




UNDERGRADUATE EDUCATION

Twenty-First-Century Climate Education: Developing Diverse, Confident, and Competent Leaders in Environmental Sustainability

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Abstract

With climate change impacting systems globally at alarming rates, the need for educating the next generation of environmental stewards is necessary. The Rocky Mountain Sustainability and Science Network (RMSSN) is an immersive field experience for undergraduate and graduate students interested in climate change and sustainability within National Parks. The program was established to educate and cultivate a diverse audience of future leaders, environmental guardians, and sustainability advocates with a focus on engaging underrepresented minorities (URM) in science. Participants were evaluated through efficacy instruments and focus groups to determine how a short-term research experience could impact a student's future outlook and perceived ability to impact science and sustainability. Findings indicate URM, and majority students were more confident in their abilities, and more motivated to continue

within their studies. RMSSN provides a framework that is translatable to other field-based curriculums. This paper addresses specific engagement mechanisms for educating future science leaders.

Key words: citizen science; field experiences; interdisciplinary action; mentorship; National Parks; networks; science; sustainability; URM students.

Introduction

Amidst the ever-changing and increasingly complex challenges facing the planet and humanity, there is a growing need to educate the next generation of environmental stewards and leaders as global citizens with sustainability mindsets (Bowser et al. 2014, Gretzel et al. 2014). Along with mentoring, critical elements of training needed to prepare this interdisciplinary workforce include experiential learning in the areas of science, communication, and leadership. The global challenges demand that this be a diverse workforce capable of recognizing and tackling ethical, cultural, political, and equity issues for a sustainable and just future (Hong and Page 2004, Yarime et al. 2012). Students between 18 and 25 and specifically underrepresented minorities (URM) are interested in the interdisciplinary approach of sustainability and see value in combining efforts to make a difference for humanity while performing scientific work (Brown et al. 2011, Bowser et al. 2012).

The Rocky Mountain Sustainability and Science Network; A Case Study in Short-term Field Experiences

In 2009, The Rocky Mountain Sustainability and Science Network (RMSSN) was launched in an effort to unite a global community of academic institutions, federal and state agencies, and nonprofit organizations. The organization's objective is to collaboratively nurture students from underrepresented backgrounds in the sciences to become leaders and decision makers equipped and prepared to address global issues related to climate change, sustainability, biodiversity, and management of natural resources on public lands. In 2010, the steering committee of RMSSN designed and launched an academy to introduce students to concepts of sustainability and science in the Rocky Mountains.

Approximately 20 undergraduate and five graduate students from institutions across the United States and throughout the world are selected from applicant pools of 120 students every year to participate in a two-week research effort that travels to Yellowstone, Grand Teton, and Rocky Mountain National Parks. RMSSN focuses on examining climate change-related research questions while highlighting teamwork and leadership skills to address sustainability issues in natural resource and park management. Hallmarks of RMSSN include the diversity of participants and supporting faculty (over 75% of the academy participants are from underrepresented groups, with an average demographic breakdown of 30% Hispanic/Latino, 20% Asian American, 20% African American, 20% Caucasian, 5% Native American/Pacific Islander, and 5% multiracial), hands-on National Park citizen science-based research projects, and collaborative partnerships with academic institutions, federal agencies, nonprofit organizations, public companies, and more (Brown et al. 2013). The organization has been funded through a National Science Foundation (NSF) grant (NSF Award #0956059) as well as through private donations and corporate sponsorship.

Annually, the RMSSN summer academy selects a cohort of students ranging from ages 18 to 35, coming from locations across the United States as well as other countries such as Mexico, France, Liberia, China, and more, through a competitive application process, which explores thoughts on both leadership and sustainability.

Students find out about the academy through academic listservs, previous attendees, faculty networks, or the RMSSN website. Students are selected based on their geographic and demographic representation, field experience (or lack thereof), and leadership qualities that they define within their initial application. While a large number of participants are pursuing degrees in science or sustainability, involvement is not limited to students majoring in these fields in order to encourage science literacy across other disciplines, and the demographic and age ranges are not restricted to applicants who would otherwise qualify for the program. The aim of the academy is to offer a free educational experience, which involves field research development, implementation, communication, and analysis during a two-week time period, to participants so that they have tools in order to become leaders and policy makers that affect climate change and impact overall environmental sustainability. Attendees also learn sustainability efforts occurring within the park and are encouraged to practice “leave no trace” initiatives during their experience. Participating students self-organize into research groups guided by faculty in order to explore relevant issues regarding sustainability, ecology, and climate science. Previous research teams have developed projects around park mammals (bats, marmots, pika, etc.), plant–pollinator interactions, and cultural resources within the parks. The students have the liberty to develop their own questions surrounding these topics, while the faculty, previous RMSSN alumni, and park managers mentor students through the research development and implementation of their project. The academy ends with a professional research presentation from each team.

