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REFORMING SCIENCE EDUCATION TO A PLACE-BASED FOCUS: CULTURAL CONGRUENCE AND 21ST CENTURY SKILL DEVELOPMENT

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Reforming Science Education to a Place-based Focus: Cultural Congruence and 21st Century Skill Development

Synopsis:

Within a university, faculty created a space where research and learning are cohesive within a course that reinforces science content with applied experiences and context connections that promote skills graduates need for success as students and responsible citizens. The current study explores the implementation of a cultural and regionally congruent curricula in a general science course and its impacts on students' school connectedness, retention, and 21st Century Skill development.

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Abstract

Within a university in the Caribbean, faculty created a space where research and learning are cohesive within a course that reinforces science content with applied experiences and context connections that promote 21st Century skills graduates need for success in academics and their future career. By intertwining the science of Caribbean natural hazards and systems and the socio-political differences that influence community resilience, the Science 100 course allows deep processing and learning of content. The current study explores the implementation of a place-based, cultural and regionally congruent curricula in a general science course and its impacts on students' school connectedness, and 21st Century Skill development.

Keywords: place-based curriculum, 21st Century Skills, Caribbean, natural hazards

Reforming science education to a place-based focus: Cultural congruence and 21st Century Skill development

Leading proponents in education reform support students and citizens' need for a strong science foundation and for science literacy. It is recognized that to be successful, active participants in life and work in a world that is increasingly dominated by science and technology, all students need to know, understand, and use certain scientific knowledge (Bybee, 2009; Roth & Barton, 2004). If science literacy corresponds to citizens who can make personal, economic, and political decisions about science-related issues, then the lack of science literacy in the U.S. may indicate a decreasing "supply of scientists and engineers, skilled workers, and technological innovation, as well as to [declining] economic growth in general," which are characteristics that currently plague the U.S. (Bybee, 2009). These issues are particularly prevalent in rural and/or geographically isolated regions like the United States Virgin Islands (USVI). These realities led to general education reform at the University of the Virgin Islands (UVI) to better equip students for academic and civil success.

In the midst of an economic crisis exacerbated by a hurricane-damaged economy, the absence of federal assistance, and lack of entrepreneurial initiatives; University administrators recognized the need for targeted education to restore a sense of control over circumstances and stressors within the community. The faculty responded to the call "for a new curriculum that would prepare graduates with the requisite competencies for productive and fulfilling lives and responsible citizenship" by completely redesigning the general education curriculum, including the introductory science course, Science 100, The Natural World: The Caribbean (Paul & Watlington, 1997). In the development of this new curriculum, faculty had to work within the following two significant restraints while serving the community's and students' needs: the curriculum could not increase the time or credits required for a degree nor could it increase net costs to the University (Paul & Watlington, 1997). Therefore, faculty focused on striving for balance between rigor and relatability within the individual courses. In this context, the creation of Science 100 was aligned to the following clusters of knowledge and skills desired of all UVI graduates:

- knowledge of the physical, geographic and demographic characteristics of the US Virgin Islands, the rest of the Caribbean, the United States and the world;
- knowledge of natural phenomena, the earth, the solar system, and the universe;
- a high level of development of speaking, listening, reading and writing skills;
- computing and quantitative skills;
- self-awareness, critical thinking and moral reasoning;
- interpersonal leadership and team transactional skills;
- information management and research skills" (Paul & Watlington, 1997).

Additionally, within this course, faculty created a space where faculty research and learning are aligned by building a course that reinforces the science content with applied experiences, contextual relevance, development of skills needed to secure employment, and reticent knowledge to be responsible citizens.

Curriculum alignment with context

Through integrated lectures and inquiry-based laboratories, Science 100 creates applied science experiences for students within the unique ecosystems and environmental issues of the Caribbean. Course content focuses on the multiple natural hazards that threaten the Caribbean islands: hurricanes, volcanic eruptions, earthquakes, and tsunami waves. For example, interactive labs allow students to track hurricanes and chart the epicenters of earthquakes, and concurrent lectures place this information within broader cultural context. Students also explore local terrestrial and marine ecosystems (field trips to mangroves, beaches, and intertidal zones/nearshore coral reefs) while learning about the increasing human pressures on these local resources (lectures on marine debris, climate change, and sea level rise).

