Creating a CIT-E Framework for Addressing Infrastructure Inequities through the Use of Case Studies

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Abstract

Inequities in infrastructure continue to exist in our society often due to previous generations' choices, constrained resources, and lack of stakeholder engagement in the infrastructure planning and decision-making process. Engineers today have an opportunity to rectify these past injustices. One such opportunity is contained in the Bipartisan Infrastructure Bill which contains funding for projects focused on previously underserved communities, and reconnecting and rebuilding communities that were divided by transportation infrastructure decades ago and have long been overlooked. Repairing inequities in infrastructure can allow affected communities better access to transportation, clean water, economic and community development, and resilient infrastructure. As civil engineering educators, it is our responsibility to apprise students of these past inequities, instruct them in recognizing and understanding their impacts and improving the lives of all individuals that infrastructure projects affect.

This paper aims to outline a framework developed as part of the Center for Infrastructure Transformation and Education (CIT-E) community of practice to assist and empower faculty in developing lessons related to past or present infrastructure inequities based on case studies that could be used in any course. The broad goals of the lessons that are developed using this framework are for students to be able to: 1) explain inequities in the context of infrastructure and its development, 2) describe and discuss the historical context with which infrastructure was developed and constructed, and how communities were affected by it, and 3) generate, create, or propose solutions to rectify past infrastructure inequities, while designing more equitable solutions in future work. This framework will help guide lesson development by providing ideas for creating assignments (for both before and after class), discussion points, activities, and other lesson materials to teach undergraduate and graduate students about the effects of infrastructure inequities and how to mitigate negative effects. The framework will provide a solid foundation for faculty to take a case study or historical example and create lesson objectives, design student exercises to be used before, during, or after a class session, and create materials to support student learning. The CIT-E community of practice is also applying this framework to create several lessons using case studies that are currently under development and will be available for use by any faculty member in the future.

Keywords: JEDI, Infrastructure, Education, Diversity, CIT-E

Introduction

The United States has developed infrastructure to promote and foster growth in many areas since the earliest days of the nation. As with any infrastructure project there have been those who have benefited greatly, those who received no benefit, and unfortunately, those who have suffered

social and economic injustices. Determination of who benefited and who was disadvantaged often was related to property ownership, race, or socio-economic status.

As an example, in the first half of the 1800s, during the construction and the early days of operation of the Erie Canal, which brought much prosperity to those who were able to own real estate alongside its path, black members of the community were barred from owning properties alongside the canal [1]. Similarly, later in the second half of the 1800s, Native Americans were stripped of their lands or accepted deals, which they did not fully understand, from people who amassed large amounts of land and built fortunes by building or financing projects like the transcontinental railroad and other railways [2].

Even the 20th century saw the recurrence of non-equitable practices, such as redlining to designate "risky" neighborhoods which often resulted in the denial of home loans and development, dividing minority city neighborhoods by the routing and construction of interstate highways through them, and prohibitions on selling property in certain areas to people of color. These practices were frequently sanctioned and enforced by the Federal Government, real estate organizations and their codes of ethics, local municipalities, and neighborhood associations [3]. Practices of unequal development of infrastructure run deep in the many elements of the built environment and have severely impacted the ability of people of color, especially African Americans, to own property, build intergenerational wealth, and advance to a higher socioeconomic status as they were denied access to the best schools, services, and infrastructure.

Civil engineers, through the exercise of their profession, have a direct impact on communities and individual lives, either positive or negative, especially concerning infrastructure systems. It is necessary to include Justice, Equity, Diversity, and Inclusion (JEDI) topics throughout the curriculum in order to develop socially conscious engineers. Given the impact of engineering students' future work, programs need to prepare them not only with the knowledge to tackle the technical challenges but also with the historical and cultural perspectives as well as the critical thinking skills to enable social justice and equity in infrastructure [4]. One way to educate future generations of professionals who shape the built environment, i.e., engineers, builders, architects, construction managers, urban planners, and policymakers, is by revisiting our history and the many landmark projects that shaped this nation but also contributed to social inequities [5]. Large housing and infrastructure projects are well-documented in the literature related to the built environment and can be used as case studies to help students understand how inequities have been engineered in our society, often supported by misguided policies. The goal of this work, which is still in progress, is to demonstrate how the framework developed by the authors can facilitate the development of lessons based on case studies that highlight JEDI aspects in infrastructure.