Since the establishment of the RMSSN academy in 2010, pre- and post-assessments of participants have been conducted to gauge their ability to define foundational concepts in sustainability and climate change along with their confidence in their own ability to help public land managers respond to problems related to environmental sustainability. Self-efficacy survey instruments were employed to evaluate an individual’s belief in their ability to achieve certain goals, which can influence their motivation to complete tasks (Bandura 1977, Schunk 1989, Vuong et al. 2010). In addition, unstructured interviews and focus groups provided a deeper look at how the experience impacted their understanding of these concepts.

The results of three self-efficacy surveys are presented here. The first, which considered leadership and climate change, is compared with two previously published surveys that also studied similar impacts on RMSSN participants (Bowser et al. 2014, Gretzel et al. 2014). A review of these three assessments in conjunction with focus group responses is intended to provide a more complete picture of how the RMSSN academy approach to sustainability and climate change education shapes understanding for students involved. In addition, this project hopes to provide translatable elements for laboratory-based courses in regard to networks and other short-term learning experiences happening across the country and the benefits of such for student understanding.

Connection to citizen science

Public lands are exceptional locations for climate change education as these outdoor laboratories emphasize the large-scale impacts of human influences driving global ecological change and can be used as an educational tool for enhancing scientific literacy (West et al. 2009, Bowser et al. 2014). A growing practice is to integrate National Park visitors into the scientific process (Leong and Kyle 2014, Watkins et al. 2018). This approach, leveraged by RMSSN, allows program participants to engage with the parks in a unique scientific manner. Citizen science provides the parks with valuable research data and insights while also offering those involved a rich educational experience and a connection to special places. Dickinson et al. (2012) explained that integrating research with public education is a “powerful way to generate ecological knowledge, inquiry, and place-based nature experiences for the

public” (p. 292). Citizen science can potentially serve as a platform to grow participant understanding of climate science, sustainability, and their environment. This approach augments the RMSSN educational strategy, encouraging exploration of the natural world in a social manner. Participating students engage in research pursuits alongside other students and faculty serving to amplify the value of the experience. This social component embedded in the educational strategy has shown to be a valuable aspect of the experience and highlight a sense of belonging (Halliwell 2019, Rainey et al. 2018, Walton and Cohen 2011).

Further, building citizen science into the educational strategy has not only provided participants with an experiential connection to the natural world but it has also facilitated connections to the research locations themselves (Schuttler et al. 2018, Halliwell and Bowser 2019). This approach to sustainability education can foster place attachment, recognition of the parks as special places, and awaken a sense of belonging to the place. Moreover, Jordan et al. (2012) suggested that benefits of such an approach could extend to social capital and resilience building for participants involved in the project. In this sense, the social capital that is developed is characterized as a growing “trust in societal systems, all of which facilitate the coordination and sharing of cultural, social, and natural resources for mutual benefit” and a sense of belonging to a particular group (Jordan et al. 2012, p. 308).

As noted, RMSSN students select one of three broad research efforts, mammals, pollinators, and cultural elements to support during the program. Approximately seven or eight students support each project. Additional guidance and context on the focus of the research effort are provided. Still, students are given autonomy to craft research questions that fall within the bounds of the broader focus. For instance, students have formulated research questions examining pika populations that considered the effectiveness of using camera trap technology for detecting presence or absence. Empowering and challenging students to formulate their research question(s) allows students to coalesce around the project from its inception. Students, with the support and guidance of faculty, are responsible for developing study protocols, collecting data, analyzing data, and reporting results at the conclusion of the program. While the three groups work independently, there is overall support, engagement, and involvement of the students for each project that they are not otherwise committed to. In this sense, students are responsible for their own project while learning from others. Allowing students the freedom to explore these topics, learn from mistakes, challenge one another, and grow together while stepping logically through the inquiry process is a valuable element inherent in the RMSSN strategy.