Broadly, place-based education empowers students to connect aspects of their schooling to their surroundings - to the specific Caribbean ecosystems and also to its culture. Indeed, while place-based learning is frequently conducted as environmental education (Woodhouse & Knapp, 2000), this pedagogical approach is truly multidisciplinary and incorporates history, language, and society. Place-based education has achieved success in rural areas, which can be attributed to geographic isolation and subsequent limited resources (Jennings, Swidler & Koliba, 2005). Similar constraints and resource limitations are found in Caribbean islands, which suggests that place-based learning can be a successful technique in the Caribbean. Moreover, the history of colonialism in the Caribbean means that many islands will not reflect the stories told in textbooks originating from the continents. Here, place-based education may also be described as culturally relevant pedagogy (Ladson-Billings, 1995), which is founded on three pillars: student learning, cultural competence, and (perhaps most importantly) the "critical consciousness" whereby students make sense of social and political realities that influence the science of their daily lives.

To foster this critical consciousness among introductory science students, the discussions of natural hazards examine the sociopolitical realities which influence disaster response and recovery. Some islands have stronger political and physical infrastructure to aid in recovery, and the course analyzes recent events familiar to students. For example, the 2010 earthquake in Haiti was devastating in large part because of the country's impoverished infrastructure, whereas the 2011 earthquake and tsunami in Japan were likely better managed because of greater resources and cultural attention to disaster preparedness (Weisenfeld, 2011). Geographic isolation can be a threat to human recovery from natural disasters; residents of the islands cannot drive to unaffected areas and environmental justice may be more extreme, as many people lack the resources to leave. By discussing these and other human factors involved in natural hazard response, students gain a better understanding of the tools that may help (or hinder) long-term community resiliency. Now, following the impacts of two unprecedented Category 5 hurricanes in September 2017, it is critical to incorporate the lived experiences of students and community members whose lives have been altered by these disasters (Redden, 2017), and who are actively gaining first-hand knowledge of the definition of "resiliency."

Ultimately, by intertwining the science of these natural hazards and systems, with the socio-political differences that influence a community's resilience, the course allows deep processing and learning of content due to direct application to students' lives. For islands such as the USVI which already face serious economic hardships, these ecosystem changes and challenges present critical environmental justice issues for all citizens. The course therefore aims to develop a consciousness of science's applicability in daily Caribbean life.

Creating Culturally Congruent Learning Experiences to Promote Psychosocial development & 21st Century Skills

Universities and colleges have been charged with developing students academically and socially. To promote student success, institutions of higher learning must deliberately create opportunities for students to understand connections between course content and their cultural and environmental realities. A place-based approach within the Caribbean context required professors to infuse culturally relevant pedagogical approaches into dense scientific content to build bridges for learning and application in STEM (Chang, Sharkness, Hurtado & Newnan, 2014; Ladson-Billings, 1995). With a primarily Afro-Caribbean student population, UVI is also striving to combat differentials in minority student success in STEM, retention, and graduation rates.

Retention of students in any degree program presents a challenge to this preparation and many institutions have initiated First Year Experiences (FYEs) to facilitate successful student transition into college life. FYE programs vary across different institutions and range from one semester freshmen orientation or seminar classes to highly structured programs with living and learning housing communities (Jamelske, 2009). As an open enrollment institution, and the only institution of higher education in the territory, serving a population of people who have been traditionally underrepresented in STEM fields, the development of a culturally congruent FYE program to improve the recruitment and retention of students of color in STEM fields was particularly important to this community.

A Freshman Development Seminar (FDS) was created to address these needs, but the developers of the general science course saw an additional need for a place-based curriculum that incorporated student experiences across the campus and within broader community environments to facilitate school connectedness, leading to the creation of Campus Wide Experiences (CWEs). Recent studies have suggested that school connectedness has a large impact on student retention rates and academic performance due to the belief that the school is an academic environment where educators care about student learning and their individual well-being (Blum, 2005; Schapps, 2003). Blum (2005) posits that strong school connectedness is facilitated with 1) high academic expectations, 2) positive relationships with adults (educators/staff) and students, and 3) physical and emotional safety.

