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Examining How Ideologies Mediate Reasoning About and Modeling Spatial Phenomena in Preservice Teacher Education

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Examining How Ideologies Mediate Reasoning About and Modeling Spatial Phenomena in Preservice Teacher Education

by

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Dissertation

Presented to the Faculty of the Graduate School of

The University of Texas at Austin

in Partial Fulfillment

of the Requirements

for the Degree of

Doctor of Philosophy

The University of Texas at Austin

August 2022

Dedication

This is dedicated to five incredible women:

To Kaitlyn, thank you for your constant patience and kindness.

To Taylor, thank you for teaching me how to be strong – physically and mentally.

To Savannah, thank you for always answering the phone and saying the right thing.

To Julie, thank you for every late-night neighborhood walk and five years living together.

To Nisha, thank you for tricking me into doing this - then doing every step with me, side by side.

I love you all so much.

Acknowledgements

I would like to thank the members of my committee. Dr. Anthony Petrosino, thank you for noticing me during my first semester, taking the time to invest in my intellectual development, and always reminding me to take a deep breath and enjoy my time here. Dr. Tia Madkins, thank you for your trusting in me to join your research team, supporting me through difficult transitions, and always being a phone call away. Dr. Flávio Azevedo, thank you for endless book recommendations, detours that lead nowhere and everywhere, and for always grounding me. Dr. Catherine Riegle-Crumb, thank you for your flexibility and reliability. Dr. Pratim Sengupta, thank you for your scholarship and mentorship – both are braided with kindness.

Outside of my committee, I would like to acknowledge and thank Dr. Emma Gargroetzi and Dr. Jill Marshall. Dr. Gargroetzi, thank you for many conversations over coffee. They were pivotal to how I think about starting (and finishing) research. Dr. Marshall, thank you for every conversation in your doorway that probably lasted too long. You inspired me to focus on place in my research and taught me the importance of knowing and appreciating the history of Austin.

My graduate cohort reached beyond years and across disciplines. A special thanks to two colleagues. Kemper Lipscomb – thank you for believing in my ideas and working to realize them in the classroom. Sneha Tharayil – thank you for five wonderful years sharing an office, laughs, and tears. Thank you to members of my cohort, specifically Ursula Nguyen, Tati Russo-Tait, and Daniel FitzPatrick. I am happy I get to cherish your mentorship and friendship for years to come. Thank you, to many others: Karina Méndez Pérez, Marc Sager, Julianna Washington, Mai Zaru, Khan Tran, Domingo Martinez, Madison Andrews, KT Doerr, Gareth Gingell, Christina Baze, Sarah Harris, Joel Walsh,

Ingrid Ristroph, Kevin Nguyen, Adam Papendieck, Natalie Freed, Boram Lee, and Hannah Lee. You all had a hand my development.

And finally, I would like to acknowledge my family. Thank you to my mom and dad, Virginia and Kyle Sherard. You supported me in every step of my education. Thank you to Kyle Jr., Rush, and Emma – my brothers and sister-in-law. Thank you for your endless support.

Abstract

Examining How Ideologies Mediate Reasoning About and Modeling Spatial Phenomena in Preservice Teacher Education

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The University of Texas at Austin, 2022

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This dissertation is organized around three articles concerned with ideologies and how they are reproduced or contested when preservice teachers model complex spatial phenomena. Each article is designed to stand alone, but when taken together, they trace how ideologies are reproduced within objects (ex. maps, models, and physical spaces) and through social and technical interactions (ex. talk between participants or talk between participants and an objects) as preservice teachers reason about spatial phenomena like racial segregation and urban heat island effect.

The first article is a theoretical argument for why the learning sciences must politicize our inquiries into model-based reasoning in science education. I focus specifically on agent-based models about sociopolitical phenomena. I merge theories about modeling from the philosophy of science (Giere, 2004, 2009, 2010) and theories about ideologies from cultural studies and the learning sciences (Hall, 2006; Philip, 2011) to position modeling as an ideological enterprise. Then, I draw on critical discourse analysis (Fairclough, 2004) to synthesize a set of analytical tools which support researchers in tracing how ideologies are either embedded in classroom objects (ex. maps

or models) or reproduced through interaction (either with maps and models or with other people).

The second article is an empirical study about ideologies within classroom objects (ex. maps and models). This study traced the ideologies about race which emerged throughout a three-day lesson series where a group of 15 preservice elementary teachers used, evaluated, and revised the NetLogo segregation model (Wilensky, 1997). Using methods of critical discourse analysis, I analyzed the teachers final revised models and model presentations to understand what ideologies about race were reproduced or contested. The study showed that, despite having read about the *de jure* causes of *racial* segregation (Rothstein, 2016), teachers reproduced colorblind (Bonilla-Silva, 2014) and liberal (Haider, 2018) racial ideologies. These ideologies portrayed segregation as a class-phenomenon (not a racial phenomenon) which emerged because of the personal preferences of individual houses for similar or different neighbors (a *de facto* explanation).

The third article is an empirical study about ideologies within social and technical interactions. This study traced ideologies about place (Cresswell, 1996) which emerged throughout a six-day lesson series where a group of 8 preservice teachers created a model to explain urban heat island effect (Oke, 1979). This paper reported on an intrinsically interesting case (Stake, 1995) of a single student, Aaron, and his efforts to reason about urban heat island. Using methods from progressive refinement of hypothesis (Engle, Conant, & Greeno, 2007) and critical discourse analysis (Fairclough, 2004), I analyzed Aaron's interactions with maps, models, virtual neighborhood tours, and his classmates to understand what ideologies of place were reproduced or contested throughout the six-day lesson series. The study showed that Aaron continually drew upon an ideology which portrayed the eastern part of the city as 'the slums' and the western part of the city as 'the

good part.' This ideology supported Aaron's efforts to explain why East Austin was warmer than West Austin, and ultimately informed his group's final model about urban heat island effect.

To conclude, these three articles connect and build upon research in the learning sciences which explore modeling and ideology in science education. I demonstrate that ideologies are social and technical achievements by examining the ideologies reproduced within models themselves and through interactions while modeling.

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Article 1: Politicizing Agent-based Models about Sociopolitical Phenomenon in Science Education

INTRODUCTION

Scientific models are representations which explain and predict the behavior of phenomena in the world (Giere, 2004, Bamberger & Davis, 2013). Creating, using, evaluating, and revising models are central practices of science (Hestenes, 1992; Giere, 1992, Stewart & Golubitsky, 1992), and as such, have earned a canonized place in science education (Clement, 2000; Justi & Gilbert, 2002, National Research Council 2012, NGSS Lead States, 2013). Traditionally, research in the learning sciences has centered disciplinarily accepted types of modeling (Wagh et. al., 2021). We have focused on how to align students' modeling knowledge and practice with that of subject-matter experts (Lehrer, 2009). However, a shift is occurring in the learning sciences. We are called to generate theories of learning which link broader power dynamics in society with moment-to-moment accounts of learning (Esmonde & Booker, 2017; Philip, Bang, & Jackson, 2018; Philip & Gupta, 2020). This shift asks learning science researchers to politicize our inquiries into learning to address the ways power and injustice are critiqued or reproduced in everyday life.

This theoretical paper aims to politicize modeling in science education. While I believe all modeling is inherently political, I focus on a particular genre and form (Sengupta et. al. 2021) of modeling in science education: agent-based models about sociopolitical phenomenon. Agent-based models are a genre of model useful for explaining and predicting the behavior of complex systems (Wilensky & Rand, 2007). These models are comprised of many agents which interact based on simple rules to simulate emergent phenomena. I focus on agent-based models which represent

sociopolitical phenomenon. For example, throughout this manuscript I discuss the NetLogo Segregation model (Wilensky, 1997) and the ethnocentrism model (Wilensky & Rand, 2007). Drawing inspiration from philosophy of science (Giere, 2004, 2009, 2010), cultural studies (Hall, 1982, 1996), and the learning sciences (Philip, 2011; Sengupta, Dickes, & Farris, 2021), I position agent-based models about sociopolitical phenomena as explicitly ideological objects. By ideological objects, I mean that these models can either critique or reproduce dominant representations of social life, and by proxy, stabilize symbolic distributions of power in the world (Bourdieu, 1991). I propose a new set of analytical tools from critical discourse studies which surface how ideologies are critiqued or reproduced within models themselves and as students use, evaluate, and revise these models.

This paper is organized as follows: First, I provide a conceptual definition of modeling from the philosophy of science and discuss how the learning sciences have (traditionally) differed in our conceptualization of modeling. Second, I provide a conceptual definition of ideology (Hall, 1982, 1996) and discuss its relationship to reasoning (Philip, 2011). Third, I bring theoretical perspectives on modeling and ideology together. I discuss how agent-based models about sociopolitical phenomenon can reproduce or critique dominant social ideologies. Fourth, I introduce critical discourse analysis as a theoretical and analytical approach for tracing which ideologies are embedded within models or reproduced when learners engage in the practice of modeling. Finally, I close by previewing two empirical studies which trace how dominant ideologies are reproduced as preservice teachers work with multi-agent-based models of sociopolitical phenomena.

MODELING IN SCIENCE EDUCATION

To understand models and modeling, I draw on the work of philosopher of science, Ronald Giere (2004, 2009, 2010). I review Giere's definition of models and modeling, differentiate between models and representations, and explain the (mediated) relationship between representations, models, and the world. Along the way, I provide examples of agent-based models about sociopolitical phenomena and compare how models and modeling have been conceptualized in learning science research to demonstrate important similarities and differences.

Models and their Relationship to Science

Giere (2004) offers the following formula to explain the enterprise of science: *S uses X to represent W for P*. *S* stands for scientist. Giere explains that *S* can represent individual scientists, groups of scientists, institutions, or scientific disciplines. The *X*, Giere explains, is a class of heterogenous objects, including words, equations, diagrams, symbols, graphs, photographs, computer-generated images, and *models*. Models, Giere explains, are the principal object which scientists create, use, evaluate, and revise. He defines models as "abstract objects constructed in conformity with appropriate general principles and specific conditions" (p. 747). By 'appropriate general principles' and 'specific conditions', Giere is referring to the generally accepted principles within a discipline and the specific experimental conditions which in which the scientist is working. Models, as well as other objects, support scientists in representing *W,* or the world. By 'the world', Giere is referring to any natural or social phenomena selected and defined by the scientist themselves. Finally, the *P* stands for purpose. Giere explains that there are various purposes which inform science. So, re-written, science is an enterprise where 'scientists (*S*) use '*X*' to represent the world (*W*) for some purpose (*P*).

Reform-based science education strives to replicate a similar relationship between novice science learners, models, and the world (W) (National Research Council, 2012; NGSS Lead States, 2013). Take for example the NetLogo segregation model (Wilensky, 1997). This model is an agent-based model, based on Tom Schelling's research on social systems, which simulates how residential neighborhoods become racially segregated (Wilensky, 1997). This model (*X*) is used by teachers and students (*S*) to represent the phenomenon of residential racial segregation (*W*). The purpose (*P*) of using this model is to teach students that racial segregation emerges from individual's preferences for similar neighbors. Even when the agents in the model have a low preference for similar neighbors, the model still produces a segregated landscape.

Models and their Relationship to Representations

Models are the primary form of representational object in the enterprise of science. However, models do more than simply represent the natural or social world. Furthermore, models and other types of representations (symbols, notation systems, etc.) are related but have important functional differences.

Many of the objects which Giere refers to as 'X' can are representations. Representations are any symbolic object which 'stand in' for a person's idea of some aspect of the world. Representations can be physical. For example, Schelling used black and red coins to represent houses from differing demographic groups when simulating racial segregation. Representations can also by graphical. For example, the NetLogo segregation model represents houses from different demographic groups with green and red squares. Representations are important because they allow scientists to capture, relate, and control aspects of the real world they consider important to a phenomenon (Giere, 2004; diSessa, 2004).

Models on the other hand, are collections of representations which explain the inner workings of a phenomenon and predict the behavior of a phenomenon. Models can explain a phenomenon by making visible the hidden internal structures of a phenomenon and relating these structures in a causal way. For example, the NetLogo segregation model 'makes visible' people's individual preferences for similar or different neighbors. Models can predict the behavior of phenomenon by processing inputs and producing outputs. For example, the NetLogo segregation model can be changed. The user can increase or decrease the number of similar neighbors a person prefers, run the simulation, and observe the resultant segregated landscape. To summarize, while representations and models both represent scientists' ideas about the world, models go a step further in explaining and predicting scientists' ideas about the phenomenon.

The learning sciences have framed models in ways coherent with Giere's definitions. Models are described as representations which aid learners in understanding, explaining, and predicting the behavior of natural or social systems (Ingham and Gilbert, 1991; Justi & Gilbert, 2002; Lehrer & Schauble, 2003). They make natural or social systems legible by explaining the "elements, relations, operations, and rules governing interactions" within systems using external notation systems (i.e., representations) (Lesh & Doerr, 2003, p. 10). Explaining a system involves focusing on only key aspects, rather than representing all aspects of such system (Schwarz & White, 2005). However, there is a critical difference in how Giere and the learning sciences have related models to the real world.

Models and their Relationship to the World

Giere complicates the relationship between models and the world by re-inserting the agents of science. By agents of science, Giere is referring to the individual scientist,

groups of scientists, disciplines, novice science learners, teachers, and a host of other social actors involved in science (2009). These agents have *purposes* for engaging in the enterprise of science, which influence how science is conducted. Giere refers to this as a *perspectival* view of science (2010); where the purposes, beliefs, and worldviews of the scientist critically shape the design and use of representations and models. Therefore, representations do not simply 'stand in' for aspects of the real world. Instead, they stand in for a scientists' idea of what the real world is. Similarly, models do not simply explain and predict a phenomenon. Instead, they explain and predict a scientists' carefully selected and parametrized notions of a phenomenon.

Take for example a critique of agent-based modeling offered by Sengupta et. al. (2021). In this study, the authors critique the ethnocentrism model (Hammond & Axelrod, 2006), a derivation of the segregation model. This model simulates how ethnocentrism emerges in a social system as the product of individuals cooperating with each other based on simple preferences. The model represents four types of people: (a) egoist: agents who only cooperate with themselves; (b) traitors: agents who only cooperate with those different than themselves; (c) humanitarians: agents who cooperate with any agent; and (d) ethnocentrists: agents who cooperate with only similar agents.

The authors focus their critique on the representation of traitors. In the model, traitors only cooperate with agents-who are considered different from themselves. By labeling this strategy 'traitorous' behavior, a whole range of lived experiences are obscured and flattened to 'fit' into the model. For example, individuals immigrating to a new country, within this representation system, would be classified as 'traitors.' Thus, the authors expose how the representational infrastructure underlying the ethnocentrism model relies on a form of symbolic violence (Bourdieu, 1991). This work highlights how

cultural, social, and political factors mediate the practice of representing and modeling the natural or social world.

