the firefighters burn the invasive plants and trees? • Is firefighting a dangerous job (in the Everglades?)	What have we learned?

3.1. Creating the Project-Based Lesson

The elementary students were divided into smaller groups of 3-4 students per group and one mentor led each group. Each group then selected one of the questions to research from the KWL section: *What I want to know about invasive plants in the Everglades?* They were told that they would bring back their new information to the entire group at the end of the activity. After some negotiation, each group selected a question from the KWL chart and began the next stage of the activity, the online search for appropriate websites.

Each student was equipped with his/her own laptop and was comfortable using the devices to search websites for information. The first group selected the question: *What other trees or plants are invasive in the Everglades?* and found a number of resources related to this question. In fact,

they were overwhelmed by the sheer volume of information available on the web related to the topic. Students found information on the following sites.

Invasive Plant Program
https://www.nps.gov/ever/learn/nature/invasiveplantprogram.htm Exotic Vegetation Management Program https://www.nps.gov/ever/learn/nature/exoticvegprogram.htm Brazilian Pepper
https://www.nps.gov/ever/learn/nature/loader.cfm?csModule=security/getfile&PageID=966760
Melaleuca Trees
https://www.nps.gov/ever/learn/nature/loader.cfm?csModule=security/getfile&PageID=966759
OldWorldClimbingFern
https://www.nps.gov/ever/learn/nature/loader.cfm?csModule=security/getfile&PageID=966758
Map distribution of the most common exotic plants in Everglades National Park https://www.nps.gov/ever/learn/nature/upload/DASM2013_map.pdf

Elementary students from the other groups gathered around the first group and were excited to compare the different types of invasive species found in the Everglades. They compared each of the unique features of the plants and were particularly interested in the unique attributes of the Melaleuca trees, as they had learned about them during the YouTube video clips. Students were also interested to see the location of the invasive plants in the Everglades and compared that map found on the website to the actual map of Florida.

The students in the other groups urged their mentors to revise the KWL chart so that each group could investigate the different types of invasive plants and trees, rather than searching for their original topics. Students were also relieved that the other groups were willing to take on some of their research responsibilities and gladly shared their research with the other groups. Thus the KWL chart was revisited and the new research questions were added (see Table 2).

Table 2. Invasive plants in the Everglades

What I already know	What I want to know about	What I have already learned about

about invasive plants in the Everglades.	invasive plants in the Everglades.	about invasive plants in the Everglades.
We know that: • Firefighters burn invasive plants and trees to protect the good ones. • Melaleuca trees are invasive trees • Firefighters ride in airboats to burn the trees	We want to know: • Where are the invasive plants and trees located in the Everglades National Park? • What other trees or plants are invasive in the Everglades? • Melaleuca trees • Brazilian Pepper • Old World Climbing Fern	What have we learned?

Elementary students began to read the information found in each of the websites, but seemed overwhelmed by the complexity of the text as well as the unfamiliar scientific vocabulary, but they were still eager to learn as much as they could about their question. Mentors recalled the steps involved in the think aloud strategies and decided to use this strategy with their groups to help them comprehend the websites. Mentors began to read the group's selected website as the students followed along with their own copy. The mentors stopped along the way to review new science-content vocabulary. Each time a new vocabulary word was identified and defined, the word would be added to the elementary students' vocabulary learning logs and would later be added to the classroom Word Wall which appeared on large sheet of paper with space to add new words based on students reading. The mentors also demonstrated how they questioned the text to gain greater understanding or wrote notes to remind themselves to reread the section or passage or ask the teacher if they were still confused. Elementary students volunteered to read a section of the website and imitated the mentors' reading habits of making predictions about the

paragraph to be read, questioning the texts and identifying any potential questions that still remained unanswered.

As the elementary students read, the mentors observed how many of the students went back and forth between the website and the Google Search Engine as they entered new vocabulary terms, often becoming frustrated as they attempted to re-enter the long URLs in the search engine field. The mentors decided that the students were sufficiently prepared to learn the next step in the PBL project, the generation of the QR codes.

