

## **1. Narrative**

### **Introduction**

Across low- and middle-income countries (LMICs), 3.1 billion people cook and heat their homes by burning solid fuels such as firewood, charcoal, and crop and animal waste [1], [2].

Approximately 80% of rural communities in LMICs rely on biomass [3] for their energy needs. The emissions from these fires, including carbon monoxide and particulate matter, result in household air pollution (HAP) that cause both acute and chronic illnesses leading to nearly three million premature deaths each year [4]–[6], and are a leading producer of black carbon emissions, a key climate-forcing agent [7].

Efficient, or improved, cookstoves are an energy solution often advanced in international development. Since the first wave of cookstove dissemination programs, little has changed in terms of the objectives and methods of the research being done. Low adoption rates have persisted [8], in part due to the behavior changes needed to use the stoves. Typically, activities to train and improve uptake rates are aimed at adult women, the primary stakeholder of cookstoves. Adults have fully formed habits and behaviors that are rooted in culture and tradition. Children are the current and future users of cookstoves. Global consumer research indicates that youth are more likely to be early adopters of new technology [9], and exert some influence in the family decision-making process [10]–[14].

This research project builds upon existing cookstove adoption research and uses *Education for Sustainable Development* [15] as a framework for examining youth as agents of change in efficient cookstoves and fuels uptake in rural Namibia. Conducted in collaboration with the Namib Desert Environmental Education Trust (NaDEET), an ESD-focused NGO located in the rural Hardap, Namibia's poorest region [16], this fellowship funded two distinct but related studies. The first was a stratified survey of two rural Hardap communities, one with a history of sending school groups annually to NaDEET's camp program, the other without. One hundred households were surveyed in each community. The second study surveyed nearly 1000 Namibian school children in grades 5-10, half of which attended NaDEET's camp in 2019. The other half were from the same schools, a grade younger, serving as a control group. All camp participants prepare their meals using improved cookstove and solar cookers, neither are common in the Hardap.

This research sought to answer the following questions, *How do children's knowledge and attitudes about new cooking technologies, such as improved cookstoves and solar cookers, impact their parents' knowledge, attitudes, and decisions to adopt these technologies? How does informal Education for Sustainable Development affect the development of children's knowledge and attitudes about household energy and sustainability?*

### **Results**

#### *Community Survey*

Demographic data collected during the survey confirmed that the control town was an appropriate control for the treatment town. Independent samples t-tests and non-parametric proportion tests were used to determine that there were no significant differences across these variables, with the exception that the control town has a significantly higher socioeconomic status. Fuel collection and usage patterns were similar across both towns.

Key differences in attitudes and knowledge about solar energy and cooking, and adoption rates of traditional cooking fires and electric stoves exists between the towns. In the treatment

town, 35 households had a past NaDEET participant in the residence. The respondents were asked to recall what they, or their family member, learned at NaDEET. Approximately 80% of these households could name at least one topic, despite an average of 3.5 years ( $SD = 0.64$  years) since participation. More than 20% of all topics were related to energy, including improved and solar cooking.

Mercy et al.'s (2008) solar energy and cooking instrument was used to determine how households felt about these topics. This scale showed adequate internal consistency,  $\alpha = 0.73$ , and a factor analysis demonstrated a single construct of measurement. Households in the treatment town had significantly more positive views about solar energy than the control, as measured by a two-samples t-test,  $t(186) = 2.48, p = 0.014$ . Comparing just the households that primarily use firewood, this difference was more pronounced,  $t(100) = 3.72, p < .001$ , Cohen's  $d = 0.75$ . Examining respondents who are parents across both towns, parents of children who attended NaDEET in the past score significantly higher than other parents in either town,  $t(163) = 2.40, p = .018$ , Cohen's  $d = 0.63$ . Examining just households that rely primarily on firewood for cooking, NaDEET households score higher than similar households in both towns,  $t(108) = 3.84, p < .001$ , Cohen's  $d = 0.75$ .

Attitudes and knowledge are important, but change occurs because behaviors. Adoption rates were determined, using Troncoso et al.'s (2013) *adoption index* formula. The adoption index was determined for each cookstove in the household, treating all devices, including traditional fires, equally. More households in the control town owned, and regularly used, their electric cookstoves. A one-way ANOVA of households in the treatment town with NaDEET experience, and those without NaDEET experience and with or without children in the house, is also significantly different,  $F(2, 97) = 3.22, p = .044, \eta^2 = 0.06$ . Independent samples t-tests were done to further examine the differences between the groups, and found that within the treatment town, households with NaDEET experience had higher mean adoption scores of electric stoves than similar homes with children and without NaDEET experience,  $t(80) = 2.27, p = .026$ , Cohen's  $d = 0.52$ . In the control, electricity is commonly the primary fuel, and thus these households have adopted their electric stoves at a higher degree than the treatment town, confirmed by an independent samples t-test,  $t(138) = 4.08, p < .001$ , Cohen's  $d = 0.69$ . There is not a significant difference between the treatment town's NaDEET households and those in the control,  $t(95) = 1.34, p = .184$ , indicating that NaDEET households are more similar to the town that primarily cooks with electricity. NaDEET households adopt their traditional cookstoves significantly less than similar households in either town.

