RESEARCH IN SCIENCE & TECHNOLOGICAL EDUCATION
https://doi.org/10.1080/02635143.2021.1944077

Forests After Florence: an informal community-engaged STEM research project promotes STEM identity in disaster-impacted students

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ABSTRACT

Background: Natural disasters, such as hurricanes, can have lasting impacts on a community

Purpose: This research evaluated how participation in an STEM education intervention after an ecological disaster affected students' persistence, resilience, and STEM identity

Sample: Hurricane Florence impacted college students (N = 50) were recruited

Design and Methods: Participants completed pre-test, post-test and daily diary measures before, during and after they completed an intervention where they collected forestry data in their home hurricane-impacted communities

Results: Participants reported higher STEM identity following the intervention learning experience. Daily interest and enjoyment in science was higher on days when they reported more positive experiences. For resilience, for male students, but not female students, the learning opportunity fostered resilience. Male students reported higher STEM identity on days when they reported more positive learning experiences

Conclusion: These findings highlight the benefit of STEM education learning opportunities, particular for disaster-impacted students.

KEYWORDS
Resilience; STEM identity; gender; forestry; hurricanes

Introduction

In recent years, natural disasters have increased at unprecedented rates (Hoeppe 2016; Ibarrarán et al. 2009). Attention to education following natural disasters is critical. First, focusing on formal schooling and academic commitments following a disaster can prove challenging for any student. Prior research, for instance, has demonstrated high rates of stress amongst students following a range of natural disasters, including following the Canterbury, NZ earthquake (Richardson et al., 2015), Hurricane Katrina in New Orleans, LA, USA (Sims et al. 2015), and the Fukushima earthquake in Japan (Taku et al. 2018). In particular, after a disaster, research in pre-college settings notes that teachers can play

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a key role in helping students to process their loss (Le Brocque et al. 2017). Further, research with college students in Puerto Rico impacted by Hurricane Maria in 2017 highlights that students reported high levels of stress and uncertainty and that community and institutional support were key in helping ensure resilience (Shelton and Thompson 2020). Much less research has been done in higher education and on how engaging in out-of-the classroom learning in disaster-impacted areas can foster student identity, learning, and persistence following such losses. Thus, the aim of this study was to examine outcomes of a STEM education intervention for college students impacted by recent hurricanes.

In particular, in this study, we describe a relevant STEM learning experience that took place outside of formal classroom environments and which was rooted in ecological education and research for disaster impacted students. We present findings on the outcomes of this intervention, both in terms of fostering student success as well as building their identity as scientists. Research has demonstrated that science learning experiences occurring outside of traditional classroom spaces can shape student science identity and interest (Goff et al. 2019). Further findings highlight the importance of science identity salience for college students, in particular, in shaping STEM trajectories (Robinson, Perez, Carmel, & Linnenbrink-Garcia, 2019; Starr 2018). One possible way to foster STEM identity is through out-of-the-classroom experiences: researchers propose that learning experiences that occur outside of formal classroom settings are critical in building students' career interests and in shaping their science trajectories (National Research Council 2009). This type of learning can occur in many different ways, for instance, through media consumption (Maier et al. 2014), through hobbies and citizen science participation (Bonney et al. 2009; Jenkins 2011; Jones et al. 2018; Phillips et al. 2018), and through science clubs or other extracurricular science pursuits (Dabney et al. 2012). Research also demonstrates that real-world relevant data collection experiences and engaging in research at the undergraduate level can be centrally important in shaping STEM identity and fostering success, especially for students who may be historically marginalized from STEM careers (Chang et al. 2014; Daniels et al. 2015; Smith et al. 2014). Building on this work, we developed an out-of-the-classroom STEM education learning experience that involved learning about impacts of hurricanes on forest habitats, gathering rich multifaceted data on tree damage following recent hurricanes, and connecting with their local communities by gathering oral histories from community members focused on the environmental impacts of the hurricanes.