Background

The motivation for the work presented in this paper stems from the need to address inequities in our infrastructure builds. The passage of the new bipartisan infrastructure bill aimed to improve and update infrastructure across the US. The "Infrastructure Investment and Jobs Act" passed on November 6, 2021 by the US Congress and provides $1.2 trillion for infrastructure. The bill has specific plans to rebuild and improve road, bridge, and railroad infrastructure, expand access to clean drinking water, ensure access to high-speed internet, tackle the climate crisis, advance environmental justice, and lastly to *"invest in communities that have too often been left behind"* [6]. Significantly, the bill also aims to tackle and repair historical inequities through programs such as "restoring community connectivity", and "retrofitting and mitigating highways or other transportation facilities that create connectivity barriers". Other programs that are part of the bill include the improvement of infrastructure to address repetitive flooding, training resources in rural communities, and improved access to public transportation [7].

Since a significant amount of money and effort will be dedicated to addressing past inequities and disparities that arose from infrastructure development, it is important to educate future engineers on the topic. These lessons would need to be more than just the history of infrastructure, as they need to be developed in such a way that students can critically analyze the context and background in which infrastructure was developed. This includes interpreting the reasoning with which decisions were made, which stakeholders were involved in making these decisions (and which were excluded), which groups were advantaged or disadvantaged, and the motivations or rationales behind them. By showcasing these past inadequacies, future engineers would be better able to recognize, reduce, or eliminate potential infrastructure inequities [5] and produce designs that would be fairer to all stakeholders impacted. At a higher level, to develop engineers with a JEDI mindset would require a change in engineering focus towards repairing past infrastructure inequities as well as addressing current harms and considering future improvements to ensure new harms are not created [8].

Decision making that follows JEDI principles is also ingrained in the American Society of Civil Engineers (ASCE) code of ethics which was most recently updated in October 2020 [9]. The code instructs engineers to "treat all persons with respect, dignity, and fairness in a manner that fosters equitable participation without regard to personal identity". It also addresses ethical responsibilities in several areas of the profession, namely: society, natural and built environment, profession, clients and employers, and finally peers. JEDI principles apply to several of these responsibilities, particularly under the responsibilities to "Society":

- part (a), *"first and foremost, protect the health, safety, and welfare of the public"* - The word public encompasses everyone, not just the people in power, or the individuals who directly benefit from the development of a civil engineering project.
- part (b), *"enhance the quality of life for humanity"* - once again the word "humanity" encompasses everyone.

- part (f), *"treat all persons with respect, dignity, and fairness, and reject all forms of discrimination and harassment"* - designs that do not take into account the wellbeing and concerns of all individuals can be a form of harassment and discrimination.
- part (g), *"acknowledge the diverse historical, social, and cultural needs of the community, and incorporate these considerations in their work"* - This part of the code is directly related to the goal of the work described here, where future engineers should aim to avoid future inequities in infrastructure projects.
- part (h), *"consider the capabilities, limitations, and implications of current and emerging technologies when part of their work"*.

In a more global context, the United Nations (UN) Sustainable Development Goals (SDGs) can be used to influence the work of civil engineers to be more in line with JEDI principles as well [10]. The 17 UN sustainability goals encompass every aspect of human life, and by the nature of their work, civil engineers have the ability to influence human lives more than many other engineering professions. Infrastructure projects can influence society and improve, or exacerbate, societal disparities. Thus, work performed on goals such as 1) No poverty, 2) Zero Hunger, 3) Good health and well-being, 5) Gender Equality, 6) Clean Water and Sanitation, 7) Affordable and clean energy, 10) Reduced inequalities, 11) Sustainable cities and communities, 12) Responsible consumption and production, 13) Climate action, 14) Life below water, and 15) Life on land, will employ civil and environmental engineers in the US and throughout the world who need to be conscious of the importance of considering JEDI principles in design and planning.