Methods

Leadership and climate change self-efficacy survey

Pre- and post-self-efficacy questions were administered to RMSSN students before and after the research effort. The statements evaluated the students’ ability and confidence in defining topics related to global leadership and climate change issues. The students were presented a total of five statements and asked to rate the degree to which they believed they could accomplish the task presented in each statement. The rating system was a Likert scale of 1 to 10, with (1) representing “No belief” and (10) representing a “Very Strong Belief” in the individual’s ability to complete the task. The following statements were presented to 71 participants immediately before (Pre) and immediately after (Post) participation:

Leadership and climate change self-efficacy statements

- 1) I can conduct experiments that will contribute useful information to the study of climate change.
- 2) I can clearly explain the importance of responding to climate change on a global scale.
- 3) I can be an effective leader in response to problems related to global environmental sustainability.
- 4) I can clearly explain the meaning and implications behind the statement, “climate change is not equitable.”
- 5) I can provide examples regarding the way in which climate change affects different cultures.

Analysis considered the response mean shift before and after the RMSSN experience. Also, one-sided paired *t*-tests using an alpha value of 0.05 compared the responses to assess whether a shift was statistically significant.

Sustainability define and assist self-efficacy surveys

Additionally, pre- and post-assessments of participants were conducted to gauge each student’s ability to define foundational concepts in sustainability and climate change. Moreover, the instruments considered their confidence in the students’ own ability to provide leadership, collect data, and help public land managers respond to problems related to environmental sustainability. The survey statements listed below considered participants’ ability to appreciate, define, assess, and support climate change issues.

Sustainability—Define and assist self-efficacy survey #1 statements (Bowser et al. 2014)

- 1) I can clearly define sustainability as it applies to natural resources.
- 2) I can clearly define sustainability as it applies to public lands.
- 3) I can clearly define sustainability as it applies to climate change.
- 4) I can effectively assist public lands managers on issues related to sustainability.
- 5) I can effectively assist natural resource managers on issues related to sustainability.

Sustainability—Define and assist self-efficacy survey #2 statements (Gretzel et al. 2014)

- 1) I can clearly define sustainability as it applies to human dimensions of natural resources.
- 2) I can clearly define global environmental sustainability.
- 3) I can be an effective leader in response to problems related to global environmental sustainability.
- 4) I can collect data that will contribute to solutions for problems related to global environmental sustainability.

Published results for both *Define and Assist Surveys* included mean pre- and post-responses to the same Likert scale noted previously, (1) representing “No belief” and (10) representing a “Very Strong Belief.” While *t*-test results were published for the first survey, the second survey did not have published *P* values.

Focus group interviews

Subsequent RMSSN cohorts were studied to further explore how the experience shaped participants understanding of sustainability. Focus groups were conducted following the academy in two separate years. Five groups were evaluated representing two cohorts. Twenty-seven students participated in the

Table 1. Leadership and climate change self-efficacy survey results.

Statement	Pre (\pm SD)	Post (\pm SD)	Shift	<i>P</i> value
(1) I can conduct experiments that will contribute useful information to the study of climate change	1.45 (\pm 0.89)	7.07 (\pm 1.50)	5.62	<0.001*
(2) I can clearly explain the importance of responding to climate change on a global scale	3.10 (\pm 1.21)	7.37 (\pm 1.32)	4.27	<0.001*
(3) I can be an effective leader in response to problems related to global environmental sustainability	1.25 (\pm 0.60)	4.23 (\pm 0.88)	2.98	<0.001*
(4) I can clearly explain the meaning and implications behind the statement, “climate change is not equitable”	1.31 (\pm 0.62)	5.28 (\pm 1.27)	3.97	<0.001*
(5) I can provide examples regarding the way in which climate change affects different cultures	2.41 (\pm 0.80)	8.11 (\pm 0.92)	5.70	<0.001*

**P* < 0.05 indicates significance.

sessions with groups ranging from as few as four individuals to as many as six. Questions/topics that students addressed included: place attachment, stewardship, memorable experiences, differences between the RMSSN experience in comparison with other National Park visits, the importance of peer participants on park perceptions, thoughts of science participation within the parks, and personal relationships to nature.

Results

Leadership and climate change self-efficacy survey results

Result of the Leadership and Climate Change assessment, displayed in Table 1, indicated a shift across all statements toward stronger self-efficacy. Furthermore, the evaluation of each statement indicates that the shift from pre- to post-assessment was statistically significant for all statements.

Statement #5, which addressed being able to provide examples of climate change affecting other cultures, saw the largest shift from 2.41 pre-survey to 8.11 post-survey. This post-survey response was the highest among all statements on this self-efficacy survey. Although still statistically significant, the smallest shift from pre to post was found in the Statement #3. This particular statement, which saw a shift of 2.98, examined leadership in regard to global environmental sustainability. Incidentally, this statement had the lowest mean response of all statements in both the pre- and post-surveys. It was also the only statement that did not see a shift beyond the midpoint on the Likert scale toward positive belief.