Theoretical framework for intervention development

Our position that post-disaster natural environments can play a key role in student learning and that engaging in authentic learning tasks around issues relevant to the disaster can be a critical learning experience for students who have experienced loss following a natural disaster is situated within self-determination theory (Ryan and Deci 2000, 2017). Self-determination theory frames motivation, including learner motivation in distinct domains, as being shaped by three key psychological needs: 1) *competence*: feeling efficacious in a particular domain, 2) *autonomy*: having the opportunity to select your own behaviors and having choice in what you pursue, and 3) *relatedness*: feeling a sense of belonging and relevance for a particular task (Ryan and Deci 2017) Further research has delineated particular dimensions of relatedness that are optimal for student

learning, with recent theory documenting three different facets of relevance that are important for student success: *personal association*, which refers to connections between a stimulus (such as a learning activity and other personally valued memories or objects); *personal usefulness*, which refers to the utility of a stimulus in fulfilling a personal goal; and *identification*, which refers to incorporation of the stimulus into one's identity (Priniski, Hecht, and Harackiewicz 2018). Our out-of-the-classroom learning intervention (centered in hurricane-impacted communities in Eastern North Carolina) builds upon each of these facets of relevance and also fosters competence and autonomy. Participants were selected from communities that were impacted by Hurricane Florence and conducted their data collection directly in their home community, ensuring the likelihood that they had strong personal associations with the science tasks at hand, as they gathered data in their home communities that directly informs understanding of the impact of the disaster on their natural environment. Engaging in learning in these zones is personally useful, as the data collected from their home communities, which have been regularly impacted by hurricanes, is beginning to inform future planning efforts and forest management practices to mitigate the impact of future hurricanes. Finally, we expect that this learning opportunity can foster greater identification, building, or rebuilding of students' STEM identity, and perceptions of themselves as scientists who can use science to help their home communities. In terms of competence, we ensured that all participants received rich, meaningful training, drawing on their prior knowledge of their home communities as well as providing them with critical new skills in using imaging equipment and recording oral histories. Finally, participants autonomously selected to participate and had autonomy in identifying and selecting sites for data collection as well as interviewees for the oral histories. Thus, the intervention was framed using the dimensions of self-determination theory (Deci and Ryan 1985, 1992; Ryan and Deci 2017) in order to foster student motivation and learning success.

Forests after Florence: the intervention

The urban areas of North Carolina and the mid-Atlantic states exhibit relatively high forest cover even over residential areas (Karp 2018). Indeed, in some cities like Raleigh, forest cover even increased in the 20th century with regional forests recovering from past clear-cutting and conversion from agriculture to other land uses, retaining a relatively high forest canopy cover despite more recent rapid urbanization (Bigsby, McHale, and Hess 2013). Dense tree cover shades many residential areas, but the proximity of trees to houses also increases risk to infrastructure during high wind and rainfall events like hurricanes (Duryea, Kampf, and Littell 2007). Trees falling on houses, cars, power lines, and roads are among the biggest impacts of hurricane events, as seen in the aftermath of Hurricanes Matthew and Florence. Urban trees may be particularly vulnerable to hurricane damage due to the nature of the geophysical environment in cities, with the urban heat island effect and buildings changing wind speed and patterns, greater impervious surface cover and compacted soils increasing stormwater runoff and flooding, and shallower root systems of many tree species preferentially planted in urban areas (Bigsby, McHale, and Hess 2013; Duryea, Kampf, and Littell 2007; Escobedo et al. 2009; Staudhammer et al. 2011; Xi et al. 2008). A recent study in Fayetteville, NC identified the vulnerability of different tree species to a range of effects from climate change (Karp 2018), including hurricane risk. Impacts of hurricanes can be two-fold

: 1) the immediate impact due to high wind causing branches and entire trees to fall down; 2) longer-term impact from flooding as waters surge in the aftermath of the hurricane, and low-lying forests can remain flooded for long periods. Both of these cause damage to urban trees in ways that result in negative and costly effects for humans (Hull 2014). Hurricanes can turn the beneficial ecosystem services of trees into disservices – and the latter aspect remains relatively understudied (Hull 2014).

Our STEM education intervention aimed to teach students about these potential impacts and to use cutting-edge research techniques to understand and explore hurricane impacts. The students learned photographic techniques to rapidly assess the extent of damage to trees, and their impacts on urban infrastructure, using 360° photos taken from the ground to analyze the three-dimensional structure of the urban forest. Students also learned methods to gather oral histories from residents of these communities who observed damage from recent and historical hurricanes.