The UN SDGs mentioned above are closely linked to eliminating undesirable outcomes such as poverty, inequalities, and injustice, which mirror the requirements of the Engineering Accreditation Commission (EAC) of ABET's Criterion 3, Student Outcomes, Outcome 4, which states that students should attain the ability "... to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts" [11]. Furthermore, the program criteria for Civil Engineering or similarly named programs states the curriculum must include the application of "... iii) principles of sustainability, risk, resilience, diversity, equity, and inclusion to civil engineering problems; v) an engineering code of ethics to ethical dilemmas" [12].

With these considerations in mind, the authors of this paper developed a framework to facilitate the creation of lessons based on infrastructure related case studies that can address JEDI issues. This paper will explain how this framework was used to create lesson outlines based on two case studies that highlight inequity in housing and urban planning.

Methodology

In August 2023, 28 participants from different universities across the United States convened

virtually for the two-day CIT-E Workshop: Teaching Future Engineers about Equitable Infrastructure. From this workshop, subgroups of individuals with shared interests in teaching civil engineering students about infrastructure inequalities were developed. One of these subgroups focused on the topic of repairing social inequities of infrastructure, looking specifically at developing ways to mediate and correct past issues and learn from them to avoid creating future injustices. The goal was to create lessons and materials that faculty could incorporate into courses that would help create an engineering social justice mindset, where future engineers would seek to create an infrastructure that would eliminate disabling barriers, and work with stakeholders historically impacted but often ignored. Integrating a social justice mindset in engineering would normalize universal design while reducing the social acceptability for "unforeseen" consequences." This group subsequently convened bi-weekly with the aim of collaboratively developing a series of comprehensive lessons that could be shared with the larger CIT-E community of practice and would follow the established CIT-E lesson template.

Motivated by the literature mentioned previously, the group decided to focus on the use of case studies of past and current infrastructure projects that resulted in social inequities as a vehicle. Case studies have been shown to broaden students' understanding and increase their sense of empathy and commitment to principles of social justice. Students also reported being better able to draw connections and evaluate decisions through the use of case studies as well as liking their use more than lectures, textbooks, or readings [5]. In civil engineering education, case studies are used to provide students with the context for an in-depth understanding of real situations or problems. They enrich the learning experience by presenting practical, contextual, and multidimensional insights that contribute to well-rounded engineering problem-solving development [13]. In addition to developing a number of lessons, the group decided to create an overall framework that they and other faculty could subsequently use to guide the development of their own lessons that were based on case studies with an emphasis on repairing infrastructure inequities. This was motivated by the feeling many faculty have that they are unqualified or uncomfortable addressing these topics, more from a lack of knowledge rather than desire [14,15, and 16]. The aim is to assist faculty and make it easier to adopt case studies and create lessons that embrace JEDI topics for inclusion in their courses. As part of the process of developing the framework, the group also created two example lessons based on case studies, with plans to continue to develop a robust collection of lessons that can be used by any faculty member and can be inserted into existing courses or course modules. The resulting materials include background information on the case study, recommended lesson objectives, pre and post-class activities, class exercises, and detailed lesson plans, all designed to enrich educator's curricula with a focus on addressing infrastructure inequities.

The two example lesson outlines based on case studies being developed concurrently with the framework to demonstrate the complex nature of infrastructure inequities are: Levittown (housing) and Robert Moses (transportation and urban planning). The lesson outlines being

developed for these two case studies conform to the CIT-E Lesson Outline template (see Appendix 1).

Results

This framework developed, and being currently added to, can be used as an aid in the development of lesson plans that can be used in civil and environmental engineering, engineering and society, JEDI in engineering, infrastructure, or similar courses. Lesson outlines on two case studies developed using the framework as examples are also described.

The goal of this project was to provide a tool that would allow and facilitate faculty members to include case studies on issues of social justice related to infrastructure. Lessons developed using this framework will enable students to recognize inequities in infrastructure, analyze them, and empower them to generate ways to repair and address current or ongoing injustices and to reduce their occurrence in future infrastructure work. Presented here is the broad outline of this framework. The framework with detailed explanations and extensive resources will be made available on the CIT-E Website later in 2024 after revisions and an evaluation. While this paper focuses on how the framework can be used, a companion paper provides the details of the framework and its development [17]. The use of this framework will aid in eliminating barriers, real or perceived, that faculty may have concerning their lack of expertise or discomfort with overarching topics of social justice related to infrastructure. In addition, several complete lesson outlines are being developed and will also be made available for use by anyone interested through the CIT-E website. The outline of the framework includes:

Step 1. Select a topic or an issue to be addressed

- Topics or issues addressed could be historical or contemporary
- Local issues are recommended since they are more relatable
- Historical issues provide an opportunity for the impacts to be analyzed in depth
- Contemporary issues highlight the fact that inequity can still be a problem

Step 2. Select a case study that illustrates the topic or issue in question

- Case studies can also be historical or contemporary
- Once again local case studies are recommended for better engagement
- A repository of case studies will be available to instructors through the CIT-E Canvas page hosted by the University of Wisconsin-Platteville

Step 3. Determine the amount of background information needed

The following elements are proposed:

- Defining and Exploring Inequity - students explain what infrastructure inequities are
- Background, context, historical perspective – students become aware that infrastructure placement affects residents' lives, and can create inequities in terms of access to work, food, housing, and education, among others.
- Impact – who and what – students identify the stakeholders and how they were

affected – historical perspective for past decisions for infrastructure placement
    - Remedy – Students generate ideas, design, and plan for remediation; this could include old infrastructure deconstruction, economic and policy proposals, and/or new infrastructure implementation that would work to eliminate inequities.

Step 4. Select the level at which the topic or issue will be addressed

- To accommodate classes offered from freshman to graduate level, the framework includes possible learning objectives addressing lower, middle, and upper levels of Bloom's Taxonomy
- If more than one element is considered, different Bloom's Taxonomy levels could be selected for each element

Step 5. Select objectives for the lesson

- Multiple objectives are available in each category of the framework to facilitate the process
- Additional objectives may be developed by the instructor as needed

Step 6. Select pre-class, in-class, and post-class activities

- A wide variety of activities are proposed for each element and each Bloom's Taxonomy level

Lesson Outlines

Using this framework two lesson outlines based on case studies are being developed concurrently with the framework to demonstrate the complex nature of infrastructure inequities. The lessons, Levittown (housing) and Robert Moses (transportation and urban planning), will conform to the CIT-E Lesson Outline template (see Appendix 1).

Levittown, synonymous with the post-World War II suburban housing boom in the United States, stands as an iconic example of mass-produced, affordable suburban communities [18]. The first Levittown, located on Long Island, New York, emerged in 1947 and became a model of subsequent Levittown developments in other states. The Levittown model prioritized quick and economical building methods, making homeownership accessible to a broad swath of the American middle class. Due to The Veterans Administration and the Federal Housing Administration (FHA) policies along with restrictive covenants, these homes were only available to Caucasian families [19]. While Levittown symbolizes certain aspects of the American Dream, it also serves as a reminder of systemic discrimination suffered by marginalized non-white communities and perpetuated social inequalities.

Robert Moses was a prominent and influential figure in urban planning and development, particularly in the mid-20th century in the New York metropolitan area. Moses held several key positions in New York City and state government, allowing him to shape the city’s infrastructure and landscape. While he is credited with numerous public works projects that transformed New York, including bridges, highways, and parks, Moses’ approach to urban planning has been

criticized for contributing to social inequalities and perpetuating racial and economic segregation [20].

Both the creation of Levittown and Moses' urban planning played important roles in shaping the post-war American landscape and infrastructure development, contributing to suburbanization trends, and influencing social and spatial patterns in cities and surrounding areas. Adding to these, the complexity of their implications in the current socio-economic environment makes these two case studies particularly significant to demonstrate the different learning levels available in the proposed framework.

The application of these steps to one of the case studies (Levittown) is shown in the preliminary draft lesson outline in Appendix 2. It includes learning objectives, instructor resources as well as suggested pre-class, in-class, and post-class activities.

Conclusions

The CIT-E community of practice has since its inception established an online repository of educational material that relates to infrastructure on a broad spectrum of topics. Interested faculty can become members of the CIT-E community and have free access to all of these resources for their instruction preparation. The framework and case study lesson outlines developed by the authors and described in this paper will be incorporated as part of the vast knowledge base housed in the CIT-E repository. These two case study lesson outlines are being developed simultaneously and in conjunction with the creation of the framework to provide a practical connection and real-time proofing of the framework as it was developed. The lesson outlines developed from these case studies are the first two example lessons that will eventually be part of the materials available for use from the CIT-E website. The CIT-E community, to ensure the quality and rigor of the lesson outlines, employs a peer review process, vetting the material for quality and accuracy, before being made publicly available on the CIT-E site for all to use. The authors envision that eventually faculty outside the original core group that wrote this paper will use this framework to develop lessons, based on case studies, for their courses and possibly to contribute as new material to share with the community of practice.