### *Youth ESD Survey*

Throughout 2019, each participant in NaDEET's school programs was surveyed at three points; one month prior to their week-long visit to NaDEET, one week after their visit, and six months later. Students were asked about their families' fuel choices, types of cookstoves used, and their general attitudes about solar energy and cooking. Students prepared their own meals while at the camp, using both improved cookstoves and solar cookers. The majority of students (71%) report being responsible for cooking at home at least once a week, confirming that children *are* stakeholders in household cooking energy. Before NaDEET, participants and students in the control group preferred modern or improved fuels (e.g., electricity, LPG, solar, use of an improved stove) at the same proportion, approximately 70% of each group. After camp, NaDEET participants exhibit a 17% gain in their preference for these types of fuels, while the control group shows no such change,  $z = 5.72, p < .001$ . Most tellingly, however, is that students

who attended NaDEET and whose families primarily cook with firewood, 70% state a preference for a modern fuel after camp, as opposed to just 41% before camp. This is a significant increase as measured by a paired t-test,  $t(42) = 3.03$ ,  $p = .004$ , with a moderate effect size, Cohen's  $d = 0.49$ . These gains persist six-months after the camp experience, with no changes in the control group.

After cooking with solar cookers for four days at NaDEET Centre, students exhibit a marked change toward the devices and solar energy in general as measured by a comparison of scores on Mercy et al's (2008) instrument, and as demonstrated by a paired t-test,  $t(393) = 4.30$ ,  $p < .001$ , with a slight effect size, Cohen's  $d = 0.24$ . Students whose families cook with firewood, exhibit the biggest gains, when comparing against other students using an independent samples t-test,  $t(392) = 3.19$ ,  $p = .002$ , with a moderate effect size, Cohen's  $d = 0.51$ . The results of a multiple linear regression indicated that there was a significant effect between baseline attitudes (pre-survey) and NaDEET experience in predicting students' attitudes after camp,  $(F(6, 462) = 24.48, R^2 = 0.24)$ . No other demographical variable was a significant predictor, including proxies for SES. Gains persist six-months after the camp experience, with no changes exhibited by the control.

### ***Significance and Impact***

These studies provide evidence of children's ESD learning being transmitted throughout the household and community. Significant differences between the NaDEET households and the treatment community, as contrasted against the control town, indicate that energy-related knowledge and attitudes are increased as a result of NaDEET's programming. Behaviors are both difficult to change and difficult to quantify. In an effort to determine whether experience at NaDEET affects energy-related behavioral change at the household level, the degree to which households adopt their electric and traditional cookstoves was examined, where adoption score was used as a proxy for behavior. Households with NaDEET experience have higher electric cookstove adoption and lower traditional cookstove adoption scores than other households in the treatment town. These are the behaviors that cookstove researchers hope to see, and were demonstrated in the absence of the promotion of a particular technology.

In the second study, the children from the poorest towns, and those whose families rely on solid fuel combustion indoors for their cooking needs, had the lowest initial scores and responses on the energy and environment attitude questions and inventories. They also exhibited the greatest gains after just four days of ESD programming, highlighting the importance of this type of education in reaching the populations who have the most to gain from it.

Taken together, these two studies confirm what has been long known to be true about ESD, that it has the potential to transform individuals and communities. The improvement in attitudes and gains in knowledge documented in these studies suggests that a change in public opinion, even for long-held beliefs and preferences, is possible, and that it may be driven by educating youth. This has long-term and positive implications for sustainability. Not only do today's youth impact their elders' view, but if they enter adulthood with a more pro-environmental worldview and an openness to alternative sources of energy, they will be well-poised to act and potentially more likely to adopt available sustainable fuels in their future.

The cookstove sector of sustainable development has changed little in its implementation policies and strategies in the last 40 years. Few implementation and adoption studies have purposefully engaged youth in its efforts, and even fewer have employed any form of sustainability education. It can reasonably be suggested then that NaDEET, through its youth

participants, has had a positive impact on communities. And while this has implications for supporting development work committed to the realization of the SDGs, the findings described here should be particularly interesting to the cookstove research community. Differences in the adoption rates of traditional and electric cookstoves, particularly between houses with and without NaDEET experiences, appear to have occurred organically in the absence of a specific cookstove implementation program. Without advancing a particular improved cooking device or brand, NaDEET's ESD programming changed participants' opinions about improved and sustainable household energy.