3.2. QR Code generation in an elementary classroom

The elementary students were asked to save the research which they had collected up to that point and were directed to the large screen in the front of the room where one of the mentors uploaded the QR code maker (QR stuff.com) website. The mentors asked the students if they had ever heard of or seen a QR code. Several students had seen the codes, but were not sure how they worked. The mentor asked one of the students to volunteer a question. The students scanned the room and quickly one of the students shouted, *how does a fire extinguisher work*? The mentor loaded the question into the Google field. Immediately, the students were directed to a new website https://www.explainthatstuff.com/fireextinguisher.html where they read about the dangers of fire, the fire triangle and the different types of fire extinguishers and how fire extinguishers work. The mentor explained that one could continue to type in the long, often complex code found in many URLS or create a QR code which would immediately take the user to the website simply by scanning a square-shape bar code. Each student received an iPad which was already programmed with a QR code scanner app (TapMedia Ltd.) and they received a brief overview how to scan a QR code with the device.

The mentor copied the URL: https://www.explainthatstuff.com/fireextinguisher.html and placed it inside the QR stuff.com field and suddenly a QR code was generated. The mentor downloaded the QR code making it appear larger on the Smartboard at the front of the classroom (see Figure 1). The students came towards the Smartboard with their QR scanners, scanned the QR code and were excited to see how quickly they were linked to the website.

Immediately, they wanted to upload their websites into the QR code generator (QRstuff.com). Patiently, each group waited to have their URL uploaded to the QR code generator. After the

each QR code was generated, each group received a hard copy of their QR code. Students began to move around the room sharing their QR codes while pointing out how the website which they had been working on suddenly appeared so quickly after having scanned the QR code. Students appeared to take notice of the unique aspects of the website including the images of the invasive plants and their unique physical characteristics. Students marveled at the beauty of the Brazilian Pepper tree with its colorful red berries, yet they compared the unique beauty of the tree with the damage that it had caused the Everglades ecosystem.

Elementary students began to make some suggestions on how to improve the information contained in the websites. Since they had spent so much time trying to figure out some of the scientific-content vocabulary within the website, they suggested that some of the terms could be hyperlinked to a glossary, so that students would be able to understand the terms and phrases: *wetlands, ecology, impenetrable thickets* without having to waste time trying to define the terms through the Google search engine or a class dictionary. They did add some of the new vocabulary to their classroom Word Wall, so that they would remember the vocabulary in the future. They also listed some of the questions that they wanted to continue to pursue, but had not been covered within the website: *Do the chemicals poison the wildlife in the Everglades? Could the poisons make humans sick? What are some things that we can do to help to the Everglades?*

To complete the lesson, as well as the KWL chart, the mentors asked the students to quickly summarize what they had learned about their group's invasive plant or tree. The students selected one member of their group to write the summary as the members made suggestions about what to include in the summary. The mentors added the summaries to the KWL chart and the students also urged the mentors to include the QR codes in the KWL chart as important evidence in their research project (Table 3).

Table 3. Invasive plants and trees in the Everglades

What I already know about	What I want to know about invasive plants in the	What I have already learned about about invasive plants in the

invasive plants in the Everglades.	Everglades.		Everglades.
We know that: • Firefighters burn invasive plants and trees to protect the good ones. • Melaleuca trees are invasive trees • Firefighters ride in airboats to burn the trees	We want to know: Where are the invasive plants and trees located in the Everglades National Park?		What have we learned? The Everglades is one of the biggest parks in the USA and is at the bottom of Florida. It is the home of many special plants and animals. They have problems with invasive plants that are killing the good plants. Something must be done to protect the park!
	What other trees or plants are invasive in the Everglades?		
	Melaleuca trees		Melaluca [sp] tree has been in Florida for a long time. Pioneers used the tree to drain the swamps and build. The tree harms native plants in the Everglades. Scientists are using insects to eat the leaves of the Mel [sp] tree.
	Brazilian Pepper		This tree looks very pretty and has white flowers and red berries. The tree is bad because it harms farms and forests in Florida. Sometimes the leaves can make our skin itchy. Scientists are still trying to figure out how to get rid of this tree.

			Some use chemicals, but they are dangerous.
	Old World Climbing Fern		People used this to make pretty gardens, but they are out of control and kill native trees. Sometimes fires climb up the vines and burn a bunch of trees. Scientists are using chemicals to kill these plants.