This intervention was implemented with students at North Carolina State University, a large land-grant institution in North Carolina, where a large number of students have been impacted by recent hurricanes. For example, 4061 are from federal disaster declared counties impacted by Hurricane Matthew in 2016 and 4796 students are from Hurricane Florence impacted counties. This amounts to nearly 15% of the total student population on campus potentially directly affected by these catastrophic weather events impacting their homes and families or their communities.

The Forests after Florence intervention targeted students who reported direct impacts from Hurricane Florence. All students from hurricane impacted counties in North Carolina were invited to apply to participate in the intervention. In total, fifty participants were selected, based on their availability to participate in the intervention and if they reported direct impact from the hurricane. After selection, participants attended a day-long interactive training where they learned to use 360° cameras to record images and video of forestry damage and to geo-tag these images with the location where the image was recorded. They also learned best practices for recording oral histories and received a training in methods for oral history data collection. Finally, during the training, participants partnered up with one other student from their home community to map locations for data collection where hurricane damage might be observable. Each pair identified 10 locations and were assigned an additional 10 'control site' locations where they would record damage. Students selected windows of time during a 2-week period in May of 2019 to meet and collect data, including both forestry damage recordings and oral histories (at least 2 per team). Data collection occurred once the semester ended in order to ensure that participants had the time to collect the data and to ensure that the home communities had recovered enough so that reaching the data collection sites would be feasible (flood-waters had receded, and roads, largely, were made passable again).

Benefits of the intervention

STEM identity

Our research is also framed by social identity theory, which demonstrates the importance of social identity in shaping concepts of both who one is, and also who one could be (Tajfel 1978). While research on social identities often attends to constructs such as gender identity

(Egan and Perry 2001) and ethnic/racial identity (Phinney and Ong 2007; Rivas-Drake et al. 2014), increasingly, researchers are exploring the role that one's science or STEM identity may play in shaping academic and career success (Leaper, Farkas, and Brown 2012; Merolla and Serpe 2013; Tan et al. 2013). As an example, prior research on STEM interventions with college students documents that science identity salience mediates the relationship between intervention program participation and ultimately matriculation into graduate STEM programs (Merolla and Serpe 2013), highlighting the important role of perceiving one as a scientist. Further daily diary research with emerging adults clarifies that perceptions that one's identity was compatible with one's STEM major was associated with greater sense of belonging in the major and greater STEM motivation (London et al. 2011). Recent research has documented that a single-item measure of STEM identity that captures how much overlap one sees between themselves and STEM is a valid measure of STEM identity, and is associated with a range of other relevant measures including STEM attitudes, self-efficacy, mastery goal orientation, and persistence in one's major and toward one's graduation goals (McDonald et al. 2019). In the present intervention, as noted above, we focused on forest-related hurricane damage in participants' home communities, giving participants the training and tools to engage in scientific practices that had immediate relevance to their own lives and communities, with the aim to foster science identity in disaster-impacted students. We expected that participation in the intervention would increase students' STEM identity – their perception of how compatible their identity is with STEM.

Academic resilience

Prior research highlights the importance of academic resilience for success in higher education (Cassidy 2016) and findings suggest that students exposed to trauma or a disaster often struggle with resilience (Galatzer-Levy, Burton, and Bonanno 2012; Ladd and Gill 2011). Further, research notes that interventions which foster self-efficacy or feelings of competence, as the Forests After Florence intervention was designed, can build academic resilience (Cassidy 2015). Moreover, research documents the importance of social resilience as communities recover from natural disasters (Pelling 2003; Ziervogel et al. 2017). Thus, we expected that participants would report higher resilience post-intervention.

Participant perceptions of learning, science and interest

Finally, we also examined participants' self-reported interest and enjoyment as research demonstrates that science interest is essential for shaping educational outcomes (Canning et al. 2018; Priniski, Hecht, and Harackiewicz 2018; Wang and Degol 2013). Further, as the intervention allowed students to engage in scientific research and learning in their local communities around a research question that was relevant to their own lives, we also examined participants' perceptions of science as a tool that could help and provide benefits to their local communities (Pain 2012; Roth and Lee 2004).

Current study and hypotheses

Thus, the aim of the current study was to examine the impact of the Forests After Florence Intervention on participants. We focused our analyses on a few key questions. First,

participants completed a post-intervention survey on their perceptions of the experience, their learning and of the relevance of science to their community following the intervention. We examined survey responses to identify if participants perceived the intervention as beneficial. Additionally, participants completed pre-and-post test assessments of their STEM identity and academic resilience, which we examined to identify if the intervention led to growth in identity and resilience. Finally, in order to more carefully understand participants' experiences, we assessed daily diary data that students completed each day during the data collection. With this data, we explored whether students experienced daily increases in STEM identity and interest on days in which they participated in data collection.