Herein lies a critical difference between how representations and models are conceptualized by Giere, and how they have been (traditionally) conceptualized in research on modeling in the learning sciences: Learning science research has centered disciplinarily accepted genres and forms of modeling. Our goal has been for students to craft representations and models of phenomenon which mirror those already accepted in traditional science disciplines. Therefore, we have centered the purposes and worldviews of scientists themselves. In the process, we have excluded from view the social or cultural forces which shape how people see and represent the natural or social world. Furthermore, we have excluded from view how power mediates the process of representing and modeling the world, whether in the lab or in the classroom. To reassert a focus on how worldviews -- and by proxy, power - shape the process of representing and modeling, I turn to research on ideologies and their relationship to learning.

IDEOLOGIES IN SCIENCE EDUCATION

To understand ideologies, I draw on the work of cultural studies scholar, Stuart Hall (1982, 1996). First, I review Hall's definition of ideology and discuss how ideologies support or critique broader social structures. Second, I review Philip's ideology in pieces (2011), a framework which explains how ideologies are reproduced or critiqued, in interaction, in classroom learning settings. Along the way, I draw connections between ideologies and models, to highlight the possible synergies between the two constructs.

Ideologies and Society

Hall defines ideologies as "mental frameworks – the languages, the concepts, the categories, imagery of thought, and the systems of representations – which different classes and social groups deploy in other to make sense of, define, figure out and render intelligible the way society works" (1996, p. 26). Ideologies are difficult to empirically locate because they operate at both the social and individual levels. Hall primarily focuses on how ideologies are reproduced at the social level.

At the social level, ideologies can either support or critique dominant social structures. By dominant social structures, I am referring to abstract and stable social, economic, or cultural systems (ex. capitalism, racism, patriarchy, democracy, etc.) (Fairclough, 2004). Ideologies can support dominant social structures by reproducing status quo representations of these systems. For example, neoliberal ideology - the dominant economic ideology - understands the social and economic actions of individuals as superordinate to the regulatory actions of states (Harvey, 2005; Navarro, 2007). This ideology represents individuals as primarily responsible for improving the conditions of society, rather than states. Ideologies can critique dominant structures by posing alternative ways of representing the world. For example, an alternative to neoliberal ideology might represent the interest of individuals as subordinate to the interests of the collective. This mental framework might represent individuals as primarily responsible for the exploitation of people and degradation of social conditions. It is important to note that different ideologies are not more or less coherent with reality. Rather, ideologies empower different groups of people from the real world and justify certain actions over others.

I see similarity between Hall's conceptualization of ideology and Giere's conceptualization of models and their relationship to science. Models, like ideologies, are

collections of representations which support scientists in rendering the social or natural world intelligible. Similar to ideologies, models can either support or critique dominant social structures within science. Models can support dominant structures within science by reproducing commonly accepted representational forms (ex. traitors as agents with cooperate with different, rather than similar agents). Models can also break from dominant forms of representation by offering new and radical perspectives on the world (ex. immigrants as agents which are forced to cooperate with different agents). However, models are not objectively coherent with reality. Rather, they are perspectival (Giere, 2010) instruments which reflect the social position of the modeler themselves. They empower certain representations of the world and engender certain actions over others.

Hall's writings are useful for understanding how a model (or an agent-based model about a sociopolitical phenomenon) can align or misalign with a dominant social ideology. However, they are less useful for understanding how ideologies are reproduced in everyday life as people reason about the natural or social worlds. For this, I turn to Philip's framework, ideology in pieces (2011).

Ideologies and Reasoning

Ideology in pieces blends diSessa's theories about conceptual change (1993, 2002) with Hall's theories about ideology (1982, 1996). This framework explains how ideologies are dynamically co-constructed as people reason about the natural or social world. While there are many tenets involved in ideology in pieces, I explain three that I found most useful for exploring the ideological nature of agent-based models about sociopolitical phenomena: naturalized axioms, social and material contexts, and ideological convergence and divergence.

Naturalized Axioms

People draw on taken-for-granted assumptions or commonsense ideas to reason about the social world. Philip calls these assumptions or ideas naturalized axioms. When creating an agent-based model about a sociopolitical phenomenon, certain groups of people are represented as agents in the model. For example, the segregation model contains two agents, red and green houses, which represent two different demographic groups (i.e. two racial or ethnic groups). Conversely, certain groups of people are excluded from representation in the model. For example, the segregation model excludes the possibility of a third demographic group (i.e., a third racial or ethnic group) or intersectional groupings (i.e. racial groups and class groups). The process of compressing people from the real world into agents within a model naturalizes certain social groupings over others.

Social and Material Contexts

Naturalized axioms are cued by specific social contexts, rather than being applied globally. When using an agent-based model about a sociopolitical phenomenon, social contexts cue different interpretations of agents. For example, the original ethnocentrism model represented people who cooperate with different agents as traitors. However, as explained by Sengupta et. al. (2021), a person with experience immigrating to a new country would likely not classify their behavior as traitorous, but rather as a product of cultural pressures to assimilate. Therefore, the social position or context of the modeler mediates the process of representing and modeling a phenomenon.

Convergence and Divergence

People over time stabilize or converge on naturalized axioms for explaining the social world. As mentioned before, individuals do not know or contain entire ideologies

in their minds. Rather, they draw on pieces of ideologies (naturalized axioms) in moments to reason about the world. However, over time certain ideologies become sedimented, converged upon, and empowered if they are repeatedly taken up by others. Philip et. al. (2018) refer to this process as ideological convergence. When students create, evaluate, or revise agent-based models about sociopolitical phenomena, they may initially draw on different strategies for representing and relating people as agents. Over time, those representations which are taken up more frequently become empowered in the classroom. Empowered representations can be converged upon, to the point where they seem like the only way of representing people involved in a phenomenon. Therefore, the group dynamics in a modeling classroom mediate the process of representing people from the real world.

Taken together, Hall and Philip describe how ideologies operate at the broader social level and the individual or interactional level. Both scholars take as their object of analysis spoken or written text, and therefore present ideologies as a mental phenomenon (existing as collections of ideas which circulate via discourse). In the next section, I discuss the potential for analyzing models as symbolic artifacts which embody ideologies as a material phenomenon.

THE RELATIONSHIP BETWEEN MODELING AND IDEOLOGY

To simplify, I summarize the key similarities I see between representations and models in science education and broader social ideologies (Table 1). This table provides a blueprint for inquiring into the political aspects of agent-based models of sociopolitical phenomenon. By viewing agent-based models as ideological objects, we can begin probing how these models represent, explain, and predict the world. For example:

1. What agents are represented and included in a model?

2. What agents are not represented and excluded from the model?
3. When agents are included, how are they represented (or mis-represented)? What other representations are possible?
4. What causal links are created between agents in a model?
5. As people model, how do they diverge or converge on representational choices?
6. How do these representational choices mirror or critique broader, ideological representations of the social and natural world?

Models (Giere, 2004, 2009, 2010)	**Ideologies (Hall, 2006; Philip, 2011)**
1. Representations are symbolic objects which stand in for a person's idea of aspects in the real world.	1. Naturalized axioms are 'common sense' representations of the world.
2. Models are collections of representations which explain and predict a scientists' parameterized understanding of a phenomenon.	2. Ideologies are collections of naturalized axioms which support people in rending the natural or social world intelligible.
3. Models are not objectively similar to reality but are based on general principles and specific conditions.	3. No single ideology is comprehensive or fully coherent with reality. Furthermore, ideologies are applied in specific contexts.
4. Models are mediated by the perspectives or purposes of the scientist who creates them.	4. Ideologies reflect differing social positions within society and can either critique or reproduce dominant social structures.
5. The process of modeling involves individuals and groups creating, using, evaluating, and revising models to better represent, explain, and predict a phenomenon.	5. Reasoning with ideologies proceeds as a group diverges and converges upon a different/similar form of representing the natural or social world.

Table 1. Key similarities between models and ideologies.

To begin answering these questions, I draw on theories and analytical tools from critical discourse studies which are particularly adapted for mining ideological influences on talk and text.

CRITICAL DISCOURSE ANALYSIS FOR REPRESENTATIONS AND MODELS

To recount, I aim to politicize modeling in science education. To accomplish this, I draw on critical discourse analysis (CDA), a variety of discourse analysis which stems from systemic functional linguistics (Halliday, 1978). The purpose of critical discourse analysis is to analyze language use to understand the social construction of reality, particularly how systems of power relate to everyday social life (Fairclough, 2000, 2004; Jaworski & Coupland, 2014). CDA scholars typically analyze talk or text, for example, speeches, newspaper articles, advertisements, and curricula (Wodak & Meyer, 2001). I extend critical discourse analysis - beyond talk and text - to focus on scientific representation and models in classroom settings.

This section proceeds as follows: First, I discuss the theoretical framework underling critical discourse analysis. This framework explains the relationship between text and society. I extend this framework to consider scientific representations and models as a form of text. Second, I discuss the analytical framework underlying critical discourse analysis. This framework provides a systematic and flexible process for analyzing multiple texts and drawing connections with broader social structures. I extend this framework to consider: (a) multiple scientific representations or models; and (b) learners' interactions with scientific representations and models. Finally, I propose a set of tools - from sociosemantic inventory (van Leeuwen, 1993, 1996) - which surface how ideologies are critiqued or reproduced within texts. I adapt these tools to focus on both representations and models as well as learners' interactions with representations and models.

Theoretical Framework

CDA scholars conceive of society as three interrelated levels: social events, social structures, and social practices (Figure 1). Each level is comprised of many possible elements to analyze, however, CDA scholars focus on the linguistic or textual element at each level. This three-tiered framing of text and society supports analysts in making claims about the relationship between power dynamics in society and events in daily life. I briefly explain each level and its associated textual features.

	Level of Society	**Textual Element**	**Modeling**
Abstract, stable, enduring	Social Structures	Ideologies	Ideologies about Race, Class, or Place
	Social Practices	Discourses	Discourses about Phenomena
Concrete, mutable, shifting	Social Events	Texts	Agent-based Models about Sociopolitical Phenomena

Figure 1. Theoretical framing of text and society (Fairclough, 2004).

Text and Social Events

Social events are any concrete and mutable happening in the world. They involve people, roles, materials, spaces/places, texts, actions, and interactions. For example, an hour-long classroom lesson is a social event because it involves a collection people, in particular roles, who gather to accomplish some activity using a variety of materials (many of which are texts). Social events are concrete because they have beginning and ends. They are mutable because they are never fully predetermined. Any number of elements can change the course of actions as the social event unfolds.

Social events involve texts in a variety of ways. For example, texts can be used in the social event (ex. classroom students will read textbook chapters, data sets, and many other texts) or produced in the social event (ex. students generate their own writing or teachers craft lesson plans). In this theoretical paper, I focus on scientific representations and models as a form of text. Students in a classroom can create, use, evaluate, or revise representations or models as part of a lesson. Furthermore, students can talk with or about representations and models as they participate in classroom lessons. CDA scholars collect, describe, and analyze texts within social events to understand their relationship with broader social structures.

Ideologies and Social Structures

Social structures are abstract and stable entities. Examples of social structures are economic structures, kinship structures, or race, gender, and class structures. Social structures are abstract because they cannot be easily observed and are stable because they are long-enduring. While social structures are comprised of many elements, CDA scholars focus primarily on the textual elements. Languages (as in English, Spanish, or any other language) are a prominent textual feature of social structures. However, I am primarily concerned with ideologies.

As a reminder, Hall defines ideologies as "mental frameworks – the languages, the concepts, the categories, the imagery of thought, and the systems of representations – which different classes and social groups deploy in other to make sense of, define, figure out and render intelligible the way society works" (1996, p. 26). Central to this definition are the concepts of representation and power: ideologies are particular ways of representing the real world for specific power-driven purposes. Because ideologies belong to the social structural level, they "have a durability and stability which transcends

individual texts or bodies of texts." (Fairclough, 2004, p. 9). In lay terms, no single text represents an ideology fully, and no single ideology shapes a text fully. This is coherent with Philip's (2011) understanding that people draw on pieces of ideologies, in specific contexts, to reason about the natural or social world.

In this theoretical paper, I mine scientific representations and models to see how they critique or reproduce broader social ideologies. No single representation or model fully embodies a particular ideology. Rather, the relationship between representations and models in a classroom and broader social ideologies is complex. Social events "are not in any simple or direct way the effects of abstract social structures" (Fairclough, 2003, p. 23), but in the same vein, do not emerge to produce the social structure. Instead, the relationship between social structures and social events is reflexive, mediated, by Fairclough's middle level – social practices.

Discourses and Social Practices

Social practices are the mediating level between social events and social structures. Social practices are "articulations of different types of social elements which are associated with particular areas of social life." (Fairclough, 2004, p. 25). In simpler terms, social practices are patterned ways of acting or interacting, relating to people, using materials, and using language. For example, in educational contexts, different pedagogies can be considered social practices. They are patterned ways of engaging with people and using materials which shape how a social event (a day in the classroom) unfolds.

There are a range of discursive elements involved in social practices. For example, people use language to get things done in particular ways (called, genres) or use language to identify people in particular ways (called styles). Here, I focus on the social

practice of *discourses*. Discourses (plural) are patterned ways of representing the world with language. For example, when a journalist writes an article about some social event, they are engaging in an act of representation. They pick certain elements of the social event to include and intentionally or unintentionally leave other elements out. This process of inclusion and exclusion is necessary because no text can fully represent all the elements of a social event. Therefore, all texts engage in some imperfect representation of the real world. Patterns in how texts represent the social world are discourses.

At this point, it seems that discourses and ideologies are similar: they are both ways of representing the world with language. However, there are some important differences: Ideologies are broad and socially shared systems for representation that support people in rendering the social or material world intelligible, for power-related reasons. They are often hard to fully define or describe, unless conjured in particular situations. Furthermore, people do not ever possess/know/or act on a single ideology (Philip, 2011). Instead, ideologies support people in interpreting social events in particular ways through the creation of discourses. Discourses are more context-specific instantiations of ideologies. A single ideology can provoke many discourses depending on the context. Stuart Hall explains that ideologies which are part of specific economic relations (such as capitalism) "cannot prescribe a single, fixed and unalterable way of conceptualizing [itself]." (Hall, 1996, p. 39). Instead, ideologies reinforce themselves through the production of discourses about social events.

In this theoretical paper, I focus on the discourses that agent-based models reproduce about the world. For example, the NetLogo segregation model reproduces what I refer to as an *individualistic* or *personal preferences* discourse about segregation. This discourse focuses on the mental actions of individual households (having personal preferences for similar or different neighbors) and the resulting material actions that these

preferences engender (moving to a new property or staying). This discourse excludes from discussion a range of other people and institutions involved in segregation (ex. banks, homeowners' loan corporation, municipal governments). Furthermore, this discourse excludes from discussion a range of other actions involved in segregation (ex. intimidation, gentrification, bulldozing). Discourses align themselves with particular ideologies about the world. By identifying the discourses reproduced in a model, it becomes easier to draw connections 'upward' to broader social ideologies.