Future Work

The work presented in this paper showcased the background and the development of the framework along with two example lesson outlines for introducing social justice in civil engineering classrooms. The authors aim to continue to develop these materials as well as evaluate and assess the impact these lessons have on 1) student perceptions and understanding of infrastructure inequalities, and 2) students' ability to plan and develop solutions for eliminating future social injustices. This assessment will be implemented in different departments the authors belong to, across seven universities. The results of this assessment will be presented in future work.

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Appendix 1 - CIT-E Lesson Outline template

Appendix 2 - Example Lesson Outline for the Levittown Case Study

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Appendix 1 - CIT-E Lesson Outline Template

A. **Authors –** list of authors and affiliations
B. **Contributors –** list of contributors and affiliations (contributors provided insight but did not work directly on the lesson materials.)
C. **Summary/Vision Statement** – 3-5 sentence abstract of the lesson
D. **Instructor Resources –** remembering that not everyone who uses this lesson will be as expert as you, the lesson developers, so please provide some background readings, websites, etc. to help bring the instructor up to speed
E. **Assumed pre-class knowledge/skills** – what do you assume that students will already know when they begin this lesson?
F. **Potential connections to other topics in this lesson** – (if this lesson is to be part of the CIT-E model introductory infrastructure course, note the other lessons that this connects to)
G. **Learning Outcomes** – complete this sentence ("at the end of the lesson, students will be able to…") with appropriate Bloom's verbs.
H. **Pre-class activities** – what do you expect students to do before the attend class?
I. **In-Class activities** – what will students do in class? When providing materials for this part (e.g. board notes, PowerPoint slides), remember that the instructor will likely not be as expert as you, the lesson developers, are. So provide guidance to them.
J. **Post-class activities** – what will you expect students to do after class (e.g. homework)? Be sure to include an answer key!
K. **Possible Modifications/customization (optional)**

Appendix 2 - Levittown Lesson Outline

A. **Authors –** Scott Hamilton, Nicholas Tymvios, Irma Wang, Thais Alves
B. **Contributors –** list of contributors and affiliations (contributors provided insight but did not work directly on the lesson materials.)
C. **Summary/Vision Statement** – This lesson's objective is to point out recent (within the last 100 years) government policies with racist intent and to have students understand the effects both immediate and long lasting **(FRAMEWORK STEP 1).** Levittown is the name of several large suburban housing developments created in the United States (including one in Puerto Rico), the first being on Long Island. Built after World War II for returning veterans and their new families, the communities offered attractive alternatives to cramped central city locations and apartments, providing some of the first suburban communities. The Veterans Administration and the Federal Housing Administration (FHA) guaranteed builders that qualified veterans could buy housing for a fraction of rental costs. However, due to FHA and VA policies and restrictive covenants, these homes were only available to Caucasian families. **(FRAMEWORK STEP 2)** The lesson will challenge students to come up with remedies for past wrongs and their longtime impact on education, wealth accumulation, and health, etc.
D. **Instructor Resources – (FRAMEWORK STEP 3)** remembering that not everyone who uses this lesson will be as expert as you, the lesson developers, so please provide some background readings, websites, etc. to help bring the instructor up to speed [Need to annotate resources to guide future users]
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E. **Assumed pre-class knowledge/skills** – **(FRAMEWORK STEP 3)** what do you assume

that students will already know when they begin this lesson? None

F. **Potential connections to other topics in this lesson** – (if this lesson is to be part of the CIT-E model introductory infrastructure course, note the other lessons that this connects to) NA, likely will go into more advanced courses or other courses.