Extensive research has documented that females often exhibit decreased science identity as compared to males, with many women not seeing science as 'for them' (Robinson et al., 2019; Starr 2018; Wegemer and Eccles 2019). Further, given that women are often underrepresented in STEM majors and STEM careers (National Science Board 2015, 2018; Noonan 2017), we were also interested in whether the intervention had different outcomes for male and female participants and tested for gender differences in our analyses.

Method

Participants

Fifty students who reported hurricane impacts were recruited as participants in the education experience (54% female and 46% male). Selected participants represented diverse majors (59.1% STEM majors) and ethnicities (75% White/European-American, 0.04% Hispanic/Latino; 9.1% Black/African-American, 6.8% Asian/Asian-American; 9.06% Other). The study was IRB approved and all participants consented to participation.

Measures

STEM identity

STEM identity was measured using a STEM-relevant Inclusion of the Self in the Other measure (London et al. 2011; McDonald et al. 2019). This measure, which has documented convergent, discriminant, and criterion validity, presents 7 sets of circles which overlap in varying degrees. One circle represents STEM and the other the participant. Participants indicated which overlapping set best represents their STEM identity (1 = No Overlap to 7 = Total Overlap). This measure was given in the pre-test, post-test, and in the daily diary survey.

Academic resilience

The Academic Resilience Scale (ARS-30) was used to measure processes of resilience, in particular cognitive-affective and behavioral ways in which students respond to adversity (Cassidy 2016). First, participants read a short vignette describing an academic context that might require resilience. Then, they responded to 30 items on a Likert-type scale (1 = likely to 5 = unlikely). The ARS-30 includes 3 subscales, which measure perseverance (14 items, range = 14–70; example item: 'I would use the situation to motivate myself'; pretest α = .90, posttest α = .90), reflecting and adaptive help-seeking (9 items, range = 9–45, example item: 'I would start to monitor and evaluate my achievements and effort'; pretest

α = .77, posttest α = .92), and negative affect and emotional response (7 items, range = 7–35, example item: 'I would begin to think the chances of getting the job I want were poor'; pretest α = .78, posttest α = .96). All positively worded items were reverse coded so higher scores indicate greater likelihood of perseverance, reflecting and adaptive help-seeking, and lower likelihood of negative affect and emotional response. This measure was given at pre-test and post-test.

Perceptions of the intervention and science

At post-test only, participants completed a measure assessing their perceptions of the Forests After Florence Intervention (11-items, Likert-type 1 = Strongly Agree to 7 = Strongly Disagree). Example items include: 'I think my community will benefit from the Forests After Florence data collection' and 'I learned a lot from the Forests After Florence data collection'.

Daily science interest

Each day of the daily diary, participants completed a single item 'How interested are you in science right now?' (1 = Extremely Interested to 7 = Extremely Uninterested) (London et al. 2011).

Daily science enjoyment

Each day of the daily diary, participants completed a single item 'How much do you enjoy science right now?' (1 = Like a great deal to 7 = Dislike a great deal) (London et al. 2011).

Data collection experience

Each day of the daily diary, participants reported if they had participated in data collection that day and rated how positive the experience was for days that they reported data collection (1 = Extremely Positive to 7 = Extremely Negative).

Procedure

Data collection. All participants completed a pre-test survey before beginning the intervention and completed the same post-test survey 3 months after the intervention ended. Additionally, for 25 days beginning 1 day prior to training until 1 day following the last possible day for data collection, participants were sent a brief ecological momentary assessment of their experiences. For this measure, they received an email each day with a link to a brief survey to track daily changes in science interest enjoyment as they participated in the learning experience. Participants were provided with small gift cards ($5) at the completion of the post-test survey to ensure high participation rates.