Analytical Framework

Critical discourse analysis scholars proceed through three general steps when drawing connections between texts in social events and broader ideologies as part of social structures: describing, analyzing, and comparing. While CDA scholars typically perform these steps with a collection of written texts, I provide notes for how I apply these same steps to: (a) agent-based models of sociopolitical phenomena; and (b) interactional data of learners creating, using, evaluating, and revising agent-based models. These steps are represented in schematic below; reproduced and adapted from Janks (1997; Figure 2).

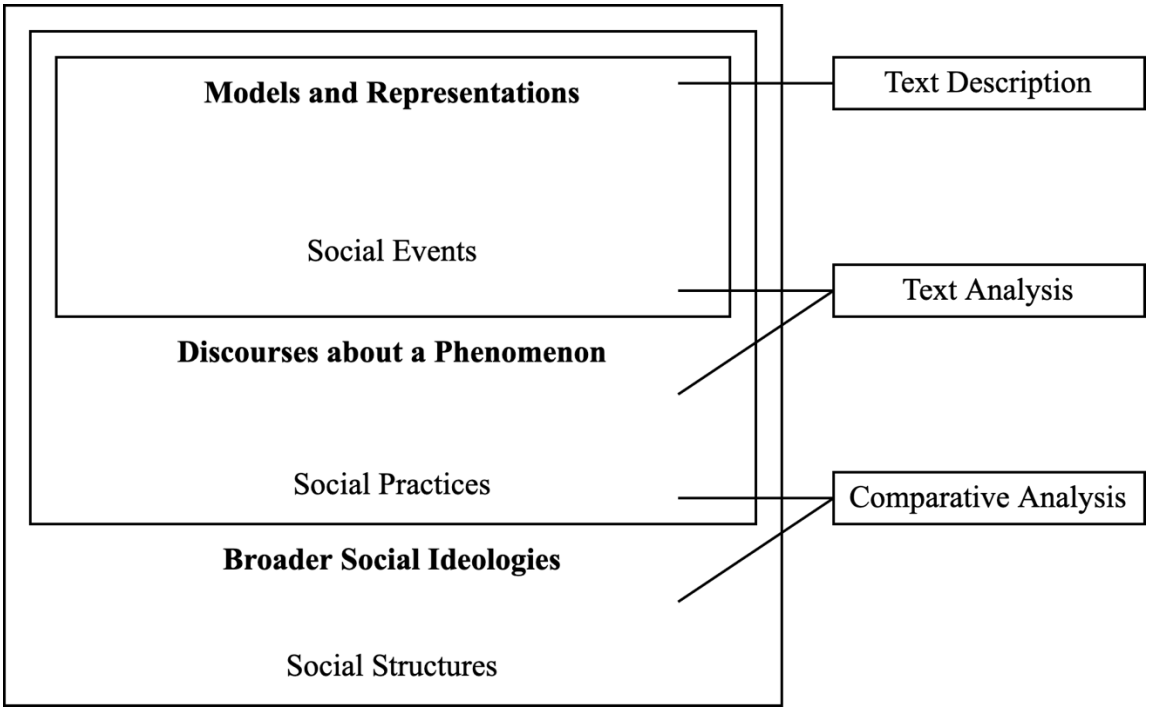

Figure 2. Analytical process underlying critical discourse analysis.

Text Description

In this phase, CDA scholars read and provide rich descriptions of a text. This phase allows a researcher to see what social actors, actions, and circumstances – from the real world – are present in a text. Social actors are any people, groups, or institutions which are represented in a text. Social actors are typically indexed linguistically as nouns, pronouns, or direct objects. Social actions are the mental or material processes – from the real world – that are represented in a text. Social actions are typically indexed linguistically as verbs. Circumstances are details about the time and place in which some social event takes place. Circumstances are typically indexed linguistically with prepositional phrases or predicates.

In the case of agent-based models about sociopolitical phenomena, I describe the agents and relationships which are present in these models. This involves carefully

documenting each agent, how it appears in the model symbolically (ex. as an icon or figure), and what the agent's basic functions are (i.e., how the agent 'acts' in the model or how the agent is related to other agents). In tandem with descriptions of the model, I also describe how learners interact with the model. I document what learners say and towards what aspect of the model they are drawing attention to. This phase produces a catalog of descriptions that are pertinent for the next phase of analysis.

Text Analysis

In this phase, CDA scholars analyze and compare the descriptions found within each text. This phase allows a researcher to see how social actors, actions, and circumstances – from the real world – can be differently represented in a text. By differently represented, I mean the range of linguistic possibilities for collapsing and representing social actors, social actions, and circumstances – into texts. Patterns which emerge from this phase are called *discourses*.

In the case of agent-based models about sociopolitical phenomena, I compare the representation of agents using a set of tools called sociosemantic inventory (van Leeuwen, 1993, 1996). Sociosemantic inventory probes the linguistic representation of social actors and social actions in texts. This tool kit outlines 11 dimensions for probing the representation of social actors and 5 dimensions for probing the representation of social actions. In the next section, I explain these tools in greater detail. However, this tool kit can be applied to both the models themselves as well as learners' interactions with the models. By applying sociosemantic inventory to models and interactions with models, we can bring into greater relief the various discourses that a model reproduces about a given phenomenon.

Comparative Analysis

In this phase, CDA scholars compare representational choices made in individual texts and across texts (discourses) with broader social ideologies. At this point, CDA scholars are looking for how particular discourses about a given topic align to or critique dominant social ideologies. This phase is least systematized in the literature on critical discourse analysis, but often draws on other critical social theories (i.e., feminist theories, queer theories, critical race theories, etc.) to interpret linguistic variations and discourses uncovered in the prior two phases.

In the case of agent-based models: after I have identified particular discourses which emerge from the model or from interactions with the model, I then cross reference these discourses with various descriptions of broader social ideologies. This process is open-ended and interpretative. I look for areas where ideologies and discourses align (i.e., produce similar representations of social actors or actions) or misalign (i.e., produce differing representations of social actors or actions). These similarities and differences indicate moments where models and modeling either critique or reproduce dominant social ideologies.

Sociosemantic Inventory: A Toolkit for Tracing Ideologies within Models

To link individual representational choices within models to broader social ideologies, I draw on a critical discourse analysis technique called sociosemantic inventory (van Leeuwen, 1993, 1996). Sociosemantic inventory analyzes and compares how social actors (individual people, groups of people, or institutions) and social actions (behaviors from social actors) from the real world can be differently represented in text. I extend these tools to focus on how social actors and actions from the real world come to be represented in agent-based models of sociopolitical phenomena. While sociosemantic

inventory specifies 11 tools for analyzing social actors and 5 tools for analyzing social actions, I draw on four tools to apply to agent-based models (Table 2). When applied to a text or model, these four tools reveal different ways social actors and actions from the real world are empowered or disempowered.

Actors/Action	**Tool**	**Dimensions**	
Analysis of Social Actors	1. Inclusion	*Included* social actors are those which are present and named in a text or a model.	*Excluded* social actors are those which are absent or not named in a text or a model. Social actors can be *partially excluded* if they are not named, but there is a trace that they exist.
	2. Personalization	*Personalized* social actors are represented as people. They are referred to by their names or social identities (ex. the president, rich people, or poor people).	Depersonalized social actors are when people are represented by *objects*, *spaces*, or *institutions* of which they are related (ex. elements, southerners, or banks).
	3. Identification	*Identified* social actors are personalized social actors who are represented by their relevant social identities. (ex. economic identities or racial identities).	*Functionalized* social actors are personalized social actors who are represented by the actions they conduct or jobs they hold (ex. builders, salespeople, or singers).
Analysis of Social Actions	4. Activation	*Activated* social actors are social actors who conduct social actions. Actions can be mental (ex. preferring or thinking) or material (ex. moving or staying).	*Passivated* social actors are social actors who receive social actions. Those actions can also be mental (ex. are preferred) or material (ex. are prohibited).

Table 2. Four analytical tools from sociosemantic inventory for analyzing social actors and actions in models.

Inclusion Analysis

Inclusion analysis describes which social actors from the real world are present or absent from a model. Authors of a model can strategically include or exclude social actors as a way of distributing power to people, groups, or institutions from the real world. However, it is not always the case that inclusion symbolically empowers a social actor and exclusion symbolically disempowers a social actor. For example, the NetLogo segregation model includes two social actors which represent demographic groups (i.e. two racial groups) and excludes a range of other social actors (banks, municipal governments, etc). In this context, excluded social actors are hidden to remove power from these groups and shift focus onto the included social actors. Therefore, context matters for understanding how inclusion or exclusion confers symbolic power to social actors.

Personalization Analysis

Personalization analysis describes whether a social actor is referred to as a human agent (ex. rich people) or as a non-human agent (ex. elements of society). Authors can strategically refer to social actors either as humans or compress these people into less-than-human objects. The most common forms of depersonalization are objectification, spatialization, and institutionalization. When social actors are objectified, they are referred to as objects. For example, a person discussing a poor community might refer to these people as ‘less desirable elements of society’, compressing poor communities into the object of ‘elements.’ When social actors are spatialized, they are referred to as the spaces/places the people inhabit. For example, a person discussing residents of the southern hemisphere may refer to these people simply as ‘southerners.’ Finally, when social actors are institutionalized, they are referred to by the organization they inhabit.

For example, ‘the office of the presidency’ or ‘banks’ are both institutional social actors. Typically, depersonalization removes power from a social actor. However, context matters for understanding how these representational strategies confer symbolic power.

Identification Analysis

Identification analysis describes whether social actors are identified by an identity trait (ex. a racial or economic identity) or a function (ex. a job or a role). Identified social actors foreground the social identities of social actors whereas functionalized social actors foreground the behavioral aspects of social actors. The way an author divides social actors into groups - whether identified groups or functionalized groups – reveals deeper understandings about social difference. Furthermore, in agent-based models, agents can only represent a single ‘type’ of social actor. Therefore, these models are limited in their ability to represent more complex features of social identity. For example, intersectional identities (the entanglement of racial, economic, and gender identities) or context-specific identities (shifting racial identities depending on location) are difficult to represent within agent-based modeling platforms like NetLogo.

Activation Analysis

Activation analysis describes whether social actors conduct actions (ex. preferring similar neighbors) or receive actions (ex. are prohibited from moving). Authors of a model draw causal relationships between social actors or attribute certain actions to social actors. For example, in the NetLogo segregation model; both agents (red and green houses) are activated in their abilities to perceive similar or different neighborhoods, prefer similar or different neighbors, and move or change locations. There are no passivations included in this model. This is striking, considering much of residential

racial segregation involved financial institutions engaging in discriminatory lending practices towards some social groups (Black and Latine residents) and not others (White residents). Activation and passivation can distribute power to different social actors. However, activation does not always confer positive symbolic power and passivation does not always confer negative symbolic power. Similar to inclusion, personalization, and identification analyses, context matters.

SUMMARY

To summarize, the learning sciences are called to politicize our inquiries into learning. In this theoretical paper, I present an argument for why and how we should politicize our inquiries into modeling in science education. While I consider all modeling to be a political enterprise, I focus on a particular genre and form of model used in science education: agent-based models about sociopolitical phenomenon.

Agent-based models about sociopolitical phenomena are politically rich artifacts. They represent and predict the behavior of complex problems that span large spaces, occur over long time periods, and involve a variety of social actors and power relationships. For example, the NetLogo Segregation model represents how two racial groups 'naturally' segregate over time based on personal preferences for similarity or difference. Classrooms which use agent-based models to learn about sociopolitical phenomena involve a variety of social and technical interactions. By social interactions, I am referring to interactions between students and teachers as they reason with these models. Students and teachers might share their personal experiences or understandings of a phenomenon, ask questions about the constituent elements within a phenomenon, or pose possible revisions to models about a phenomenon. By technical interactions, I am referring to interactions between students and agent-based models or other materials used

alongside agent-based models. For example, students might use a model to talk through understandings about a phenomenon, compare the model with a reading about a phenomenon, or revise the model using a data set related to the phenomenon.

Traditional research in the learning sciences has taken a techno-centric approach to researching how people learn with agent-based models. This body of work focuses primarily on the cognitive learning gains that students demonstrate *after* having used agent-based models. This dissertation contributes to learning science research by expanding and politicizing our field's inquiries into modeling in science education: To expand inquiries into modeling in science education, I analyze both the agent-based models themselves as well as the social and technical interactions between students, teachers, and classroom materials as they engage in the process of modeling a sociopolitical phenomenon. To politicize inquiries into modeling in science education, I draw on methods from critical discourse analysis to unearth the broader social ideologies reproduced in science classrooms.

While CDA research typically focuses analytical attention on written texts, I extend these techniques to analyze materials in the classroom. By materials, I mean the scientific representations and models that are used in classrooms. I position scientific representations and models as a form of text in the classroom. These texts can support dominant social structures by reproducing status quo discourses and ideologies. However, these texts could also be sites of conflict, where learners critique dominant social structures by offering alternative discourses or drawing on critical ideologies. To understand whether representation and models reproduce or critique broader social ideologies, I draw on a CDA toolkit called sociosemantic inventory (van Leeuwen, 1993, 1996). This toolkit offers many dimensions to analyze the representation of social actors and social actions. Patterns in representation can indicate the discourse that a particular

model or representation draws on when simulating a phenomenon. These discourses can be strategically compared to understand how the align to or critique broader social ideologies.

In the following articles, I present two empirical studies which utilize critical discourse analysis to trace the discourses and ideologies reproduced as learners used agent-based models to learn about sociopolitical phenomenon.

In the first empirical study (Article 2), I traced the discourses about segregation and ideologies about race (Bonilla-Silva, 2014; Haider, 2018) which were reproduced as a group of preservice teachers to used, evaluated, and revised the NetLogo segregation model. This study focused primarily on discourses and ideologies which exist within representations and models themselves. However, I supplement this analysis with excerpts from teachers' presentations of their model. Therefore, I also consider how discourses about segregation and ideologies about race are further reproduced as people talk about or explain their models to the class.

In the second empirical study (Article 3), I traced the ideologies about place (Cresswell, 1996, 2004) which emerged from a single student, throughout a six-day lesson series about urban heat island formation in Austin, Texas. This study focused primarily on ideologies which were reproduced during interactions with classmates and interactions with various representations and models (ex., maps of Austin, agent-based models of urban heat island effect, and readings about urban heat island effect).

Both studies apply critical discourse analysis to artifacts and interactional data. However, each study utilizes a slightly different analytical protocol. The first study (Article 2) provides a more regimented and systematic method for deploying critical discourse analysis on sets of texts (in this case, a set of models designed by preservice teachers). This paper highlights how artifacts or materials themselves can embody

ideologies. The second study (Article 3) provides a more reflexive method for deploying critical discourse analysis on multi-modal data sets (video recordings, artifacts, zoom-chats) which span multiple days of observation. This paper highlights how interactions between people and artifacts/materials in the learning environment, over the course of days, tend to stabilize or converge on particular ideologies. Taken together, both papers demonstrate ideologies as social and technical achievements, embodied in materials and artifacts as well as interactions in everyday life.