### ***Future Research***

The findings of these studies affirm the benefits of a multidisciplinary approach to cookstove implementation programs. Specifically, NaDEET had an impact on energy attitudes at the community level, indicating that youth education is an effective tool for communicating and affecting change. A logical next step would be to conduct a cookstove implementation program in collaboration with an organization such as NaDEET to ascertain the feasibility and efficacy of using ESD as an intentional piece of a behavior change communication framework.

This dissertation made use of the Adoption Index [18], [19] to better understand participants' commitment to both their traditional cookstove and any improved or other cooking device in the home. It may be possible that by treating all cooking devices equally, and by applying the same metrics to each, that we may better understand a new technology's potential to be taken up by a recipient community. That said, there are a number of current issues with, and limitations of, the Adoption Index, and this idea needs further consideration. First and foremost, the metrics used to report the successes of cookstove implementation program varies widely with few areas of overlap [20], [21]. The Adoption Index, commissioned by the Clean Cooking Alliance, is a first step to address this issue. However, since its publication in 2013, few studies use or report this index. Further, there are issues with the index itself. As the cookstove community moves away from definitions and expectations of *exclusive use* toward *cleaner stacks* [22], this index does not adequately encompass the nuanced ways that energy sources are prioritized within the home, and over time. Future research in this direction, including some guidance on universal metric reporting, particularly those that incorporate temporal and seasonal changes to cookstove stacking, would advance the field in terms of being able to distill and share best practices from a collection of disparate studies.

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## **2. Publications**

The following publications acknowledge, or will acknowledge, the Link Foundation's support of this work:

Lindgren, S. (2020). Clean cooking for all? A critical review of behavior, stakeholder engagement, and adoption for the global diffusion of improved cookstoves. *Energy Research & Social Science*, 68, 101539.

Lindgren, S. (September 21, 2020). A broader definition of cookstove stakeholder: The inclusion of youth and education in sustainable energy development. Published Conference Proceedings from the 8<sup>th</sup> International Conference on Sustainable Development.

Lindgren, S., & Keding, V. (October 8, 2020). Recycled fireballs: Transmission of youth EE skills across communities. Poster Presentation to the 17<sup>th</sup> Annual National American Association of Environmental Education Research Symposium.

Lindgren, S., Elliott-Litchfield, J.B., & Bond, T. (in preparation). The impact of Education for Sustainable Development and household cooking energy choices: Evidence from rural Namibia. Intended publication: *Energy for Sustainable Development*.

Lindgren, S. (in preparation). Youth, Cookstoves, and Education for Sustainable Development: A Proposed Research Agenda for Improved Cooking. Intended publication: *Energy Research & Social Science*.

## **3. How did the fellowship make a difference?**

Without the generous support of the Link Foundation's Energy fellowship, this dissertation could not have happened. My advisor retired during my third year of grad school leaving me without a lab but with the opportunity to chart my own course. With that opportunity came the task of funding my own research. The logistics of my dissertation research was quite expensive requiring a relocation to Namibia for six months. The Link Foundation's support allowed me to travel to, and afford life in, Southern Africa, which included the rental of a small house and a car so that I could travel between research sites which were hundreds of kilometers apart. Parts of this research could have occurred remotely but would have suffered from a lack of context and perspective. Spending time in the communities in which I collected data allowed me to understand how people live and the forces that have shaped their daily life. For instance, in the two towns I conducted my research in, fewer people now have access to electricity than they did during Apartheid. This is directly related to landownership, which is still predominantly owned by white people, and Apartheid-era economic policies, which in turn have created issues of climate justice amongst others. The Link Foundation's support allowed me to understand, to the extent that it is possible as a white outsider, the communities in which I was collecting data and writing about. This dissertation has already yielded several conference presentations and multiple publications are in-preparation to be submitted to journals this coming academic year.

Because of the support from the Link Foundation, I was able to make a donation to NaDEET, the NGO that opened its doors to me and let me follow their work for six months, and interview people associated with their work in the past. The work they do to promote

sustainability has been recognized by UNESCO, and is an important part of Namibia's climate change mitigation agenda.

And finally, the Link Foundation's support allowed me the freedom to focus on research in a way that I hadn't had time to do previously. Before arriving in Namibia, and throughout the duration, I worked on a systematic literature review examining the roles of behavior change communication and youth in cookstove adoption studies. This review was recently published in *Energy Research and Social Science*, a peer-reviewed journal with an impact factor of 5.5. The time to contribute intellectually to the field that I study was incredibly valuable.