Learning experience. All participants were provided with a stipend of 1000 USD for their participation in the learning experience. This decision was made in order to ensure that students who were already impacted by the hurricane could participate without financial concerns (such as a need for additional employment) to prevent their participation. Further, this stipend is in line with stipends offered for all National Science Foundation Research Experiences for Undergraduates ($500 per week) and follows best practices that note that stipends are a key factor that allows a diverse group of students to participate in these types of programs (Gonzalez-Espada and LaDue 2006; Russell and Dye 2014). They

all were trained in a one-day training in advance of participation. Then, participants were grouped into teams of two with each team including two students from the same geographic region. The teams worked collaboratively to collect data (method described above) at their 20 targeted locations and to record the oral histories. While they could collaboratively select the dates and times for their data collection, all data collection occurred over a 2 week period in late May of 2019.

Results

Participant perceptions of the intervention and science

Preliminary analyses determined that there were no differences by gender or major (STEM/Non-STEM) in participant perceptions of the intervention. One sample t-tests (against the neutral mid-point of the scale (4)) were conducted in order to assess whether participants perceived the Forests After Florence intervention as beneficial to their learning, and to their community as well as if they perceived science as a way to address local issues. See Table 1 for results.

Pre-test and post-test

STEM identity

A 2 (gender: male, female) X 2 (time: pre-test, post-test) ANCOVA with repeated measures on the last factor and co-varied by major (STEM/non-STEM) was conducted on STEM identity. Results revealed a main effect of time: $F(2, 37) = 6.68$, $p = 0.014$, $\eta_p^2 = .15$. This revealed that participants expressed higher STEM identity at post-test ($M = 5.50$, $SD = 1.78$) than at pre-test ($M = 5.15$, $SD = 1.95$).

Resilience

A 2 (gender: male, female) X 2 (time: pre-test, post-test) ANCOVA with repeated measures on the last factor and co-varied by major (STEM/non-STEM) was conducted on perseverance, reflecting and adaptive help-seeking and negative affect and emotional response. For perseverance, there were no significant main effects, however the interaction between time and gender approached significance: $F(1, 33) = 3.42$, $p = 0.07$, $\eta_p^2 = .09$. Thus, we further probed this interaction and discovered that, for females, perseverance scores did not differ at post-test ($M = 25.05$, $SD = 6.59$) and pre-test ($M = 23.33$, $SD = 7.99$), but for males,

Table 1. Participant perceptions of the intervention and science.

Item	Mean (SD)	T	Significance
I enjoyed the Forests After Florence Data Collection	1.88 (1.18)	−11.77	.000
I learned a lot from the Forests After Florence Data Collection	2.00 (1.16)	−11.36	.000
I think my community will benefit from the Forests After Florence data collection	2.16 (1.44)	−8.33	.000
I think I will benefit from the Forests After Florence data collection	2.12 (1.22)	−10.13	.000
I feel like I belong at [the] university after the Forests After Florence data collection	2.26 (1.40)	−8.18	.000
Research can address problems relevant to my life	1.65 (1.09)	−14.15	.000
Research doesn't help people	6.55 (0.59)	27.86	.000
I can make a difference in my community through science	1.74 (1.10)	−13.26	.000
It is hard to make change as a scientist	4.53 (1.76)	1.99	.053
Helping others is a part of science	1.88 (1.37)	−10.16	.000
Getting my degree is important to me	1.26 (0.95)	−18.87	.000

perseverance scores were higher at post-test (M = 30.07, SD = 9.95) than at pre-test (M = 22.87, SD = 5.33), p = .005. For reflecting and adaptive help-seeking, we found a main effect of time $F(1, 32) = 4.24$, $p = 0.048$, $\eta_p^2 = .22$, which was qualified by a time by gender interaction, $F(1, 32) = 4.98$, $p = 0.03$, $\eta_p^2 = .13$. This revealed that for females, reflecting and adaptive help-seeking scores did not differ at post-test (M = 17.20, SD = 5.33) and pre-test (M = 17.20, SD = 5.55), but for males, reflecting and adaptive help-seeking scores were higher at post-test (M = 23.20, SD = 8.95) than at pre-test (M = 16.00, SD = 4.05), p = .004. Finally, we did not document differences in negative affect and emotional responses from pre-test (M = 17.68, SD = 5.20) to post-test (M = 19.55, SD = 5.02), $F(1, 35) = 1.44$, $p = 0.24$, $\eta_p^2 = .04$.