REFLEXIVITY

In learning science research, it is important to acknowledge and understand how our social positions mediate the process of designing investigations, collecting and analyzing data, and crafting results. This applies especially to research which aims to politicize learning contexts. I am a White, cis-gendered, gay male researcher. I was raised in the rural Southeastern United States and have lived, taught, and researched in six states in a region commonly referred to as the 'Deep South'. These social and spatial identities mediated how I engaged in this dissertation research.

In the first empirical study (article 2), I investigated ideologies of race which were reproduced as a group of teachers created models about residential racial segregation. My own racial identity proved to be a significant blind spot when designing this lesson series. I believed that if teachers could read about the historic and *de jure* causes of racial segregation, they would be able to easily incorporate these understandings into their models. Furthermore, even when watching the teachers' final model presentations, I did not notice the glaring pattern: race was continually backgrounded and replaced with class identity. However, critical discourse analysis and sociosemantic inventory in particular

are powerful methodologies for exposing the ideological nature of talk and revealing ideologies which are deeply embedded into social and technical learning environments.

In the second empirical study (article 3), I investigated ideologies of place which were reproduced as a group of teachers created models about urban heat island effect. Having lived in six states across the Deep South, I have been repeatedly exposed to discourses and ideologies about the geography of cities. In Nashville, Tennessee, people use the river to divide the city into East Nashville and West Nashville. People often framed 'East Nashville' as an 'up and coming' area which 'used to be bad - but is now good.' Austin, Texas also divided into Eastern and Western regions (although by a highway) and is often discussed in a similar manner. The refrain of cities as split into 'good parts' and 'bad parts' has followed me throughout my educational and research journey. For this reason, I am particularly sensitive to how people talk about place and the affective relationships they layer onto places. Critical discourse analysis and sociosemantic inventory have provided a routinized way for exploring segments of talk and artifacts to 'mine' these moments for their ideological nature.

Article 2: How Racial Ideologies Mediate Reasoning about and Modeling Segregation

INTRODUCTION

Contemporary research in the learning sciences illuminates the central role that ideologies play in STEM learning and instruction (Philip 2011, Philip et. al. 2018, Philip & Gupta, 2020). In this paper, I contributed to this body of scholarship by investigating how racial ideologies (Bonilla-Silva, 2014; Haider, 2018) became salient resources for reasoning about and modeling about spatial phenomena.

Specifically, I examined a group of preservice teachers throughout a three-day lesson series where they used, evaluated, and revised the NetLogo segregation model (Wilensky, 1997). The NetLogo segregation model is an agent-based model inspired by Tom Schelling's research about the emergent properties of social systems (1980, 2006). This model represents segregation as occurring because of individual's preferences to live near people similar to themselves. On the final day of the lesson series, teachers were asked to draw new models which better represented how neighborhoods became racially segregated. To inform these drawings, teachers read about the legal and municipal causes of racial segregation (Rothstein, 2017). I focused on the final day of the lesson series when teachers presented their revised segregation models to the class. Using techniques from critical discourse analysis (van Leeuwen, 1993, 1996), I traced how the original and revised segregation models reproduced dominant ideologies about race in society. Three research questions guided the analysis:

1. How do preservice teachers represent the phenomenon of residential racial segregation when modeling?
2. What discourses about segregation emerged from their models and presentations?

3. What broader ideologies about race were reproduced across the set of models and presentations?

I have two goals for this paper: My first goal is specific to research about ideologies and learning (Philip, 2011, Philip, et. al., 2018). These studies focus on how participant's talk and social interaction reproduce or critique ideologies. In this study, I showed how ideologies were reproduced within the original NetLogo model and the teachers' revised models. Towards this end, I aim to show that ideologies are reproduced within talk *and* materials in the classroom. My second goal is more general to research about agent-based modeling in STEM education. Recent studies demonstrate the utility of using agent-based models to teach people about complex sociopolitical phenomenon (ex., Hostetler, Sengupta, & Hollett, 2018; Guo, 2019). This study began as an attempt to support teachers in reasoning more critically about racial segregation. However, analysis revealed that dominant ideologies of race were reproduced, even when teachers attempted to critique and revise the original NetLogo model. Drawing on the work of Sengupta et al. (2021), I critique my own use of agent-based models for teaching about sociopolitical phenomenon.

In what follows, I conceptualize, justify, and explain my analysis of the final day of this lesson series. First, I introduce my theoretical framework for conceptualizing ideologies and their relationship to modeling. Theoretically, I draw on work from cultural studies (Hall, 1986), political science (Bonilla-Silva, 2014; Haider, 2018) and the learning sciences (Philip, 2011). Second, I explain my methodological and analytical approach for examining ideologies reproduced in models and presentations of models. I draw on methods from critical discourse analysis (Fairclough, 2004; van Leeuwen, 1993, 1996) which are particularly adapted to tracing how ideologies mediate talk, text, and symbolic representations. Third, I present the findings from this analysis. I present the

findings in three phases, corresponding with the phases of analysis and research questions. Finally, I close with a discussion about implications for teaching, learning, and research on ideology and modeling.

THEORETICAL FRAMEWORK

The broader goal of this project is to build on studies which investigate the relationship between learning and ideology. I conceptualize learning as a sociotechnical process where people interact with each other and their material surroundings to "generate new understandings, extend navigational possibilities, and adapt meaning-making practices to new forms and functions." (Roseberry, Ogonowski, DiSchino, & Warren, 2010, p. 324). Stuart Hall defines ideologies as "the mental frameworks – the languages, the concepts, categories, imagery of thought, and the systems of representation – which different classes and social groups deploy in order to make sense of, define, figure out, and render intelligible the way society works." (1996, p. 26). To understand the relationship between ideologies and learning, I turn to Philip's framework ideology in pieces (2011). In the sections that follow, I summarize ideology in pieces and extend the framework to focus on ideologies reproduced within classroom artifacts.

Ideologies and Reasoning

Ideology in pieces blends diSessa's theories about conceptual change (1993, 2002) with Hall's theories about ideology (1982, 1996). This framework explains that ideologies are dynamically co-constructed as people reason about the natural or social world. While there are many tenets involved in ideology in pieces, I explain three that I found most useful for this study: naturalized axioms, social and material contexts, and ideological convergence and divergence.

People draw on taken-for-granted assumptions or commonsense ideas to initiate reasoning about the social world. Philip calls these assumptions or ideas naturalized axioms. In interaction, people initiate reasoning by posing a naturalized axiom. For example, when teachers were asked to explain what caused residential racial segregation, they began by listing out variables they thought of as commonsense: class and housing cost.

Naturalized axioms are cued by specific contexts and are not applied globally. Naturalized axioms are cued when people interact with others or with materials in the classroom. For example, teachers in this study used the NetLogo segregation model. This model represented the world as a series of patches (properties) with turtles (houses) moving around 'on top' of the patches. All the teachers utilized the same patch-turtle system for representing racial segregation in their final model. Therefore, the NetLogo model cued similar ways of representing racial segregation.

People over time stabilize or converge on naturalized axioms for explaining the social world. As mentioned before, individuals do not know or contain entire ideologies in their minds. Rather, they draw on pieces of ideologies (naturalized axioms) in moments to reason about the world. However, over time certain ideologies become sedimented, converged upon, and empowered if they are repeatedly taken up by others. Philip et. al. (2018) refer to this process as ideological convergence. For example, throughout the lesson series, the group of teachers produced four distinct models. However, these models converged on one of two ideologies of race when representing racial segregation.

Ideologies within Artifacts

I draw on critical discourse studies to theoretically link teachers' individual models with broader social ideologies. Critical discourse studies view text in everyday social life as deeply tethered to broader social structures. Texts (whether spoken, written, or symbolized) are inherently representational (Fairclough, 2004). By representational, I mean that texts capture and reflect certain aspects of the real world, while ignoring or excluding other aspects (Fairclough, 1995). Patterns in how a set of texts represent the world are called discourses, and these discourses can either reproduce or critique dominant ideologies about the world. Figure 1 depicts the relationship between texts, discourses, and broader social ideologies.

To link individual representational choices within models to broader social ideologies, I draw on a critical discourse analysis technique called sociosemantic inventory (van Leeuwen, 1993, 1996). Sociosemantic inventory analyzes and compares how social actors (individual people, groups of people, or institutions) and social actions (behaviors from social actors) from the real world can be differently represented in text (or in this case, a model). I draw on four tools from sociosemantic analysis to analyze how social actors and social actions are represented (Table 2).

To make the connection between specific classroom artifacts and broader social ideologies, I proceeded through three general phases. First, I described and analyzed the social actors and actions in each model using the above four tools. Then, I compared across the set of models to examine similarities and differences with how each group represented people (social actors) and behaviors (social actions) involved in modeling segregation. I considered similar ways of representing the social actors and actions to be discourses about segregation. Finally, I compared discourses about segregation with central frames of various racial ideologies. Discourses about segregation either reproduce

or challenge broader ideologies about race. To understand the central frames of racial ideologies, I drew on the work of Bonilla-Silva (2014) and Haider (2018). In the next section, I describe more about the context of this research, describe data sources, and delineate the specifics of data analysis.

METHODOLOGY

This empirical study is part of a broader research project which explored how ideologies mediated reasoning about and modeling spatial phenomena. This empirical study is a qualitative examination of 15 preservice elementary teachers enrolled in an Elementary Science Methods course. The preservice teachers participated in a three-lesson series where they used, evaluated, and revised an agent-based model which simulated residential racial segregation. This analysis focused on the final day of the three-lesson series where participants presented their revised NetLogo model to the class. As a reminder, the research questions guiding this analysis were:

1. How do preservice teachers represent the phenomenon of residential racial segregation when modeling?
2. What discourses about segregation emerged from their models and presentations?
3. What broader ideologies about race were reproduced across the set of models and presentations?

This section is organized as follows. First, I describe the context of the research. By context, I am referring to: (a) the institution and course in which the study takes place; (b) the participants involved in the study; and (c) the design of the lesson series and technology used in the study. Second, I describe the process of data collection, organization, and transformation. Finally, I explain the three-phase procedure for using

critical discourse analysis to examine original model, the final models, and the model presentations.

Contexts

This research was conducted within an elementary teacher education program at a large university in the U. S. Southwest. Preservice teachers enrolled in this program obtain an undergraduate bachelor's degree in education and simultaneously work towards an elementary teaching credential. This research occurred during the Fall of 2019 in a course titled Elementary Science Methods (ESM). The ESM course was designed to provide preservice teachers with: (a) a general understanding of the theoretical foundations of science teaching and learning; (b) opportunities to participate in elementary science lessons; and (c) opportunities to plan elementary science lessons.

Participants

The participants in this research were a group of 15-preservice elementary teachers enrolled in the ESM course. Here forward, I will refer to the group simply as the teachers. All 15 of the teachers identified as women. 11 of the preservice teachers identified as White, 3 identified as Latina, and 1 identified as Asian American. The preservice teachers sat in groups of 3-4 students for the entire semester. These groups functioned as their project groups for in-class activities, class assignments, and for this research endeavor. Below, I provide the pseudonyms, groupings, and social identities of the participants (Table 3).

Groups	Pseudonyms	Racial or Ethnic and Gender Identities
1	Harriet	White, Woman
	Ingrid	White, Woman
	Jacinta	Asian-American, Woman
	Riley	White, Woman
2	Gertrude	Latina, Woman
	Harriet	White, Woman
	Kait	White, Woman
	Erin	White, Woman
3	Bree	Latina, Woman
	Sage	White, Woman
	Cady	White, Woman
4	Rai	White, Woman
	April	White, Woman
	Lynette	White Woman
	Ashley	White Woman

Table 3. Participant names, groupings, and social identities.

The Lesson Series

I examined a three-day lesson series which took place at the end of the semester. The lesson series was designed to provide preservice teachers with the opportunity to engage in the model-based learning cycle (Louca & Zachariah, 2005); a pedagogical approach to using models in science or social studies classrooms. In this three-day lesson series, teachers participated in an abbreviated model-based learning cycle where they investigated a social phenomenon: residential racial segregation. When I refer to residential racial segregation, I am referring to the phenomenon by which people from different racial or ethnic groups in urban residential area(s) come to be integrated (living near each other in heterogenous organization) or segregated (living apart from each other, in homogeneous organization) over time (Rothstein, 2017). An abbreviated description of the three-day lesson series is provided in Table 4.

Lesson	MbL Cycle Phase	Description
1 (11/20/19)	▪ Observing ▪ Using ▪ Evaluating	▪ First, participants *observed* racial settlement patterns local to Austin, Texas using the Racial-Dot Map (Cable, 2013). ▪ Second, participants *used* the Netlogo segregation model to learn about how spaces become racially segregated by individual preferences. ▪ Finally, participants *evaluated* and critiqued the original NetLogo segregation model based on personal knowledge about segregation.
2 (11/27/19)	▪ Collecting	▪ Participants read excerpts from Richard Rothstein's *The Color of Law* and took a walking tour of campus to learn about *de jure* and *de facto* influences on racial segregation in Austin, Texas. ▪ These experiences were framed as chances to *collect* new information to revise the NetLogo segregation model.
3 (12/04/19)	▪ Revising	▪ Participants used the readings, the walking tour, and other prior knowledge to draw a *revised* NetLogo model to better explain how places become racially segregated. ▪ Participants presented these revised models to the class.

Table 4. Brief description of the three-lesson series

Data Collection

A variety of forms of data were collected throughout the three-day lesson series. As mentioned before, this empirical study focused on the final day of the lesson series where participants presented their revised segregation model to the class. Two forms of data were collected during these presentations: (a) photographs of revised models; and (b) video footage of the model presentations.

Revised Segregation Models

Teachers revised the NetLogo segregation model by drawing new, hypothetical, models. Each group created one revised model, resulting in a total of four revised models. Each model was drawn on 3 x 2.5-foot chart paper using colored markers. Two of the models were positioned vertically (with the shorter side on top) and two of the models

were positioned horizontally (with the longer side on top). All four models resemble the original NetLogo model in that they had a visual simulation screen, buttons, toggles, sliders, and graphs. However, each model varied from the original NetLogo model and from each other in important ways, which I explored in this study. To capture these models as data, I hung each model on a white background and photographed it. I analyzed these drawn and revised models to better understand how teachers visually represented residential racial segregation.

Model Presentations

After teachers completed their revised segregation models, they presented these models to the class. Each group presented by gathering at the front of the class, providing a short description about the changes they made in their model, and responding to questions from fellow students and myself. Presentations ranged from 2-7 minutes long. Each presentation was video recorded, then transcribed using the Jeffersonian transcription technique (Jordan & Henderson, 1995). In these transcripts, I documented the teacher who spoke, what they said, the gestures they made with their hands, and areas of the model they pointed to or referenced in their presentation. I analyzed these transcripts to supplement the analysis of the visual artifacts alone. In presentations, teachers clarified – and in some cases, contradicted - the representations of residential racial segregation in their revised models.