Again, similar to Statements #3 and #5, the remaining three statements, #1, #2, and #4, also saw a statistically significant shift toward greater confidence in the participants' ability to carry out the action. Each statement had a post-mean response greater than 5.0 on the Likert scale. Statements #1 and #2, which addressed being able to conduct experiments and communicate climate change importance,

Table 2. Sustainability—Define and assist self-efficacy survey #1 results (Bowser et al. 2014).

Statement	Pre (\pm SD)	Post (\pm SD)	Shift
(1) I can clearly define sustainability as it applies to natural resources	2.61 (\pm 1.16)	6.79 (\pm 1.21)	4.18
(2) I can clearly define sustainability as it applies to public lands	1.36 (\pm 0.63)	5.86 (\pm 1.58)	4.50
(3) I can clearly define sustainability as it applies to climate change	2.14 (\pm 1.01)	6.52 (\pm 1.13)	4.38
(4) I can effectively assist public lands managers on issues related to sustainability	1.20 (\pm 0.55)	4.83 (\pm 1.36)	3.63
(5) I can effectively assist natural resource managers on issues related to sustainability	1.30 (\pm 0.64)	4.90 (\pm 1.06)	3.60

Table 3. Sustainability—Define and assist self-efficacy survey #2 results (Gretzel et al. 2014).

Statement	Pre	Post	Shift	<i>P</i> value
(1) I can clearly define sustainability as it applies to human dimensions of natural resources	1.55	4.39	2.84	<0.001*
(2) I can clearly define global environmental sustainability	2.17	6.56	4.39	<0.001*
(3) I can be an effective leader in response to problems related to global environmental sustainability	1.25	4.23	2.98	<0.001*
(4) I can collect data that will contribute to solutions for problem related to global environmental sustainability	1.41	7.08	5.67	<0.001*

* $P < 0.05$ indicates significance.

respectively, had a post-survey response greater than 7.0 indicating a stronger belief in one's abilities post-experience. Interestingly, Statement #4, which explored explaining climate change equitability, saw a mean post-response of 5.28, second lowest among the five statements. However, Statement #5, which evaluated ability to provide examples of how climate change impacts other cultures, not only saw the highest mean post-response of 8.11, but also saw the largest shift from pre- to post-assessment. Potentially, the results from this statement are reflective of an educational approach, which explores climate and sustainability in a diverse social setting. Further research is warranted in this area.

Sustainability define and assist self-efficacy surveys results

Similarly, the responses reported by Bowser et al. (2014) and Gretzel et al. (2014) in Tables 2, 3, respectively, all saw a shift toward stronger self-efficacy following the experience. Of note, confidence in being able to collect data pertaining to global environmental sustainability saw the largest shift of all statements on either of the two *define and assist* surveys. None of the statements on either pre-survey saw a mean response exceed 2.61, which addressed defining sustainability as it applies to natural resources.

All statements that considered one's confidence in defining terms saw a shift toward greater confidence exceeding 5.0 except Statement #1 on the second survey. Interestingly, this statement also asked participants to define sustainability in regard to natural resources, just as Statement #1 in the first survey did; however, it specifically assessed human dimensions of natural resources. The idea of addressing human dimensions of natural resources appeared to present a greater challenge than simply defining sustainability as it applies to natural resources alone.

While the three statements that explored assistance or leadership (#4 and #5 on the first survey; #3 on the second survey) did see a shift toward greater efficacy, none exceeded 5.0 on the Likert scale. Still, as noted, the shift is an indication that the RMSSN approach, outlined previously, instills confidence in leadership skills and effective assistance regarding sustainability. As evidenced by the highest mean pre-response of 1.30 (Statement #5 on the first survey), students entered the experience with rather low confidence in their ability to contribute in this regard.

Focus group interview results

In a focus group setting, students explained aspects of the educational experience that impacted them. Responses from both cohorts that were evaluated reflected very similar assessments of the experience and its impact, further reinforcing the findings. When asked to articulate memorable elements of the research effort one student noted "the most memorable part of it for me was actually living sustainably while there." This comment displays how the day-to-day routine of the RMSSN academy can leave an imprint on participants. When looking back, students were inclined to highlight how seemingly routine aspects of the experience impacted their learning.

As evidenced by the quotes in Fig. 1, participants spoke highly of the opportunity to contribute toward relevant science in the parks. Those involved recognized this engaging component of the educational experience to be an impactful program attribute. Participants valued the ability to pursue scientific questions and practice sustainability in iconic park locations. They noted that such an opportunity facilitated connections with these places. Furthermore, they explained that this experience served to remove perceived barriers to science while igniting interest and affirming academic pursuits. They expressed a sense of autonomy and empowerment to explore and learn under the RMSSN approach.