Daily fluctuation in STEM identity, science interest and science enjoyment

For the daily diary data, in order to explore daily fluctuations in STEM Identity, Science Interest and Science Enjoyment, unconditional models including only day of diary completion were fit for STEM Identity, Science Interest and Science Enjoyment, in order to assess the variance within and between exhibits. The inter-class correlations (ICC) for science interest (.27), and science enjoyment (.72) were sizable, and STEM identity (.08) was smaller. These ICCs indicate that we should account for daily fluctuations in responses. Thus, accounting for a random effect of day, multilevel models were estimated using the mixed command in SPSS Version 25 (IBM Corp 2017) following best practices for multilevel modeling in SPSS (O'Dwyer and Parker 2014). Models including gender, positivity and the interaction between gender and positivity were fitted, with day as a random effect.

Descriptive statistics

Participants generally reported that their daily experiences during the program were very positive (M = 1.89, SD = 1.06). Further, they reported high levels of science interest (M = 1.74, SD = 0.79), science enjoyment (M = 1.69 SD = 0.73) and STEM identity (M = 5.44, SD = 1.69).

Science interest

For science interest, multi-level modeling results revealed a significant effect of positivity, but no effect for gender or the interaction between positivity and gender. In terms of positivity, findings revealed that students reported higher science interest on days when they reported their experiences were more positive, B = .347, SE = .05, t = 6.76, $p < .001$.

Science enjoyment

For science enjoyment, multi-level modeling results revealed a significant effect of positivity, but no effect for gender or the interaction between positivity and gender. In terms of positivity, findings revealed that students reported higher science enjoyment on days when they reported their experiences were more positive, B = .306, SE = .04, t = 6.29, $p < .001$.

STEM identity

For STEM Identity, multi-level modeling results revealed a significant effect of positivity and a significant interaction between positivity and gender, but no significant effect of gender. In terms of positivity, findings revealed that students reported higher STEM identity on days when they reported their experiences were more positive, B = –.494,

$SE = .11$, $t = -4.17$, $p < .001$. In terms of the interaction between positivity and gender, this revealed that male students reported higher STEM Identity on days when they reported more positive experiences, but that female students' reports of STEM identity did not vary based on the positivity of their daily experiences, see Figure 1.

Discussion

The novel results of this study document that a STEM education learning experience can benefit students who have experienced hurricane related impacts. First, we found that students reported high levels of learning and perceived that the intervention would be beneficial to themselves and their communities. Moreover, following the intervention, participants perceived science as a tool that could be used to help their communities and help people. Further, we found that participants reported high STEM identity following the learning experience. We also found that students' daily interest and enjoyment in science was higher on days when they reported more positive experiences with participation in the out-of-the-classroom learning opportunity. Finally, we documented interesting gender differences. For resilience, we found that for male students, but not female students, the learning opportunity fostered resilience (perseverance, and reflecting and adaptive help-seeking). We also found that for male students, but not female students, STEM identity was enhanced on days when they reported more positive learning experiences. These findings highlight the benefit of relevant, community-focused STEM education learning opportunities, particular for hurricane-impacted groups of students.

As environmental and natural disasters become increasingly common, students are often left to continue their academic lives while also dealing with the traumatic after effects of damage and environmental destruction in their home communities. While scant research to date has identified successful ways to foster resilience in these students, prior research does

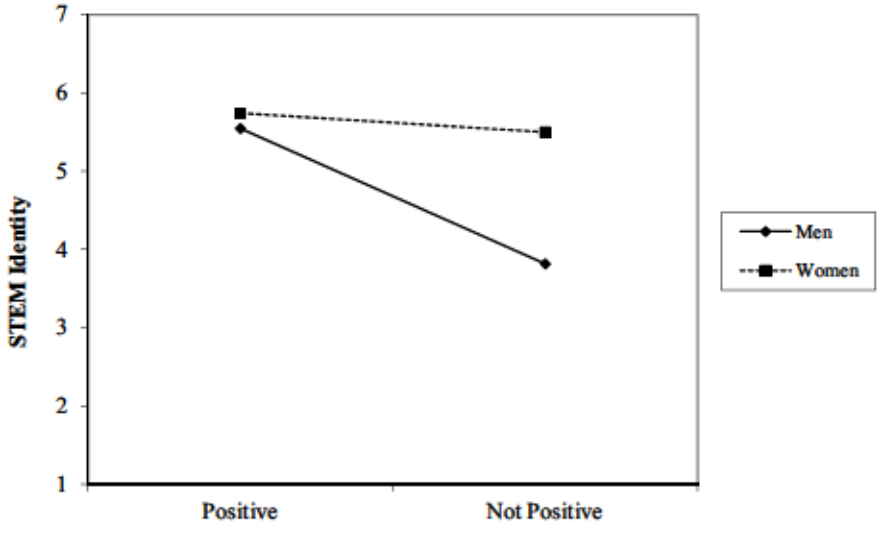

Figure 1. Daily reports of STEM identity for men and women by daily positivity. Higher Scores reflect higher STEM Identity.