Data Analysis

The goal of this analysis was to better understand: (a) how teachers represented residential racial segregation in their revised models (RQ 1); (b) the discourses they drew upon in doing so (RQ 2); and (c) the ideologies that were reproduced or critiqued about

race in the process of modeling residential racial segregation (RQ 3). To support these goals, I crafted a three-phase analytical process which drew on four tools from critical discourse analysis explained earlier in the manuscript: inclusion, personalization, identification, and activation analysis (Figure 3).

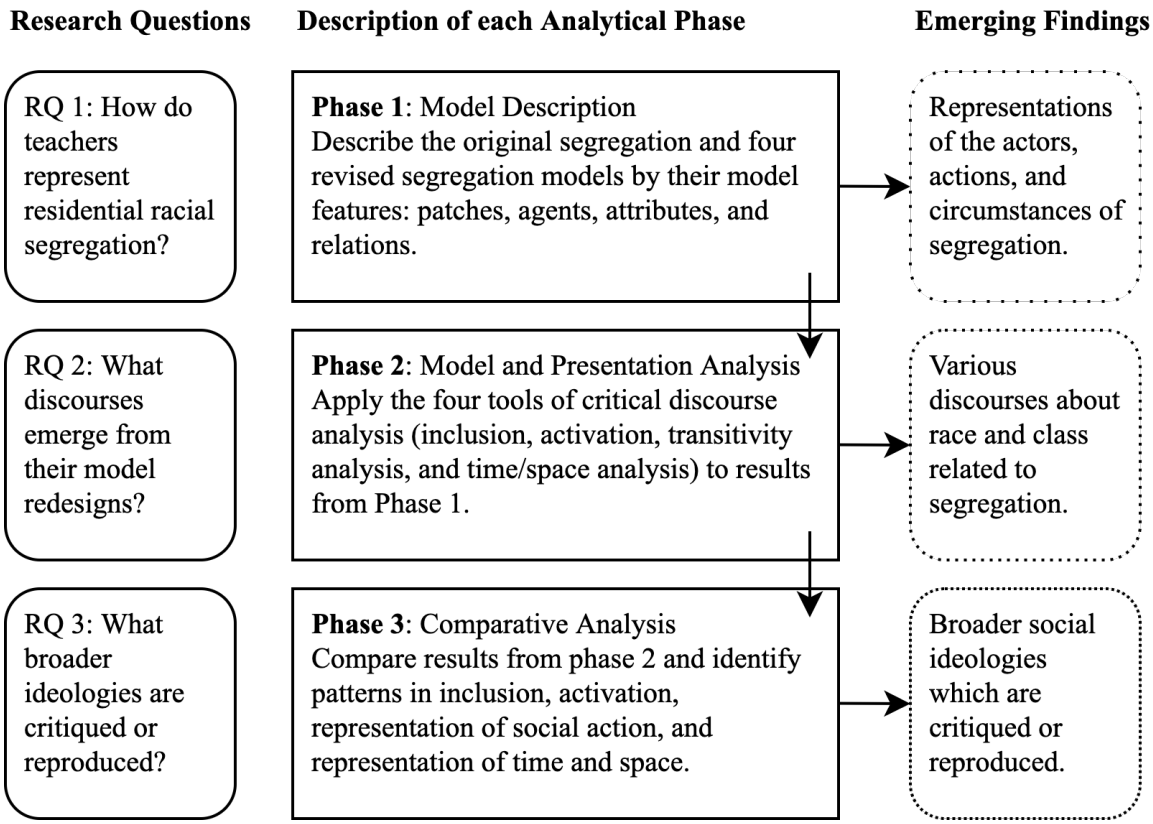

Figure 3. Three-phase procedure for analysis of the original and revised models of segregation.

First, I wrote a descriptive memo of the original NetLogo model and each group's revised segregation model. This phase allowed for a superficial understanding of how individuals, groups, or institutions from the real world are represented and related in the original and revised models. Furthermore, this phase provided an initial understanding of

what aspects from the original model were retained and changed as teachers went about revising the model. However, this phase did not reveal deeper discourses or ideologies about segregation. For this, I turn to critical discourse analysis.

Second, I subjected each model and presentation to the four tools of critical discourse analysis (Table 2). I applied these tools to both the original NetLogo segregation model and each group's revised model and presentation. I then created an analytical memo for each group to summarize the analysis results. This phase allowed for a deeper understanding of which individuals, groups, and institutions from the real world are included, partially excluded, and fully excluded. Furthermore, this analysis delineated how included individuals, groups, or institutions are related to one another, and how time and space play a role in representing residential racial segregation. Analysis of the individual models and presentations allowed me to trace which discourse(s) each group drew upon to understand and represent residential racial segregation. However, it is in the final stage where we begin to see which ideologies are reproduced or contested within the greater class context.

Finally, I compared the critical discourse analysis results from the four revised models and presentations with each other and with the original NetLogo segregation model. This comparison resulted in a final analytical memo which summarized patterns in inclusion, identification, personalization, and activation. These patterns reveal broader social ideologies about race which were reproduced or critiqued in the classroom.

RESULTS

I present the results in order of the analysis phases: In the first section, I describe the original NetLogo segregation model and the four revised segregation models (phase 1, research question 1). In the second section, I describe the results from analyzing each

model with the tools from critical discourse analysis. I discuss the discourses each group drew upon when revising the segregation model (phase 2, research question 2). In the final section, I describe the patterns which emerged from comparing the four revised segregation models with each other and the original NetLogo model (phase 3, research question 3). I use these patterns to discuss the broader ideologies which were reproduced or contested amongst the set of revised segregation models and presentations

Phase 1: Model Description

In the first phase of analysis, I described the turtles, patches, and user settings for the original NetLogo model and for each of the four revised models. Then, I summarized how the revised models differed from each other and the original NetLogo segregation model. These results are summarized in Table 5.

Models	**Turtles**	**Patches**	**User Settings (Sliders, Toggles)**
Original Model	Red houses (racial group 1) Green houses (racial group 2)	Properties	*Sliders*: %-similar wanted, %-too-similar, density *Toggles*: diversity?
Group 1 Model	1-houses (above-average income) 2-houses (average income) 3-houses (below-average income)	Properties differ based on cost, not specified in the model	*Sliders*: %-similar wanted, %-too-similar, density, *Toggles*: diversity?
Group 2 Model	Blue houses (racial group 1) Purple houses (racial group 2)	9-10$ properties 6-8$ properties 3-5$ properties 1-2$ properties	*Sliders*: %-similar wanted, %-too-similar, density, % blue-budget < 6, % purple-budget < 3 *Toggles*: diversity?
Group 3 Model	Red houses (high income) Blue houses (middle income) Green houses (low-income) Checkmark (good school) X-mark (bad school)	Properties differ based on cost, not specified in the model	*Sliders*: red % similar wanted, blue % similar wanted, green % similar wanted, red % options available, blue % options available, green % options available
Group 4 Model	Orange houses (racial group 1) Green houses (racial group 2) Schools	Quadrant 1 properties Quadrant 2 properties Quadrant 3 properties Quadrant 4 properties	*Sliders*: quadrant 1 income, quadrant 2 income, quadrant 3 income, quadrant 4 income, %-similar wanted, %-too-similar, density, *Toggles*: diversity?, segregation previously?,

Table 5. Summary table cataloging each model in terms of turtles, patches, and user settings (sliders and toggles).

The Original NetLogo Model

This model had one type of turtle with two variations: squares which were either red or green. Red and green squares represented houses from two different (but unspecified) demographic groups. In the lesson series, we interpreted the red and green houses to represent different racial groups (fieldnotes, 11/20/19). For example, red houses represented Black families and green houses represented White families. Red and green houses could either be happy or unhappy. When a house was happy, it was symbolized as a square. When a house was unhappy, it was symbolized as a circle.

This model had one type of patch: light-purple squares, behind the red or green houses. Light purple squares represented properties that houses could move into. Properties could either be occupied (have a house on top of them) or be empty (have no house on top of them).

The model had three user settings. First, the model user could control a slider called '%-similar-wanted.' This slider controlled how many similar neighbors a house would want to be happy. For example, if the %-similar-wanted slider was set to 50%, at least half of a houses' neighbors would need to be the same color, otherwise that agent would be unhappy and attempt to move. This slider represented ethnocentric individual behaviors (preferring similar neighbors). Second, the model user could toggle on 'diversity?' and control a slider called '%-too-similar.' This slider controlled how many similar neighbors is too similar. For example, if the %-too-similar slider was set to 75%, at least a quarter of the houses' neighbors would need to be a different color, otherwise that agent would be unhappy. This slider represented what is referred to as cosmopolitan behaviors (preferring different neighbors). Finally, a density slider at the bottom of the

model controlled how many turtles were present. When set to a lower value, there would be fewer houses in the model and therefore more available properties.

Figure 4. The Original NetLogo Segregation Model (Wilensky, 1997).

In summary, the original NetLogo model simulated segregation as emerging from the behaviors of individual houses. If a house was happy with how similar its surrounding neighbors were, it would stay on its property. If a house was unhappy with how similar its surrounding neighbors were, it would move until it was happy again. The model would continue until it reached a stochastically stable state where it maximized the number of happy red or green houses.

Group 1's Revised Model

This model had one type of turtle with three variations: squares which were labeled as 1, 2, or 3. On the second note at the bottom of the model, it was indicated that the numbers corresponded with income levels: 1 corresponded with above average income; 2 corresponded with average income; and 3 corresponded with below average income. This was a shift from the original representation of houses: houses were broken into three groups which represented three distinct economic classes, rather than two groups which represented two different racial groups.

This model had one type of patch: white squares behind houses. Three notes at the bottom of the model modified what these patches represented. On the first note, the group indicated that patches "will be assigned colors to represent property value". The third note indicated that there is an interaction between agents (1, 2, or 3 households) and the property value of each patch. This note stated that "if above 50% of surrounding turtles are above average the patch color will change as property value increases." And finally, the fourth note indicated that "turtles who don't meet # needed to stay on the colored match need to move." This is a change from the original representation of patches or properties: properties could differ based on their economic value which was influenced by the income of the houses nearby. Furthermore, the fourth post-it note specified that properties could exclude or allow for houses to move into or out of them. All the user settings from the original NetLogo model were retained in this model. No new user settings were added.

Figure 5. Group 1's Revised Segregation Model

Group 2's Revised Model

This model had one type of turtle with two variations: squares which were either purple or blue. These purple and blue squares represented houses from two different but unspecified demographic groups. Furthermore, like the original model, these houses could either be happy (symbolized as a square) or unhappy (symbolized as a circle).

This model had one type of patch: white squares behind the houses. However, instead of identical patches in a grid like fashion, the simulator screen was divided into four regions. Each region now possessed a numerical monetary range. For example, quadrant 1 (top, right quadrant) was labeled '$9-10', quadrant 2 (top, left quadrant) was labeled '$6-8', quadrant 3 (bottom, left quadrant) was labeled '$1-2', and quadrant 4

(bottom, right quadrant) was labeled '$3-5'. This represented a range of possible property values associated with patches within each of the four quadrants. I interpreted this as representing how different neighborhoods in a city might have higher or lower property values.

This group retained all the user settings from the original NetLogo model; however, they added two new sliders. The first slider was titled '% blue budget < 6' and the second slider is titled '% purple budget < 3'. These sliders represented that blue houses and purple houses each had a budget that can be controlled by the model user. Furthermore, the use of inequalities suggested that some percentage of the agents will have a budget below a certain fixed value. In the case of blue houses, a certain percentage of agents would have a budget lower than '6'. In the case of purple houses, a certain percentage of agents would have a budget lower than 3.' Therefore, blue and purple houses each had a unique range of possible incomes, either below or above 6 and 3 respectively.

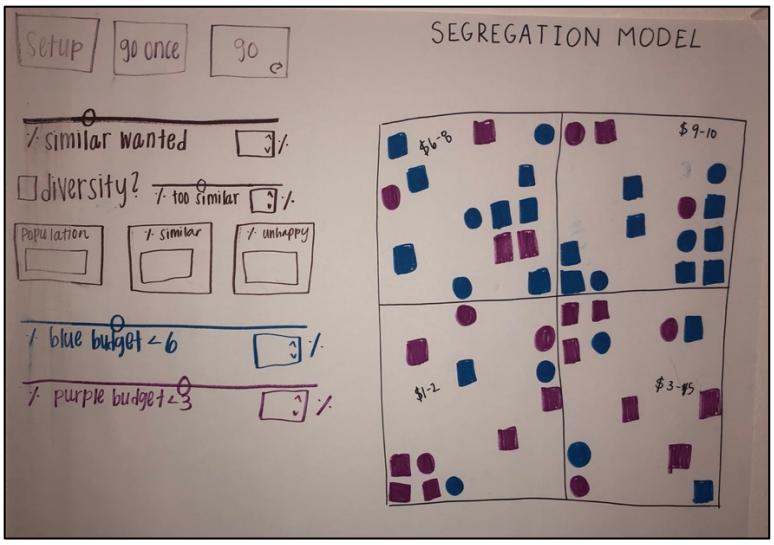

Figure 6. Group 2's Revised Segregation Model

Group 3's Revised Model

This model had two types of turtles: houses and schools. Houses were divided into three variations: red squares, blue squares, and green squares. A legend located at the top of the model indicated that red squares were high income (indicated by an arrow pointing up), blue squares were middle income (indicated by an arrow pointing to the left and right), and green squares were low income (indicated by an arrow pointing down). This was a shift from the original representation of houses: houses were broken into three groups which represented three distinct income-classes, rather than two groups which represent differing racial groups. Schools were the second type of turtle in this model. One patch had a 'check-mark' symbol and one patch had an 'x-mark' symbol. Based on fieldnotes (fieldnotes, 12/04/19), these represented a 'good school' (check-mark) and 'bad school' (x-mark), respectively. However, there was nothing labeled on the model to indicate this.

Patches in this model were represented similar to how they were represented in the original NetLogo model. However, new user settings were added which modified how properties behaved in the model.

Perhaps the most significant change to this model involved the modification of the '%-similar-wanted' sliders and the addition of a new slider series. The original segregation model had one %-similar-wanted slider which dictated how similar or different houses preferred their neighbors to be. In this revised model, group 3 had split the slider into three unique sliders – one for each income level. This represented a system where different income classes could be given (by the model user) different desires for similar neighbors. This group added a new slider series titled '% options available'. Similar to the %-too-similar sliders, there was one slider per income group. I interpreted

this slider to represent the number of properties available to a particular agent from a certain income class.