With the goals of retention, graduation, and matriculation into the workforce; courses also need to address aspects of student psychosocial development. Development of 21st century skills help students be successful within both academic and career spaces. These 21st century skills include Critical thinking and Problem Solving, Communication, Collaboration, and Creativity and Innovation (Partnership for 21st Century Learning, 2007; Alismail & McGuire, 2015). Critical Thinking and Problem Solving includes students' capacity to reason effectively, to use system thinking, to make judgements and decisions, and to solve problems in conventional and innovative ways. Communication and Collaboration require that students learn to communicate effective (listen and contribute) and to collaborate (flexibility, helpfulness, and tolerance of differences). Lastly, Creativity and Innovations requires students to generate and evaluate ideas, work creatively with others, and implement innovations.

In order to encourage students to use these 21st century skills, they are integrated into Science 100 classroom activities and assessments challenging students to employ course content to extend their current understanding, to apply to local problems, and to innovate solutions addressing real world issues. Additionally, students are afforded an opportunity to practice the 21st century skills through their participation in the extra credit Campus Wide Experiences (CWEs). Thus, positioning these extracurricular activities at an intersection of school connectedness and 21st century skill development. Students employ critical thinking and problem solving by discussing the following questions in their CWE reflections: What did you learn from the experience? How was it relevant to the course? Did it improve your understanding of a course topic? Did it improve your understanding of other courses that you are taking? Would you recommend it to others? How did it impact you as a person living in the USVI?

Students exercise communication and collaboration skills not only through writing their reflection papers, but also through participation in CWEs such as the bat cave hike where students work together to ensure that everyone make the climb up rocks to the top of the mountain over the cave or the small group discussions where they act as a member of a citizen safety and migration advocacy group in an assigned role of citizen, business owner, government agent, or scientist to debate the previous solutions based on their role in the group. Lastly students show creativity and innovation by participating in CWEs such as the campus HackFest where students develop original prototype phone apps based on specific themes like the 2016 Health and Wellness theme. Each CWE incorporates opportunities for the development of multiple 21st century skills as well as a deeper connection to the school environment to assist in the transition of first year students to higher education.

Assessment and Evaluation/Research

With the advent of data driven educational practices, colleges are now being asked to provide proof of learning, evidence of student psychosocial development, and career readiness. In the plans for developing the Science 100 course, faculty members understood the need for documenting process and outcomes in learning and development. To assess gains from these enriched courses, faculty use quantitative and qualitative sources of data interwoven into course activities.

Quantitative Data

The Science 100 course includes various assignments and formative assessments that provide evidence of content and applied knowledge. Additionally, the university has maintained retention data on students after completion of the Science 100 course and students are also provided an opportunity to complete an assessment modified by the researchers to measure the types of Campus Wide Experiences (CWEs) students engaged in and whether students perceived gains from participation (Storey, 2010). Participation in the researcher assessment is voluntary for extra-credit in the course. This online survey is accessed through a link within the Blackboard platform and includes 9 items focused on learning (i.e. "I understand new ways of interpreting and analyzing information), science literacy (i.e. "I have an increased understanding of global scientific issues), and institutional connection (i.e. "I have stronger connections with the surrounding UVI community"). Each question uses a 5-point likert with 1=strongly disagree to 5=strongly agree.

A summary score is calculated for each of the sub-categories for learning, science literacy, and institutional connection (see Table 1).

Table 1.
Survey items included for science literacy, place-based/contextualized learning, and learning.

Variables	**Survey questions**
Science Literacy	General academic knowledge Making judgments about the value of information, arguments, or methods such as examining how others gathered and interpreted data and assessing the soundness of their conclusions. **Lecture**-Applying theories or concepts to practical problems or in new situations. **Lab**-Applying theories or concepts to practical problems or in new situations.
Place-Based/Contextualized Learning	Understanding of national issues. Understanding of global issues. The lectures are relevant to me as a person living in the Caribbean Knowledge of a natural disasters and ecosystems for the region.
Learning Outcomes	**Lecture**-I have improved my skills and knowledge regarding science methods. **Lecture**-I have improved my skills and knowledge regarding science knowledge. **Lab**-I have improved my skills and knowledge regarding science methods. **Lab**-I have improved my skills and knowledge regarding science knowledge.

Note. *N*=51, Scores are a mean calculation across items

Qualitative Data

Students are required to attend two CWE experiences and to submit a reflection of two or more paragraphs within two weeks of the experience. A maximum of five additional CWEs can be completed for five points each, allowing students to earn up to 25 extra points in addition to the 1000 total points for the class. These reflection essays are entered into the Windows Word program for analysis for emergent themes using a phenomenological analysis approach.