As the project was wrapping up for the day, the elementary students could be overheard commenting on how they enjoyed the project. Several students claimed that they felt like inventors when they located the websites and URLS, which then allowed them to generate QR codes. According to one student: "*It is a like magic… suddenly you go from having weird, code which you dump in in a field and voila…you get this cool, little box that can be scanned. You are whisked off to a website…it is amazing*!" Once students had returned to their assigned seats, the mentors asked them to quickly complete an Exit Slip describing s new fact or idea which they had learned, a suggestion that they would like to make or a question which they still had about the project. Comments ranged from concerns that students had about the delicate ecosystem in the Everglades as well as possible negative effects of invasive plants and animals in their neighborhoods. Many of the students lived on farms and were familiar with family conversations about the health and well being of the crops. Students recognized that invasive plants might seriously damage their own harvests.

Other students made several suggestions about the project as well as ideas for further QR code implementation in the school. One student mentioned that his grandfather wanted to bring him his lunch, but got confused trying to find the main office. *If he saw a QR Code he could just scan it, and a map of the school could pop up and he could find his way!* Others suggested placing QR codes throughout the school building to let visitors know where they might locate the nurse's office, the cafeteria and they gym. Students also came up with creative ideas for using QR codes including creating a school scavenger hunt where other classmates would have to

identify information embedded in QR codes. Once the participants solved all the messages, they would win a prize. Students also commented that they were excited to show their friends and families how to scan the QR codes to additional information in advertisements.

4. Discussion

The QR code PBL science activity in the context of societal applications reveals that QR codes specifically were used as a powerful learning tool to enhance student knowledge of scientific challenges. Comments from the third-graders suggested that they were excited to be part of PBL communities that engaged in hands-on, activities where they collected relevant information on plants and then designed QR codes to enhance their knowledge and awaken their curiosity on invasive plants in the Everglades. Several of the students suggested placing QR codes to around the school building to guide parents and new students to important locations including the nurse's office, lunchroom and the gymnasium.

The important role that effective pedagogical strategy implementation in PBL learning cannot go unmentioned. The mentors carefully applied strategies such as KWL and other prediction strategies to initiate learning while constantly encouraging elementary students to share ideas and developing insights through Think Aloud strategies. Students were asked to elicit their developing background knowledge, question, and refine their understanding to enhance their learning. These reading and writing strategies embrace an active learning environment with a societal connection that is at the core of PBL instruction.

In PBL students are motivated to think like scientists in developing creative solutions to societal problems involving science and technology (Kumar, 2015; Purichia, 2015). Students are engaged in "doing science" gain skills and knowledge that are not only transferable to future situations by equipping themselves with the academic and career tools to succeed but also enable them to see the interaction between science, technology and society.

Connecting science, technology, and society is a key element in preparing students for the future although any one instructional practice should not be deemed a one-size-fits-all approach to teaching and learning. "Ongoing developments in the field of neuroscience show an emerging connection between the critical role of context and learning. Enriched contexts are essential to engaging students in problem-based learning in STEM. Multimedia platforms are quite suitable

for developing enriched contexts to enhance problem-based learning in STEM education" [27, p. 6]. QR code technology instruction helps to enhance PBL, making it one of the most practical instructional designs to equip students with knowledge and cognitive skills needed to address 21st century challenges.

5. Recommendations and Implications

Problem based learning in science in the context of societal application through QR code should be implemented in schools and with different age group and student populations including students with learning challenges or children, for whom English is not their native language. Meaningful technology applications and instruction should engage ALL students in a variety of subject areas. Although, both elementary students and mentors felt a great sense of accomplishment and enjoyment in PBL facilitated through QR code, it is difficult to determine if this activity contributed to greater technology integration within the classroom or school. The activity was part of a brief visit by a group of motivated and enthusiastic high school students – mentors, who were eager to share their knowledge with younger, elementary students. Teachers should be encouraged to provide students with active, technology-enhanced learning environments such as QR code. It is essential that teachers be invited to meaningful and consistent in-service training where they are exposed to academically enriching QR code technology which they will be able to adapt to the unique needs of their students. Students need to have a good basis for strategies to help them build the knowledge for meaningful integration of QR codes in society-based problem solving activities in science.

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