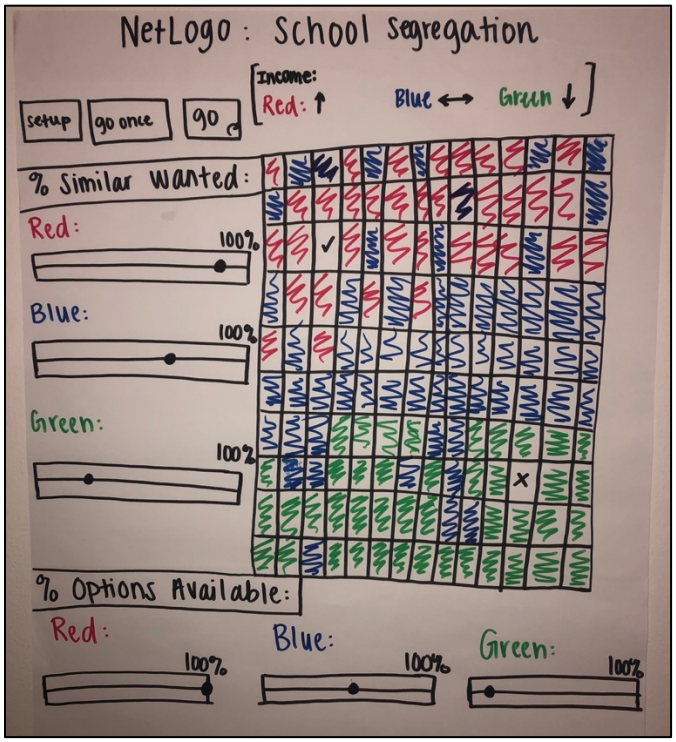

Figure 7. Group 3's Revised Segregation Model

Group 4's Revised Model

This model had two types of turtles: houses and schools. Houses were divided into two variations: orange houses and green houses. There was no indication on the model drawing about what social actors were represented by orange and green houses. Schools were the second type of turtle added to this model. Schools were represented with a house-shaped icon drawn in blue.

This model had one type of patch: white squares behind houses. The white squares represented properties. However, new user settings changed how properties

functioned in the model. This group divided the model simulator into four quadrants and created new user settings which controlled the property value of patches within each quadrant.

Few of the user settings from the original NetLogo simulation were included in this model. However, the group added three new user settings. The first user setting was related to property values. The model user could modify one slider per quadrant which changed the value of properties within that quadrant. This represented properties within different quadrants as having values or costs associated with them. The second user settings were related to schools. The model user could input the number of schools, then indicate (by selecting a toggle) whether the schools will be placed either randomly in the model (represented by a toggle switch titled 'random?') or a second option which said 'per quadrant'. Thus far, it was not clear what might happen in a model if the user selected 'per quadrant.' The third user setting was a toggle titled 'segregation previously?' and a text-input feature which read 'coordinates affected'. This indicated that the group considered segregation to be a phenomenon which could have happened previously in time in some areas, and perhaps not in others.

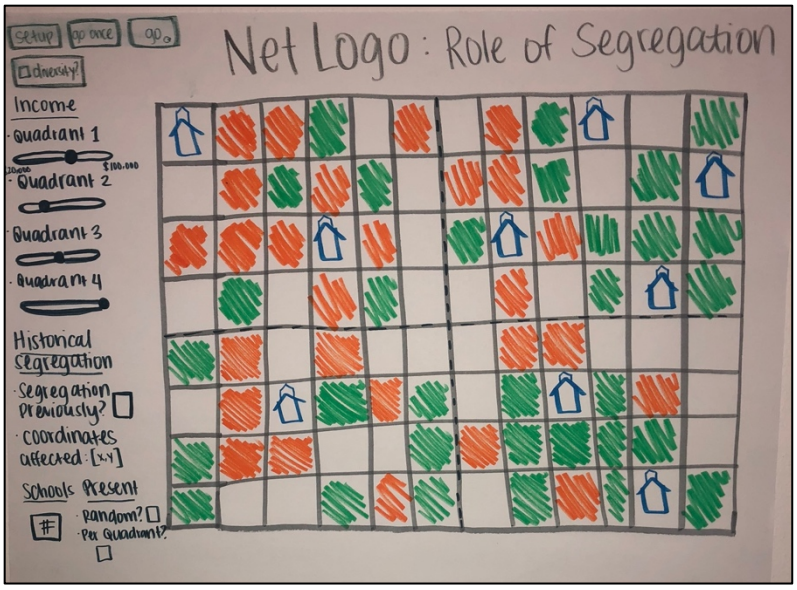

Figure 8. Group 4's Revised Segregation Model

Summary from Phase 1 of Analysis

To summarize, I compared the four revised models with the original NetLogo model. Two of the groups modified the representation of houses from the original NetLogo model. The original NetLogo model used two different colored turtles to represent houses from two demographic groups. These houses were voiced throughout the lesson series as representing two different racial groups.

Groups 2 and 4 maintained this representation of houses. Group 2 used two different colors, blue and purple, to represent two different but unspecified demographic groups. Group 4 used two different colors, orange and green, to represent two different but unspecified demographic groups. Groups 1 and 3 modified the representation of houses. Both groups chose to replace race with economic classes. Group 1 used a three-tiered system which centered on the 'average' income. Houses could either be above-average income, average income, or below-average income. Group 3 used a three-tiered

system which spatialized income. Houses could either be high income, medium income, or low income.

Two groups added schools as a new class of turtle to the model. Group 3 added two schools: one good school and one bad school. Group 4 added many schools to their model, along with a user setting which allowed the model user to control how many schools could be added and where they would be placed.

Patches were modified in all four of the group's models. Patches in the original NetLogo model represented many, identical properties. These properties could either be occupied or empty and could either allow or prohibit movement. Group 2 and 4 split the model simulator into four quadrants and created systems for modifying the property values in each patch. Group 1 and 3 indicated that properties were differently valued but did not split the model simulator into different quadrants. Group 1 indicated in their notes that the patches would be colored to represent different values. Group 3 indicated with a new slider that certain properties would be 'available' to certain agents, although they did not specify how.

This phase of analysis allowed me to unpack the variations of turtles, patches, and user settings within the original NetLogo model and the four revised model. However, this step does not tell me how these representations relate to social actors from the real world. For this, I turn to phase two of analysis: critical discourse analysis.

Phase 2: Model and Presentation Analysis

In the second phase of analysis, I connected model features from the segregation models to social actors, social actions, and circumstances from the real world. Using the tools from critical discourse analysis, I scrutinized: which social actors were included or excluded, how these social actors were represented (whether they were personalized or

depersonalized and identified or functionalized), and which social actors were activated and passivated. I completed this phase by naming and describing the discourses each group drew upon when representing residential racial segregation in their models and model presentations.

The Original NetLogo Model

The original Netlogo model included three social actors: red houses, green houses, and properties. Red and green houses were included in the model as turtles. As mentioned before, the NetLogo model information did not specify which general groups that red and green houses could represent. However, throughout the lesson series myself and the students voiced red and green houses to represent two different racial groups. Therefore, red and green houses were racially identified social actors. Properties were included in the model as patches. Properties were spatialized social actors, which means they are spaces/places which can conduct or receive actions.

The original NetLogo model had one partially excluded social actor: 'those who control density.' 'Those who control density' were partially excluded in the model as a user control: the density slider. The density slider controlled how many agents were present in the model. Although the slider was controlled by the model user, we can imagine that a social actor from the real world is responsible for influencing density in a residential space. This social actor was partially excluded, and the role of controlling density was offloaded to the model user.

Red and green houses were activated in four ways: First, houses could perceive and count their neighbors as similar or different. This was represented by the way the model would check each house's surroundings to see if that house was happy or unhappy with its neighborhood demographic make-up. Perceiving counting are mental social

actions. Second, houses could prefer similar neighbors or prefer different neighbors. This was represented with the two user-controlled sliders: %-similar wanted and %-too-similar. Preferring similarity or preferring difference are mental social actions. Third, houses could be happy or unhappy. This was represented visually in the model when houses changed shape from squares (happy) to circles (unhappy). Being happy or unhappy is a mental social action. Fourth, houses could move or stay. This was represented in the model when houses would change positions on the simulator screen. Moving or staying are material social actions.

Red and green houses were passivated in one way: Houses could be prohibited from moving by a property, if that property was full. Conversely, properties were activated in their abilities to prohibit or allow movement of a house. This was represented in the model when a house was unhappy, attempted to move, but no properties were empty. Therefore, the house would stay put and continue to be unhappy. Being prohibited (in the case of the house) or prohibiting movement (in the case of the property) is a material social action.

Group 1's Revised Model

Group 1's revised model included four social actors: above-average income homes, average-income homes, below-average income homes, and properties. Above-average income homes, average-income homes, and below-average income homes were included in the model as turtles. A note at the bottom of the model indicated that each house type was represented with a corresponding number (1, 2, or 3). Furthermore, during the presentation, Helen said: "each turtle would be assigned a number 1 to 3 to represent income (.) with one being above average – two being average – and three being below average." (00:16:10-00:16:15). Therefore, each of these house-types were

economically identified social actors, meaning they are grouped by their relative economic class.

Properties were included in this model as patches. Properties are spatialized social actors, meaning they are spaces which can conduct or receive actions. Although not symbolized, the group included a note which explained that properties would be differentiated by values. Furthermore, during the presentation Helen explained that: “we thought that we would assign each patch a color to represent property value (counts on fingers) and that would be the background (taps on the model poster).” (12/04/19; 00:16:00). Therefore, properties were also economically identified social actors.

Houses were activated in the same ways as the original NetLogo model. Each house type could: (a) perceive and count similar or different neighbors; (b) prefer similar or different neighbors; (c) be happy or unhappy; and (d) move or stay.

Group 1 included two new social actions in their model: First, Above-average income houses were activated in one new way. Above-average income houses could change the value of properties around them. Conversely, properties were passivated by above-average income houses. This was represented in the third note at the bottom of the model. This note explained that if greater than 50% of the surrounding houses were above-average income houses, the property value of the property would increase. This was a material social action that is only attributed to above-average income houses.

Second, average income and below-average income houses were passivated in one new way. These houses could be prohibited from moving by properties if their income level didn’t match or exceed the property’s income level. Conversely, high-income properties were activated in their ability to prohibit average income and below-average income houses from moving. This was represented on the fourth note at the bottom of the model. This note explained that ‘turtles who don’t meet # needed to stay on

the colored match need to move." Being prohibited from moving (in the case of average-income and below-average income homes) and prohibiting movement (in the case of high-income properties) is a material social action.

Group 2's Revised Model

Group 2's revised model included three social actors: blue houses, purple houses, and properties. Blue and purple houses were included in the model as turtles. The group did not explain in their model drawing what blue and purple houses represented in terms of social groups. However, during the model presentation, Kait was explaining the inclusion of the sliders which controlled budgets for purple and blue houses. While explaining these sliders, Kait said:

1.1 1.2 1.3 1.4	13:50	Kait	In real life there is a racial wealth gap (opens hands, palms facing up) and a disparity (.) it represents that how (pointing to the purple and blue budget sliders) we don't have a fair playing field here. They start at a disadvantage.

In this quote, Kait acknowledged two things. First, she acknowledged that the budget sliders were intended to show two different economic conditions for blue and purple houses. Blue houses had a higher possible range of budgets than did purple houses. Second, she explained that the disparate economic conditions represent the racial wealth gap. This indicated that her group intended for blue and purple houses to also represent two different racial groups. Therefore, I interpreted blue and purple houses to be racially and economically identified social actors.

Properties were included in the model as patches. Properties are spatialized social actors, meaning they are spaces which can conduct or receive actions. Properties were further differentiated by value. The group divided the simulator screen into four

quadrants and labeled each quadrant with a value range. Therefore, properties are also economically identified social actors.

Group 2's revised model partially excluded two social actors: 'those who set property values', and 'those who assign budgets.' 'Those who set property values' were partially excluded in the model as an attribute about patches. As explained, properties could be one of four differing value ranges, depending on their location on the model simulator screen. However, the social actor responsible for setting property values is not mentioned. Therefore, I interpret 'those who set property values' as a partially excluded social actor. 'Those who set budgets' were partially excluded in the model with two sliders: '% blue budget < 6' and '% purple budget < 3.' As explained before, these two sliders controlled the amount of money blue and purple agents had access to. Although the slider was controlled by the model user, we can imagine that a social actor or social process from the real world is responsible for influencing people's budgets. Therefore, I interpret 'those who control budgets' as a partially excluded social actor.

Houses were activated in the same ways as the original NetLogo model. Each house type could: (a) perceive and count similar or different neighbors; (b) prefer similar or different neighbors; (c) be happy or unhappy; and (d) move or stay.

Group 2 added one new social action to their model. Houses were passivated in one new way. Houses could be allowed or prohibited from moving based on their budget. Conversely, properties were activated in their ability to allow or prohibit movement of houses. If a house had a budget higher than the property value, the house was allowed (by the property) to move. If a house had a budget lower than the property value, the house was prohibited (by the property) from moving. Being prohibited from moving (in the houses with low budgets) and prohibiting movement (in the case of high-income properties) is a material social action.

Group 3's Revised Model

Group 3's revised model included five social actors: high-income houses, medium-income houses, low-income houses, schools, and properties. High-income, medium-income, and low-income houses were included in the model as turtles. The group provided at key at the top of the model to indicate the identities of the three types of houses. The students' model had a relatively equal portion of all three types of turtles in the model. High-income houses were mostly located at the top of the model, middle income houses were located in the middle of the model, and low-income houses were located at the bottom of the model. Each of these house-types are economically identified social actors, meaning they are grouped by their relative economic class.

Schools were also included in the model as turtles. The model symbolically showed one 'check' mark in the upper left quadrant and one 'x' mark in the lower right quadrant. The model drawing did not clarify what these symbols meant. However, during the presentation Sage explained the symbols:

2.1 2.2 2.3 2.4 2.5	00:40	Sage	In this [model] there is (*points to the top of the model*) considered a good school (*makes air quotes*) and considered (*points to the bottom of the model, makes air quotes*) a bad school (.) just based on available materials and I guess school funding.

Schools are institutional social actors, meaning they are organizations of people which can conduct or receive actions. On lines 2.1-2.2, Sage mentioned that one school was considered 'good' and the other considered 'bad'. One lines 2.3-2.4, Sage explained that the status as good or bad schools is 'based on available materials' and 'funding.' Therefore, schools are also differentiated social actors. Differentiated social actors are actors who are evaluated by the speaker (in this case, Sage).

Properties were included in the model as patches. Properties were spatialized social actors, meaning they are spaces which can conduct or receive actions. Similar to properties in the original NetLogo model, Group 2 represented properties as identical segments of land. However, during the presentation the groups complicated this representation. When asked about the '% options available' sliders at the bottom of the model, Cady explained:

3.1 3.2 3.3 3.4 3.5 3.6 3.7 3.8 3.9	02:14	Cady	So within each patch (.) obviously (.) we would have to do like (.) in the code (.) we would have to put how much that (.) patch costs (.) So like (.) if the patch (.) for example (.) obviously like how we have here (steps in view of camera, holding paper, points to green options available slider) the green (.) their options are really low because they cannot (points with paper to top of model) even afford to live in that patch specifically (turns to face class) so we would have to like have it in the code somewhere to be like - that each patch -

Here, Cady explained that the group had imagined properties to have different values associated with them (lines 3.1-3.2). These differently valued properties would then operate to prohibit or allow certain house types (for example, green houses) from moving into a property. Therefore, properties are also an economically identified social actor.