Student reflections were transcribed and verified through review of each document against submitted originals to make any necessary corrections. These transcriptions were subjected to a process that divides the utterances into statements or “horizonalizations.” This information is then compiled into clusters of meanings which were restated as psychological and phenomenological concepts. These clusters are then linked together to form an integrated description of the experiences that encapsulates “what” was experienced and “how” it was experienced (Creswell, 1998).

Consensus coding of statements included reviewing student reflections, organizing the data and using manual coding procedures, as outlined by Stevick-Colaizzi-Keen and modified by Moustakas (1994). Reliability was maintained through having all coders complete a selected 15% of the cases separately and compared. An 82% inter-rater reliability was assessed and all inconsistent codes were re-coded together. The data collected has been used primarily for evaluation of the course and teaching faculty. This data analysis has allowed an in-depth look at student, faculty, and institutional level variables to understand the benefits of place-based curricula and CWEs in student development (21^{st} Century Skills), school connectedness, academic persistence, STEM efficacy development, and academic performance.

Results

Sample

Participants included 51 students enrolled in the general science course in the Spring 2017 semester at UVI. With a predominantly male group (70%), freshmen made up the bulk of respondents (freshman = 76.9%, sophomore = 19.2%, and juniors = 3.8%).

Quantitative Findings

Descriptive analysis was done for all survey items to assess patterns for place-based curriculum integration and the associations between science literary, place-based/contextualized learning, and learning outcomes (see Table 2).

Table 2.
Descriptive statistics for place-based/contextualized learning, learning outcomes, and science literacy.

	Mean	SD	Range
Place-based/Contextualized Learning	4.11	.78	1-5
Learning Outcomes	3.55	1.37	1-5
Science Literacy	3.67	1.10	1-5

Note. *N*=51

A zero-order correlation was conducted to measure the association between place-based/contextual learning processes and students' cognitive learning in STEM (content and skill development) and science literacy (applying science knowledge beyond the classroom). A strong significant relationship emerged between place-based learning and learning outcomes, $r = .64$, $p < .01$. Additionally, place-based learning was significantly associated with students' development of science literacy, $r = .70$, $p = .01$. Lastly, place based processes were highly correlated with increases in student learning outcomes. $r = .89$, $p < .01$ (see table 3). These strong associations indicate that as place-based learning processes increase, students have increased science learning (knowledge and skills) and an increase in students' science literacy (application of theory and knowledge beyond the classroom).

Table 3.
Zero-order correlations for place-based/contextualized learning, learning outcomes, and science literacy.

Variables	1	2
Place-Based/Contextual Learning	--	
Learning Outcomes	$.64^{**}$	--
Science Literacy	$.70^{**}$	$.89^{**}$

Note. N=51, ** $p < .01$

When asked for the most impactful lecture classes, student selected the content directly related to the Caribbean context including: Plate tectonics/Earthquakes (55%), Oceans in Motion/Tsunami (43%), and Hurricanes (30%). The lab sessions rated as most impactful included Mangrove Ecosystems (83%), Marine Intertidal Ecosystems (48%), and Geology Field Exercise: The Rocks of the local environment (43%) which were paired with experiential learning activities. The least effective course content per student ratings were Library Exercise (43%) and Map Reading (41%).

Qualitative Findings

Analysis of student reflections (N=70) yielded six emergent themes related to School connectedness and 21st Century Skill development. These themes included 1) establishment of positive peer networks, 2) value of participation in extracurricular activities on campus, 3) positive attachment to school, 4) development of academic motivation and academic self-concept, 5) developing a future orientation academically and socially, and 6) learning applied and career focused information to align academic goals. Themes highlighted in this study contribute to course based innovation to promote student engagement, retention, and academic persistence which combats barriers to student success and matriculation (Blum, 2005; Chang, Sharkness, Hurtado & Newnan, 2014).

Establishment of Positive Peer Networks (School Connectedness)

A major gain for students' participation in CWEs was the development of a diverse and expanded network of peers that shared in the challenges, victories, and learning. These networks became spaces of collaboration and accountability for academic, career, and social goals. These place-based activities maximized island-based opportunities for students to contextualize science content while working with peers. One student who participated in a CWE nature hike stated *"I was extremely happy that I chose to go on this hike. Going up the trail was much easier than going down but when we reached the bottom, the looks of accomplishment on everybody's face was astonishing."* Students gain a peer network of support within an academic sphere to allow a normalizing of academic success with cohorts of students.