The second theme that emerged was the importance of the social elements of the educational experience. This finding reflects the work of Parrish et al. (2019), which also recognized the value of social networks within citizen science programs. The learning that occurs during the RMSSN effort does not occur in isolation, rather the importance of exploring science, sustainability, and climate issues in a diverse community is embraced. Again, quotes in Fig. 1 illustrate the importance the community of engaged learners had on one another. Participants highlighted being able to connect with others that shared similar interests while embracing the rich diversity that the program is built on. The program approach created a space for participants to feel welcomed to learn and explore in community. Students alluded to this diverse, yet like-minded social setting as a buffer or "shield" that was a critical program aspect necessary for learning to flourish for many. Comments that addressed this element of the experience drew connections to the proposal of Jordan et al. (2012) that citizen science can bolster resilience in community. This ability to learn in a supportive community potentially allowed participants overcome obstacles that could have otherwise challenged the educational experience.

Science and Sustainability	Networks and Social Aspects
I would say actually doing science was something that actually connected me most...It just made me really appreciate that environment.	It was just really cool being with a group of people who were so passionate about being outside in the environment
Doing science gave me a reason to be here (in the parks), I had a special reason to be here... I'd love to keep doing it.	The program served as a shield, if I'm truly honest if I was to go home tomorrow, I would not come back unless it was in a social construct like this. This program in itself made me comfortable because I was able to meet people from all over.
Being able to do science has helped me know what I want to do... It reinforced my passions.	Having a diverse group made me fell in love with this place with others.
Doing research always appeared to be done in an ivory tower. This experience leveled the playing field a bit and made it more accessible to me.	RMSSN gave me a new perspective... with this it was about doing research and being in the field while also enjoying what's around me. This program provided that homey feeling. Being in a group with like-minded people and how we all care about the environment. It was nice to be around.
I always idolized scientists and biologists that were out there doing really cool stuff but after this experience I definitely feel doing science is more in reach.	I appreciate the diversity of the faculty everyone specializes in something different. That gives me the confidence to believe that I can go do that... I can go do research in the future. That's possible for me... the diversity of the group and the different backgrounds made me feel better.
We are used to information being fed to us... this gave me the opportunity to ask our own questions. The faculty, all the different people give a new perspective on what you can be curious about. The action of doing science puts the responsibility back in your hands to learn about things.	The diversity of the faculty and the students is amazing and it helped to change my perspective. Everyone brings in a new perspective... it provides a lot of interesting conversations, educational conversations, conversations that push boundaries. It's educational but a very social experience as well.

Fig. 1. Student anecdotes from RMSSN experience, based on focus group questions and comments.

Discussion and Conclusions

There are compelling indications that the effectiveness of sustainability and climate education can be enhanced through hands-on exploratory programs that encourage and empower participants to investigate these topics in a social setting. Consistent with the findings of Bowser et al. (2014) and Gretzel et al. (2014), the results of the *Leadership and Climate Change* self-efficacy survey indicate that students that participated in the RMSSN research academy displayed a statistically significant shift toward greater confidence in competency, scientific knowledge, and sustainability perceptions across all research statements. Students generally enter the experience with very low confidence in their ability to define, explain, or assist in climate change efforts. Over the course of the program, the students' confidence and sense of assurance that they could accomplish such tasks were enhanced. This study offers indications that an experiential educational approach, which embraces diversity among students and faculty to examine climate-related questions, improves participants' certainty in being able to contribute effectively toward climate discussion and action.

As explained, the RMSSN approach to climate education is grounded in experiential exploration, allowing students to tackle climate-related questions through citizen science efforts. Through interactions with each other, faculty, and public lands ideally suited for such studies, a deeper understanding of sustainability and climate change emerged. The immersive approach to climate education created space for students to grow and learn together. This investigative, diverse, and supportive learning environment, modeled by RMSSN, provides a possible framework for effective climate and sustainability education.

Incorporating citizen science in a diverse social program appears to have a notable impact on shaping education and enhancing participants' confidence. Such an educational approach can create a welcoming atmosphere for learning and exploration of these issues. Accordingly, this research recommends that climate and sustainability education programs incorporate citizen science components, which allow for student-guided exploration with the support of a diverse and engaged cohort of peers and instructors. To be sure, educational settings, programs, and resources can differ greatly. Still, seeking to incorporate and encourage such elements appears to have a positive impact on learning outcomes, aiding in the development of assured, devoted, and passionate leaders prepared to address complex climate and sustainability issues.

For more information about the RMSSN program, please visit www.rmsn.org.

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