G. **Learning Outcomes** – **(FRAMEWORK STEPS 4 AND 5)** complete this sentence ("at the end of the lesson, students will be able to…") with appropriate Bloom's verbs.
   a. Describe housing inequality in Levittown
   b. Understand origins and persistence of housing inequality till today, such as Levittown is less diversified compare to others in the county
   c. Explain existing inequalities could perpetuate those inequalities over time for people through wealth accumulation
   d. Develop a framework to address Levittown's housing inequalities from perspectives in legal/policy, financial institutions, social acceptance, and education
   e. Define the following terms: generational wealth, restrictive covenants, suburbs, government backed loans.
   f. Summarize the historical background and original goals of the Levittown communities and identify who these were supposed to benefit.
   g. Identify groups that were excluded; explain why and how this was done.
   h. Analyze and calculate the financial losses to excluded groups due to these policies.
   i. Propose remedial actions that could repair and fix these past inequities; discuss obstacles, blocks, and difficulties enacting them as well as opportunities that they present.

H. **Pre-class activities** – **(FRAMEWORK STEP 6)** what do you expect students to do before they attend class?
   a. Background Reading:
      1. The controversial history of Levittown, America's first suburb or
      2. Levittown History Collection or
      3. A history of the Levittown housing developments
   b. Watch YouTube video:
      1. Levittown: A living history (28 mins) or
      2. Levittown: Separate and Unequal (9 mins)

I. **In-Class activities** – **(FRAMEWORK STEP 6)** what will students do in class? When providing materials for this part (e.g. board notes, PowerPoint slides), remember that the instructor will likely not be as expert as you, the lesson developers, are. So, provide guidance to them.
   a. Discussion: What were the goals of Levittown
   b. Presentation - Look at laws that prevent home ownership by blacks, covenants, policies [Source: The Color of Law (Rothstein 2017)] Note also Jews were

excluded - despite the Levit's being Jewish.

c. Presentation - Look at the population of the US in 1945, Look at the number who served in the military, look at African American participation. What % of houses should have gone to African Americans?
d. Student ACTIVITY Generational Wealth
    i. Look at the Zillow map for Levittown, NY. What seems to be the range of the sale prices for homes currently for sale?
    ii. What is $8,000 in 1948 dollars today? [e.g. Use CPI inflation calculator $8,000 in 1948 is worth $101,917.34 today]
    iii. Discuss what the practical effects of this are today for excluded populations
e. Student ACTIVITY: Education
    i. Look at Niche for school districts rating in Levittown. Compare student demographic and test scores in different school districts: Jericho Union Free School District, Hempstead Union Free School District
    ii. Discuss the causes and impacts of lower school education to African American families
f. Student ACTIVITY: Develop framework on eliminating housing discrimination
    i. Discuss the different elements need to be addressed to eliminate housing discrimination
    ii. instruct students to work in groups, each group draft a list of actions towards one element
g. Student ACTIVITY: In small groups 3-4, brainstorm ways to repair or fix the past injustices of policies seen in Levittown today. Share with class
h. Class Discussion: As a whole class list the opportunities of the fixes and repairs listed by the groups; list the challenges and potential obstacles to enacting them.
i. For a deeper and more nuanced discussion, look at the size (square footage) of the Levittown houses today; what does this tell us? [additions, expansions, improvements] Does this change things (loss of generations wealth, remedies proposed, etc.)?

J. Post-class activities – **(FRAMEWORK STEP 6)** what will you expect students to do after class (e.g. homework)? Be sure to include an answer key!

K. Possible Modifications/customization (optional)

a. Discussion Questions (i - xi take from "Journey to Reconciliation Dialogue Prompts", Greenwood Rising Black Wall Street History Center, Tulsa, OK, 2023)
    i. What steps can we take to begin healing from the historical; damage of racial injustice? Who in your circle should take the first step and what should it be?
    ii. How much progress in race relations have been made?
    iii. If "reparations" aim to repair damage from injustices, what would

reparations look like for you? How would they directly or indirectly impact you and your community?

iv. How would Black economic empowerment change race relations?
v. Is it possible to heal historical racial trauma without reparations? Why or why not?
vi. How much progress is possible outside white dominated systems like banking and finance?
vii. What are the pros and cons associated with reparations?
viii. Do lasting changes only happen in government? How important is political engagement?
ix. How do you deal with friends and family who have different political views? Do you engage if there are moral disagreements?
x. What are your sources of information? Do you think there is such a thing as one truth? How does that affect how we deal with each other?
xi. What are the sacrifices associated with racial justice? Who must be willing to make them?