Value of Participation in Extracurricular Activities on Campus (School Connectedness)

The value of participation in extracurricular activities refers to the shared belief that CWEs were beneficial to students. Students discussed participation as personally, academically, socially, and civically beneficial for themselves and other students. These activities allowed exploration of new horizons and modalities for students' to positively impact the world around the campus. One student stated, "*This class has inspired me to become a bit more active in making sure our local environment is taken care of. I've already started to put a group together to do so [in my community]. Hopefully, this summer will be the start of a youth led environmental movement in my community.*" Students were inspired to continue activities beyond the course to connect with peers, the institution, and community.

Positive Attachment to School (School Connectedness)

Students communicated gains in their sense of belonging and affinity for the school through participation in social and institutional activities (i.e., sporting events and cultural fairs). Institutional activities, although not focused on student development, revealed the positive contribution and reputation of the university in the community. The university hosts a cultural fair on campus for the larger community which was offered as a CWE opportunity in which a student stated, *"It was the best experience ever and this little experience made me say to myself that if I have a family I would take them here to be amazed also."*

Development of Academic Motivation and Academic Self- Concept (21st Century Skills)

The development of non-cognitive skills that contribute to academic success emerged in student reflections also. Students reported increases in academic motivation, academic self-concept, self-efficacy, and self-regulated learning behaviors. Some student participated in CWEs that focused specifically on skills and techniques for academic success. A student that completed a student success workshop stated "*My thoughts about this CWE was that it was not only very informative but also very useful not only for Science 100 but for all my classes. In this workshop, I learned how to have better time management and how to take more effective notes also I learned different study techniques which can be applied to all of my classes."* The incorporation of learning techniques by students through CWEs helps promote their academic success and matriculation.

Developing a Future Orientation Academically and Socially (21st Century Skill)

Students described a future oriented focus for improvement in academics, engagement in future social and institutional activities, and career aspirations. Students with a healthy future orientation are able to link current activities to long-term goals in academic and career domains.

A student that participated in a CWE computer coding competition expressed connections made through the event and an intent to improve and try again at the next event by saying, *"Sadly. my group did not win, but that did not mean I didn't enjoy my time because I absolutely did, and I plan to attend again next year."* Students not only connected through CWEs but communicated plans for future engagement beyond the course such as a student's response to a beach cleanup. After that experience, she said "The beach clean-up is related to science and the class because it gives the students the opportunity to have a living understanding of the marine life. It was a nice experience and I think I'll volunteer again."

Learning Applied and Career-Focused Material

The CWEs were purposely diverse to help student increase the breadth of their college experience into fields beyond their declared majors. Student reflections revealed greater student affinity for relevant hands-on experiences (beach cleanup) and career focused experiences (hack-a-thon). Within these contexts students used problem solving, creativity, and collaboration to solve problems or complete a project. One student in particular used their knowledge of a scientist role to critique a movie about a natural disaster stating *"For instance, the scientists acted realistically when they used the proper tools such as, seismographs, cameras, ph testing kits, and spiders, to investigate the volcano. Another instance of exceptional effects was the eruption of the volcano. The pyroclastic flow and lava flow were an awesome sight to see."*

Conclusion

In alignment with university goals of graduating students with knowledge of natural phenomena and a high level of speaking, listening, reading, and writing skills, the course content for the general science course shifted to a curriculum with a Caribbean context. Based on student evaluations, the activities most closely relevant to a place-based focus with an additional experiential learning component were most favorable, and as place-based learning processes increase, students have increased science knowledge and skills, as well as an increase in the application of scientific theory and knowledge beyond the classroom. The addition of Campus Wide Experiences extends the learning environment beyond the classroom into the broader community and facilitates the development of 21st century skills as evident through student reflections indicating a greater connectedness to the school environment, and the development of non-cognitive skills and an increased academic and social orientation to their future selves with a school context. Thus, the addition of place-based curriculum with a focus on supporting the transition into higher education and 21st century skills development may support an increase in scientific literacy and learning in students who are traditionally underrepresented in STEM careers.

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