Group 3's revised model partially excluded one social actor: 'those who evaluate schools.' As described previously, Sage explained that schools were 'considered' good or bad 'based on available materials' and 'school funding.' The past-tense verb 'considered' indicated that some social actor is responsible for considering schools to be good or bad. However, this social actor is removed through a linguistic process called passive agent deletion. Therefore, I interpret 'those who evaluate schools' to be a representation of the public consensus and a partially excluded social actor.

Group 3's revised segregation model contained the greatest number of changes from the original NetLogo model. Houses were activated in the same ways as the original NetLogo model. Each house type could: (a) perceive and count similar or different neighbors; (b) prefer similar or different neighbors; (c) be happy or unhappy; and (d) move or stay.

Group 3 added two new social actions to their model. First, houses were differently activated in their ability to prefer similar neighbors. The group represented this differential activation by creating a '% similar wanted' slider for each house type. This represented a world where different income classes had different preferences to live nearby similar neighbors. In the model drawing, the group represented high-income houses to have the highest preference for similarity and low-income houses to have the lowest preference for similarity.

Second, houses were differently passivated in their ability to be accepted into a property. The group represented this by adding a new slider called '% options available' for each house type. This slider controlled how many properties were open to various house-types. This represented a world where house types are passivated to conditions about the properties. Conversely, this represented properties as differently activated in their ability to prohibit or allow certain house types from entering a property. On the model drawing, the group represented high-income houses as having the highest number of options available to them and low-income houses as having the lowest amount of options available to them.

Both the social actions of preferring similar neighbors and having options available were further clarified and changed during the presentation. When Bree explained these sliders, she said:

4.1 4.2 4.3 4.4 4.5 4.6 4.7 4.8 4.9	01:30	Bree	So like the red people (*points to red similar wanted slider*) **wanted to stay** mostly around red (*opens hands, points to the top the of model*) **but allowed for** some blue – the blue (*points to blue similar wanted slider*) **would stay** mostly around blue (*opens hands and points to the middle of the model*) **but would prefer** maybe more red (*opens hands, points to the top of the model*) – and then green (*opens hands, points to green similar wanted slider*) is kind of like (.) **wherever they can** (*both hands open, waving circles over the bottom of the model*).

In lines 4.1-4.2, Bree explained that red houses (high-income houses) "wanted to stay" around red but "allowed for" some blue. In lines 4.3-4.4, Bree explained that blue houses, or medium-income houses, 'would stay mostly' around blue, but 'would prefer' more red. And finally, in lines 4.6-4.7, Bree explained that green houses (low-income houses) live "wherever they can." This quote illustrated that students attribute different amounts of power to agents based on their income level. High income agents have the greatest amount of power because they have wants (mental social actions) and can "allow for" other agents to be around (can conduct material actions towards other social actors). Low-income houses, on the other hand, simply live "wherever they can."

In the model drawing, there were no clues regarding how schools may have been activated or passivated. However, during the model presentation the students clarified how they believed schools might function. Sage asked the rhetorical question:

5.1 5.2 5.3 5.4	01:55	Sage	Do you have the option of moving (opens hands, extended outwards) to the school that you are (.) like the area that you desired (.) do you have the financial means (opens hands, sliced downwards).

This quote indicated that the group believed house-types had desires to attend good schools but had financial means that limited their ability. Therefore, schools are

passivated by house-types, in that they are either desired or not desired. Shortly after, Bree added:

6.1 6.2 6.3 6.4 6.5 6.6 6.7 6.8 6.9	02:46	Bree	"So we were talking about how people who are moving – or people who pay a lot (points to top of model) for a house that is zoned to a good school and if they redraw the boundary line (moves hand in slicing motion through the middle of the model) and then their kids now have to go to the bad school (makes air quotes around bad school) like not only do their kids being forced to go to the bad school (makes air quotes around bad school) – but then the property value (points to top of model) of their house decreases."

This quote indicated that the group believed schools could also influence the property value of house-types. If a house type was placed into the boundary of the 'bad school', it would be lowered. If a house type was placed into the boundary of the 'good school,' it would be raised. Therefore, schools are activated in their ability to influence property value of the house-types.

Group 4's Revised Model

Group 4's revised model included four social actors: orange houses, green houses, schools, and properties. Orange and green houses were included in the model as turtles. The group did not symbolize which social actors from the real-world orange and green houses represented. In the bottom left-hand corner of the model, the students had created a key – but marked out the text. Furthermore, the students did not clarify what the orange and green houses may have represented in the model presentation. However, there are two clues that indicated the identity of these social actors. First, the students retained the two-color representational system from the original NetLogo model rather than creating a three-color representational system as did Groups 1 and 3. Second, the students added

economic conditions to the patches rather than to the turtles themselves. Therefore, I considered orange and green houses to be racially identified social actors.

Schools were included in the model as turtles. Schools are institutional social actors because they are organizations of people which conduct or receive actions. Unlike Group 3, the students did not indicate symbolically whether schools were 'good' or 'bad.'

Properties were included in the model as patches. Properties are a spatialized social actor, meaning they are spaces which can conduct or receive actions. Similar to Group's 1 and 2, this group indicated that properties could differ in their cost or value. This was indicated by the creation of four sliders, which controlled the property values in different quadrants. Therefore, properties are also an economically identified social actor.

Group 4's revised model had two partially excluded social actors: 'those who build schools' and 'those who set property values.' 'Those who build schools' were partially excluded in the model with two new user settings: (a) the toggle for schools to be built randomly or by quadrant; and (b) the input feature to control how many schools were built. These two features allow the model user to control where schools are built (randomly, or specifically) and how many schools are built. However, by offloading this capability to the model user – a social actor from the real world is obscured. The real-world social actors who are responsible for determining school locations and school amounts are partially excluded from this model.

'Those who set property values' were partially excluded in the model with the four new sliders which control property values. Similar to other groups, the model user is allowed to control the property values. However, this obscured social actors from the real world who influence or determine property value. Therefore, those who control property value are partially excluded in this model.

Houses were activated in the same ways as the original NetLogo model. Each house type could: (a) perceive and count similar or different neighbors; (b) prefer similar or different neighbors; (c) be happy or unhappy; and (d) move or stay.

The only modification related to the new feature about property values. Although not indicated in the model drawing, during the presentation the group explained that properties could allow or exclude houses based on their income. Lynette explained:

7.1 7.2 7.3 7.4	06:45	Lynette	Based on that income of that quadrant (*driving finger into palm*) people might be content there or not (*pivots hands back and forth*) (.) um::: (.) if that makes sense (.) or certain types of people might live there."

This quote indicated that there was some match or mismatch between property values and the 'types of people' who might be content there or not. I interpreted this to mean that properties were activated in their abilities to exclude or allow differing house types.

Schools were a new social actor which were included in this model. However, it was not clear in the model drawing how they were activated or passivated. During the model presentation, the Lynette clarified this:

8.1 8.2 8.3 8.4 8.5 8.6 8.7 8.8 8.9 8.10 8.11 8.12	00:07:10	Lynette	Then we added schools present (*points to schools*) (.) so we kind of talked about this idea where if there are a lot of schools present (.) um (.) ideally there would be (*hands open, palms facing upwards, spreading outward*) a better distribution of materials and of resources and funds (.) and um (.) if there are fewer schools (.) then more kids are going to have to go that school because it is the closest thing that mayube they are zoned for (.) and um (.) in that case the school may be overcrowded and have too little resources and ultimately will end up as like a failing school (*makes air quotes around failing schools*).

In this quote, Lynette explained how her group conceptualized schools and their relation to segregation. Depending on the number of schools present (controlled by the model user or some partially excluded social actor), schools would either be more or less resourced. Therefore, schools are activated against each other. If more schools are present in an area, they have less students and more resources. If less schools are present in an area, they have more students and less resources.

Perhaps the most interesting modification in Group 4's model was the inclusion of a toggle switch titled 'segregation previously?' and an associated text input feature where the model user could include which coordinates on the model simulator were affected. During the model presentation, Lynette explained how this functioned:

9.1 9.2 9.3 9.4 9.5 9.6	07:00	Lynette	We also added historical segregation::: (.) so you can check off a. box that is like 'segregation previously' and um (.) and for the cod eyou would have to set parameters (.) like on here we added 'coordinate affected' (*points with fingers and draws circle around coordinates affected*) so you would basically enter in like an x-value and a y-value.

This feature indicates a particular representation of time and space involved in segregation. Here, the group is indicating that segregation is a phenomenon which could have happened previously in time and in some spaces rather than others.

Summary from Phase 2 of Analysis

To retrace my steps, I began by describing each model in terms three model features: turtles, patches, and user settings (phase 1). This allowed me to make cursory comparisons between the original NetLogo segregation model and the four revised segregation models. Then, I analyzed these model features to understand what social actors and actions from the real world were represented in each model (phase 2).

Specifically, I drew on four tools from sociosemantic analysis to answer the following questions: What social actors were included, partially excluded, and fully excluded? How were included social actors represented? How were social actors activated or passivated? What social actions were attributed to various social actors? With each model analyzed, I now summarize the results in terms of three discourses that were reproduced about how residential neighborhoods become segregated. I named these three discourses: (a) personal preferences; (b) personal preferences, mediated by class; and (c) personal preferences, mediated by race and class.

- *Personal Preferences*. The original NetLogo model reproduced a personal preferences discourse about how residential neighborhoods become segregated. This discourse had two primary social actors: people and spaces. People are the primary social actor in this discourse. People can be split into any number of smaller groups, but the identity which defined the group is not relevant to the cause of segregation. All people shared some common desire to either: (a) be near people like themselves (the ethnocentric person); (b) be near people different than themselves (the cosmopolitan); or (c) a mixture of the two. The desires of individual people determined whether people are happy or unhappy and move or stay. Spaces are the second social actor relevant in this discourse. Spaces are any area which people can move into or out of. In this discourse, spaces were undifferentiated and could accept a new person only if they are empty. This discourse excludes any mention of governmental institutions, financial institutions, and race- or class-based identity organizing (i.e., neighborhood covenants).
- *Personal Preferences, mediated by Class*. Groups 1 and 3 reproduced the personal preferences discourse but mediated this discourse by including class as an

important factor in creating residential racial segregation. In this discourse, people and space were both given class traits. In other words, people and spaces were split into economically identified groups. People could either be rich or poor, and spaces could either be expensive or cheap. The economic identities of people and space acted only to mediate whether they were allowed to move into or out of space. In simpler terms, rich people could move to more spaces and poor people could move to fewer spaces. However, the driver of segregation was still people's preference to be around individuals similar to themselves. This discourse excludes any mention of governmental institutions, financial institutions, and race- or class-based identity organizing (i.e., neighborhood covenants).

- *Personal Preferences, mediated by Race and Class*. Groups 2 and 4 reproduced the personal preferences discourse but mediated this discourse by including race and class as important factors in creating residential racial segregation. In this discourse, people were given both racial traits and class traits. In other words, people were split into racially identified groups, and then further into economically identified groups. Similar to the previous discourse, spaces were only given class traits. The economic identities of people were connected to the racial identities people, but not explicated in any causal way. However, the driver of segregation was still people's preferences to be around individuals similar to themselves. This discourse excludes any mention of governmental institutions, financial institutions, and race- or class-based identity organizing (i.e., neighborhood covenants).

Phase 3: Comparative Analysis

In the final phase of analysis, I explain how this set of models reproduced dominant ideologies about race. To do this, I compared how each model represented social actors and social actions involved in segregation. Then, I connected these representational variations with and central frames or elements of ideologies about race. I identified two ideologies about race which were reproduced in this set of models. The ideologies about race were: (a) colorblind racial ideology (Bonilla-Silva, 2014); and (b) liberal racial ideology (Haider, 2018). More critical racial ideologies (Haider, 2018) were not reflected in any of these models.

Colorblind Racial Ideology

I drew on Bonilla-Silva (2014) to conceptualize colorblind racial ideology. Bonilla-Silva explained four central frames or elements to colorblind racial ideology:

1. *Abstract liberalism*: Liberalism is a modernist philosophy which values individual rights and liberties, universal notions of right and wrong, equality of treatment, and the notion that society can be gradually improved. Abstract liberalism, as Bonilla-Silva defined, involves "using the ideas associated with political liberalism (e.g., "equal opportunity," the idea that force should not be used to achieve social policy) and economic liberalism (e.g., choice, individualism) in an abstract manner to explain racial matters." (p. 70)
2. *Naturalization*: Naturalization is the process of relegating social or cultural problems to realm of nature. Related to ideologies about race, Bonilla-Silva explained that "naturalization is a frame that allows White people to explain away racial phenomena by suggesting they are natural occurrences." (p. 71).

3. *Cultural Racism*: Cultural racism is a modern alternative to biological racism. Where biological racism justifies racial violence based on (supposed) biological differences between races, cultural racism justifies racial violence on the basis of cultural differences between races. Therefore, colorblind racial ideology ignores race and instead emphasizes culture as creating differences between racial groups.
4. *Minimization of Racism*: Minimization of Racism posits that discrimination on the basis of race is "no longer a central factor affecting minorities' life chances." (p. 72).

Two discourses and three models reproduced central frames or elements of the colorblind racial ideology. The original NetLogo segregation model and the 'personal preferences' discourse about segregation reproduced three frames from colorblind racial ideology: abstract liberalism, naturalization, and minimization of racism. Abstract liberalism was reproduced in the way the model represented houses, properties, and movement. The model included two types of houses from unspecified demographic groups. These households had equal abilities to: perceive and count the similar and different neighbors, be happy or unhappy, and move or stay. Furthermore, this model also included properties as a social actor which influenced whether households could move or stay. Properties were represented as individual and identical squares which were equally available to all households (so long as they didn't already have a household). This model represented segregation as occurring from (equally held) preferences for similar or different neighbors. Furthermore, this model represented movement as a material social action which all social actors had equal access to. Therefore, this model reproduced abstract liberalism in its representation of racial segregation.

Naturalization was reproduced in the way the model presented segregation as an inevitable outcome of preferring similar preferences. If only using the '%-similar-

preferred' slider, the model always yields some form of segregated landscape. If complicating the model by toggling on 'diversity?' and using the '%-too-similar' slider, the model would continue on in perpetuity; however, constantly representing unhappy agents. Therefore, this model represented racial segregation as a naturally occurring and inevitable phenomenon.

Minimization of race was reproduced in the way the model backgrounded the demographic groups which could be represented by red and green houses. Nowhere in the model or model code was the term 'race' mentioned. Furthermore, the model information explained that this model could be used to represent segregation of two different groups of people, but never specified what those groups could be. Although we voiced red and green houses as two different racial groups, the racial identities we ascribed to houses had no impact on how the model ran. Therefore, this model minimized race as an explanatory element of racial segregation.