indicate that disaster-impacted students are a vulnerable population in need of support. The current project aimed to address the needs of disaster-impacted students through an outside of the classroom learning opportunity. Building on principles from self-determination theory (Ryan and Deci 2017), we implemented a learning experience focused on gathering data on forest damage following recent hurricanes as well as oral histories from community members regarding environmental damage following hurricanes. The learning opportunity was structured to foster autonomy (students selected their sites), relevance (they collected the data in their home communities, gathering data that is immediately helpful for their communities as they recover and plan for future environmental disasters), and competence (they worked in teams, gathering data using rigorous methods that they were trained to employ in their own communities, drawing on their local expertise and knowledge). As expected, students reported high levels of learning, and understanding of science as a tool that can help their communities following the intervention. Further, they found the experience personally relevant and meaningful, as one participant noted: 'I enjoyed the field work and being able to discover new things throughout the day about an area I've lived in my whole life.' As another participant reflected, personal connections were especially important: 'My partner and I get along great and have become pretty good friends. I loved, loved, loved our interview experience today. Most of all though, I am really surprised and humbled by how ready the community is to participate in this project. Every time I call someone and say its research about the effects of the hurricane people jump at the opportunity and are ready to answer anything .... if what we did today was science, then that's what I enjoy!'

Further, following the learning experience, participants reported higher STEM identity. Even after accounting for their major, at post-test, STEM identity scores were higher than at pre-test. Thus, this learning opportunity fostered a sense that the students see overlap between themselves and STEM. Although the increase was somewhat modest (less than ½ point on a seven-point scale), the large effect size indicates that the difference from pre-test to post-test was sizable. This is important as STEM identity has been associated with a range of other factors including persistence in one's major, STEM self-efficacy, and STEM attitudes (McDonald et al. 2019), as well as greater feelings of belonging in STEM and in one's major, and increased STEM motivation (London et al. 2011). Prior research exploring change following formal classroom experiences (introductory chemistry classes) documents that STEM identity can change in a short period of time (Robinson et al., 2019), but our work is the first to document increases in STEM identity following a brief out-of-the-classroom STEM learning opportunity linked to students' personal communities and environmental disasters. The value students saw in the program is highlighted by comments such as this statement by a participant: 'Depending on the activity and level of involvement, I can feel very excited about my involvement with scientific studies and projects. It helps if I feel like what I am doing will result in useful information or change, and/or if I feel like I am personally getting a valuable experience from it. I enjoy how it makes me feel more involved and makes life feel more purposeful, given I am otherwise rather sedentary. Another benefit is that the experiences can bolster my resume, knowledge, and experiences which can alter my perception and outlook on the world for the better'.

Interestingly, while male participants' STEM identity fluctuated depending on if their daily experience was positive or not, female participants maintained quite a high STEM identity across the intervention. Research demonstrates that STEM identity is especially important for women as identity fuels women's STEM motivation both for school and career trajectories

(Starr 2018). Further, research shows that stereotypes linking STEM to men can reduce women's STEM identity (Starr 2018). Students also connected their learning to action in this project, which may have bolstered their sense of STEM as part of their identity; as a female participant says 'I enjoy/am interested in science because I'm super curious about all that goes on around me. Science is especially fun because you typically do more than just sit at a desk.'

What we document in our study is that women and men both benefited from this learning experience in terms of strengthening their STEM identity, but that, for men, STEM identity may fluctuate more than for women.

Further, we document that on days when participants reported more positive data collection experiences, they also reported higher science interest and science enjoyment. Interest and enjoyment are key motivational constructs that can shape continued engagement with a particular domain (Harackiewicz, Smith, and Priniski 2016; Sinatra, Heddy, and Lombardi 2015). Prior research has shown that out-of-school learning opportunities can be especially beneficial in fostering interest and that participants report science learning that occurs outside of formal science classrooms as enjoyable (National Research Council 2009). What the current study adds is an acknowledgement of the importance of exploring daily fluctuation in interest and enjoyment. STEM experiences in the field or outside of the formal classroom environment may at times be unpredictable and difficult. For instance, in the current project, students generally reported very positive experiences. However, sometimes equipment failures, difficulty in accessing hurricane damaged locations, and challenges coordinating oral history interviews created hurdles for students to overcome. For example, a participant noted 'Getting the camera to stay connected to the app was difficult, even when standing side by side'. As an example of variation in experiences, another participant rated her experience one day as very positive writing 'Put the finishing touches on our poster to put up in the Hispanic bakery. Went by the bakery and posted the pamphlet and our flyer asking people to stop in and tell us their story on Saturday'. On the day when they were planning to conduct interviews, she rated her experience as negative, saying 'We had set up an event to collect oral histories but weren't able to attract very many people to record.' What we document is that science interest and enjoyment do fluctuate and that students do not allow one negative experience or data collection day to sully future experiences. Instead, although participants generally reported their experiences as very positive, on more positive days they reported higher levels of interest and enjoyment, while on more negative days, they reported less interest and enjoyment.

Our findings for resilience were more complex. While we did find that male students were more resilient (more likely to report persevering and engaging in reflecting and adaptive help-seeking) following the learning experience, female students did not report similar gains. Thus, while there is promise that learning experiences, such as this one, can foster resilience in disaster-impacted students, the program was more effective for male students than female students. This may be a result of factors such as stereotypes that indicate that STEM is not for women (Rattan et al. 2018; Stout et al. 2011; Wang and Degol 2013). Despite the lack of growth in resilience for females, our female participants did report higher STEM identity following the intervention. As a participant noted reflecting on her experience, 'I've gained insight into a lot of potential careers.' Thus, the program did provide them with benefits, but these may not have carried over into their general academic career in the ways they seem to have for men. The experience did, however change how they view themselves and science, as exemplified by

a participant who wrote 'This project is helping me view science in a more positive light'. Thus, although we did see benefits for female students, future programs such as this should carefully attend to potential gender stereotypes and to difference experienced by men and women.

Limitations

Although the study has many strengths, it is important to note a few limitations. First, it is important to note that both male and female participants' resilience scores were still fairly low, even though they did express important impacts of the project beyond the measured constructs. This is demonstrated by a participant who said 'It is amazing to immerse yourself in a scientific way of thinking. You begin to realize that we aren't that small in the world' as well as by a participant who said 'I feel like I can make a difference in my community with this project'. Thus, while the project did positively impact students' lives, we did not see as much improvement in resilience as we would have hoped. This suggests that multi-modal interventions that also attend to students' mental health needs, financial needs or other needs following environmental disasters may be important. In fact, prior research does point to mental health needs as critically important for fostering student success following disasters (Le Brocque et al. 2017). Additionally, the intervention was rather short in duration, with students only actively collecting data over a two-week period. It may be that longer-term educational experiences are necessary to foster change in resilience. Finally, all measures were self-report measures. It would be interesting to follow these students longitudinally and to examine additional markers of STEM identity and resilience, such as grades or entry into the STEM workforce.

Conclusion

What the present findings document is the benefits of developing and implementing STEM education programs that allow students to learn STEM methodology and to participate in scientific research that are embedded in and helping their local community. Students reported high levels of science interest and engagement and showed growth in their STEM identity. The program we implemented may be modified or adapted in response to the unique environmental disasters experienced in different communities and has high potential for success in shaping students' STEM academic trajectories.

Availability of Supporting Data

Supporting data can be provided upon request to the first author.

Authors' Contributions

KLM, MK, DO and DE designed the study and trained the students prior to the intervention, MK and MC implemented the intervention, KLM surveyed participants, prepared the data file, developed the hypotheses, conducted the analyses and drafted the paper, AJ assisted in preparing the datafile and conducting the analyses. All authors read and helped to edit the manuscript.

Acknowledgments

We thank the participants, the community members who assisted the students during the intervention and the undergraduate research assistants to assisted in cleaning the datafile.

Disclosure statement

No potential conflict of interest was reported by the author(s).

Funding

This research was funded by the National Science Foundation Grant DUE- 1906366.

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