Group 1 and Group 4's revised models and the 'personal preferences mediated by class' discourse reproduced the same three elements of the colorblind racial ideology. However, there was a slight modification of the fourth frame: minimization of race. Both groups modeled segregation by splitting houses and properties into three economic classes. Houses could either be high, medium, or low income and properties could either be high, medium, or low cost (respectively). This strategy overtly removed race from the representational infrastructure of the segregation model. Therefore, I interpret this as a deeper instantiation of the fourth frame, minimization of race. Here, both groups represent residential racial segregation as a purely class phenomenon, rather than a racial and class phenomenon.

Liberal Racial Ideology

I drew on Haider (2018) to conceptualize liberal ideologies about race. This ideology, while still dominant, stands in contrast to colorblind ideologies about race. Haider explained three central frames or elements about dominant and liberal racial ideology:

1. *Racial Essentialism*. Racial essentialism is the notion that people's racial identities are essential, individual, and fixed qualities. Haider explained "the ideology of race claims that we can categorize people according to specific physical characteristics, which usually revolve around skin color." (p. 43) While these identities are typically indexed by physical characteristics, they can also be indexed by spatial characteristics (where people are located).
2. *Racialized social effects*. Racialized social effects refer to the condition where White racial identity is privileged, and other identities are not. Haider draws on McIntosh (2003) to describe White privilege as a set of "special provisions, maps, passports, codebooks, visas, clothes, tools, and blank checks" afforded to White people that provide them with a social and cultural advantage. All other racial identities are framed as 'other' to White racial identity.
3. *Racism as differential social effects*. Racism, therefore, emerges from certain racial groups being privileged over others, and is described as the differential benefits provided to White people and the consequences provided to other racial groups.

In lay terms, a liberal racial ideology provides three frames: races are biological and culturally fixed traits of individuals, certain races are privileged over others, and racism is the product of certain privileges being granted to some races and denied to others.

Haider delineated the liberal racial ideology to offer a more critical and contrasting reading of race and racism. In Haider's critical racial ideology, it is racism that creates races, not the other way around. A critical racial ideology has three counter frames:

1. Races are not essential identities, but rather, socially, historically, and spatially situated identities.
2. Privilege is not 'attached' to White racial identity, but rather "the constitution of whiteness as identity and its constitution as privilege are simultaneous" (Haider, 2018, p. 46). Therefore, White identity and privilege are one in the same and are situationally constructed.
3. Racism creates races. Racism is tightly bound up with other social identities (i.e. gender, sexuality, class) and social structures (i.e. capitalism, colonialism).

I delineate Haider's liberal and critical racial ideologies to highlight the distinction between the two. In the liberal racial ideology: races are real and racism is the negative treatment of some races. In the critical racial ideology: racism is real, and races are a social identity constructed to divide and subjugate the working class to extract capital from people and places.

Group 2 and 4's models and the discourse 'personal preferences mediated by race and class' reproduced two of frames from the liberal racial ideology. Racial identity as an essential characteristic was reproduced in both models in the ways that social actors were represented. Group 2 represented two types of social actors: blue houses and purple houses. Blue and purple houses represented two, unspecified demographic groups. During the model presentation, Kait clarified that their model attempted to represent segregation and the racial wealth gap. Furthermore, Kait mentioned "we don't have a fair playing field here. They start at a disadvantage." (12/04/19, 13:50, 1.4). Two things were

inferred from this quote. First, blue and purple houses represented two different racial groups. Second, purple social actors represented an economically disadvantaged or unprivileged racial group and blue houses represented some economically advantaged or privileged racial group. Therefore, Group 2 reproduced the framing that races are essential characteristics (which can be represented in a model) and that some racial groups are economically privileged over others.

Group 4 also represented two types of social actors: orange houses and green houses. However, it was less clear what social groups these house types represented. I inferred that these house types represented racial groups, since economic identities were attached to the property rather than to the agent explicitly (as had been done in Group 1, 2, and 3). If this group did intend for orange and green houses to represent two racial groups, then they reproduced the liberal notion of essential racial identities which can be represented and modeled.

Racism as a differential social effect was reproduced in how both models activated social actors and simulated segregation. Similar to the original NetLogo model, both groups indicated that people moved or stayed based on their preference for similar or different neighbors. Both groups complicated the process of moving or staying by including economic conditions. However, personal preference was still the driving cause behind residential racial segregation. This explanation of residential racial segregation equated racism with differential social effects. Some social actors are privileged and can move whereas other social actors are not privileged and cannot move. This explanation of racism ignored the institutional social actors involved in segregation, such as: municipal governments, banks (HOLC), federal loan programs, spatial features, and neighborhood associations. Furthermore, this relegated racism to be an affect-driven process, where people either ‘like’ or ‘do not like’ certain people. This explanation of racism excluded

the physical violent behaviors of dominant racial groups (i.e. White racial groups) towards racialized 'others'.

DISCUSSION

In this study, I set out to accomplish two goals. My first goal was specific to studies about ideology and learning. I aimed to show how ideologies can be reproduced within classroom artifacts. My second goal was more general to research in the learning sciences. I aimed to critique the use of agent-based for teaching and learning about sociopolitical phenomenon, like residential racial segregation. In this discussion, I review my progress towards achieving each goal.

Ideologies as Socio-technical Achievements

Previous studies about ideology and learning have "drawn attention to the micro-interactions through which ideological stances are taken by participants, taken up by others, and contested and co-constructed in interaction" (Philip & Gupta, 2020, p. 200). In research on teacher education, Philip (2011) traced the ideologies about race and class that a single teacher drew upon to reason about student successes and failures over the course of a semester. In research on computer science education, Philip, Olivares-Pasillas, and Rocha (2016) analyzed moments in high school classrooms were students and teachers made sense of data visualizations by drawing on broader ideologies social of race and more specific local knowledge. In research on engineering education, Philip, Gupta, Elby, and Turpen (2018) traced how the ideological categories of 'civilian' and 'terrorist' were interactionally constructed and converged upon throughout a single class period where students were learning about drone warfare.

Similar across these works is their close attention to people's talk as the primary medium through which ideologies are drawn upon, contested, and constructed. Each study relied on methods - such as stance analysis (Du Bois, 2007) - which describe, analyze, and connect participant's talk in interaction with broader social ideologies. From this perspective, ideologies are mental phenomenon which arise during social interactions.

However, ideologies are only partly discursive (van Dijk, 2008; Cresswell, 1996). Ideologies can also be drawn upon, contested, and constructed: (a) within materials themselves; and (b) when people interact with materials. By materials, I am referring to any artifact which can contain meaning(s). For example, the teachers in this study used, evaluated, and revised the NetLogo segregation model. To revise this model, teachers drew new models on large sheets of chart paper. Then, they presented these models to the class to explain their reasoning about how residential neighborhoods become racially segregated. In both the models themselves and the interactions with the models, teachers reproduced dominant ideologies about race. From this perspective, ideologies are a material phenomenon which arise during technical interactions. To illustrate this, I return to two examples from the findings of this study.

The first example illustrates how ideologies are reproduced within materials themselves. The original NetLogo segregation model reproduced a colorblind racial ideology. This ideology was reproduced in how the model represented social actors. This model included two social actors. The social actors were symbolized as red and green squares and represented two unspecific demographic groups of people. Although the class voiced these unspecified groups as members of two racial groups, the model itself did not mention race in the model features, the code, or the model information. This representation of people involved in segregation reproduced the third frame of colorblind

racial ideology: minimization of race. Race was removed from this model and replaced with an abstract representation of two different groups. Furthermore, two of the revised models similarly minimized race. Groups 1 and 3 removed racial groups from the explanation of segregation and instead included class as the defining group identity.

The second example illustrates how ideologies are reproduced when people interact with materials. During group 3's presentation, Sage and Bree explained the changes they made when modeling segregation. The drawn model represented three economic classes (high-income houses, medium income houses, and low-income houses) as the primary social actors. These social actors had different abilities to move around the simulator screen, represented by sliders drawn at the bottom of the model. High-income agents had the highest percentage of properties available to them, medium income agents had a moderate percentage of properties available to them, and low-income agents had the lowest percentage of properties available to them. When explaining these sliders, Bree said:

4.1 4.2 4.3 4.4 4.5 4.6 4.7 4.8 4.9	00:01:30	Bree	So like the red people (*points to red similar wanted slider*) **wanted to stay** mostly around red (*opens hands, points to the top the of model*) **but allowed for** some blue – the blue (*points to blue similar wanted slider*) **would stay** mostly around blue (*opens hands and points to the middle of the model*) **but would prefer** maybe more red (*opens hands, points to the top of the model*) – and then green (*opens hands, points to green similar wanted slider*) is kind of like (.) **wherever they can** (*both hands open, waving circles over the bottom of the model*).

By explaining her drawn model, Bree clarified more about how she viewed different groups of people from the real world and the actions they can conduct or receive. Rather than each group simply having a different percent of options available to them, we now see mental and material actions brought into light. Wealthier people are

given more power in their ability to want similar neighbors and allow for other types of neighbors. Poor people, on the other hand, are given no agency or power. They simply go 'wherever they can.' This conversation, between Bree, her model, and the class reproduced the first third of colorblind racial ideologies: naturalization. This conversation naturalizes differences between economic classes and further instantiates the power differences that exist between them.

In summary, this study demonstrated that ideologies are both mental phenomena which (cued in social interaction) and material phenomena (cued in technical interaction). Therefore, I consider ideologies to be sociotechnical achievements.

Critique of using Agent-based models about Sociopolitical Phenomenon

As mentioned before, I began this study with the intent of providing teachers with the opportunity to use, evaluate, and revise the NetLogo segregation model to more critically explain how neighborhoods become racially segregated. I was inspired by other research which had used agent-based models to teach people about critical social issues (Hostetler, Sengupta, & Hollett, 2018; Guo, 2019). However, despite teachers having had rich conversations about the *de jure* and *de facto* causes of residential racial segregation, all four revised models either removed race completely or backgrounded race and racism as an effect, rather than a cause of segregation. Collectively, these models drew on discourses which represented segregation as a class phenomenon and reproduced either colorblind or liberal racial ideologies. Furthermore, none of the models included any institutional social actors such as banks, neighborhood covenants, municipal governments, or federal loan programs.

At first, I imagined this to be a failure of the lesson series, the readings, my ability to lead a lesson about segregation, or teachers' own comfort with to explaining race.

However, the consistency in how this group of teachers modeled segregation might point to another reason. The original NetLogo segregation model divided the world into two planes: the social plane and the spatial plane. In the social plane are turtles, which represent the people, groups, or institutions which can move around, act, and interact in space. In the spatial plane are patches, which represent the background on which turtles move around, act, and interact. The infrastructure is a smooth and simple environment for rendering complex phenomena visible and manipulatable. However, how simple is too simple? What is lost when the complex world is squeezed into a model? What phenomenon are acceptable to model and what phenomenon are not? How might the simplicity of NetLogo engender overly simple representations of a complex, nuanced, and emotional phenomenon? While I do not have answers to these questions, I turn to Haider for inspiration on the matter:

> "[W]e gain nothing by reducing these concrete instances to a single abstraction., which we can explain in isolation from the specific circumstances. As I have already suggested, the better way of proceeding is to recognize that this abstraction of "race" is already an active component of our ways to understanding the world, but to explain it by adding back all the specific, concrete factors that have generated it – moving from our thoughts to the material world and its history." (Haider, 2018, p. 44).

Perhaps creating the model should not be the goal of a lesson which uses agent-based models to represent complex sociopolitical phenomena. Rather, we should begin with our abstractions of the world and work to add back all the specifics that get lost along the way.

Article 3: How Ideologies of Place Mediate Reasoning about and Modeling Urban Heat Island Effect

INTRODUCTION

Contemporary research in the learning sciences has illuminated the central role that ideologies play in STEM learning and instruction (Philip citations; Philip & Gupta, 2020). In this paper, I contributed to this body of scholarship by investigating how ideologies of place (Cresswell, 1996) became salient resources for reasoning about space (National Research Council, 1997, 2006). Specifically, I examined a group of preservice teachers throughout a six-day lesson series where they created models to explain urban heat island effect in Austin, Texas. I focus on one student, Aaron, who repeatedly discussed his understandings about the city of Austin and various neighborhoods within it. Using progressive refinement of hypothesis (Engle, Conant, & Greeno, 2007) and critical discourse analysis (van Leeuwen, 1993, 1996), I traced how Aarons' ideologies about various neighborhoods in Austin became an important resource for reasoning about and modeling urban heat island effect.

Ideologies are "socially shared systems of representation" (Philip, 2018, p. 186) that people use to "make sense of, define, figure out and render intelligible the way society works" (Hall, 1996, p. 26). Ideologies of place, therefore, are socially shared meanings which people use to make sense of, define, figure out, and render intelligible the way space works. By space, I am referring to the quantifiable aspects of the three-dimensional world which can be systematically investigated. Spaces are made of points, areas, and volumes. Spatial reasoning "distills patterns, relationships, and contexts embedded in space [which] serve as a neutral container, field, or platform to hold concrete abstract objects" (Cho & Yuan, 2019, p. 548). However, spaces are not only neutral containers. Spaces become places as they acquire social meanings about their

nature. These meanings describe the boundaries of a place, how one place is different from the next, and what people, materials, and actions are natural or unnatural in a place. As such, I posit that people's ideologies about place are important resources for reasoning about space.

I have two goals in conducting this analysis: My first goal is specific to research about the relationship between ideologies and learning. Most research about ideologies and learning focuses on participant's talk and social interactions (Philip, 2011, Philip, Gupta, Elby, & Turpen, 2018). These studies portray ideologies as a primarily discursive and mental phenomenon. In this study, I show how ideologies are drawn upon, contested, and constructed through social and material interactions. Towards this end, I portray ideologies as a mental and material phenomenon. My second goal is more general to research about spatial reasoning. One body of research about spatial reasoning focuses on students' abilities to use mathematics to reason about spatial (in)justices. These studies caution that students' knowledge about place can be a hindrance to reasoning with spatial data. In this study, I show how dominant ideologies of place mediate reasoning about space. However, I do not frame moments as a hindrance to learning. Rather, I conceptualize these moments as possible sites where others can engage in ideological divergence (Philip, Gupta, Elby, & Turpen, 2018) or transgression (Cresswell, 1996), towards more just representations of space and place.

This paper is organized as follows: First, I present my theoretical framework. I draw on cultural studies (Hall, 1986), the learning sciences (Philip, 2011), and geography (Cresswell, 1996, 2004) to conceptualize ideologies and discuss their relationship to learning. Second, I review my methodology. I discuss how Aaron's case emerged from the data as an intrinsically interesting (Stake, 1995) case to understand how ideologies of place relate to reasoning about space. Third, I present my findings from this study. I

begin by explaining Aaron's ideological geography of Austin. Then, I provide two examples of how Aaron used these ideologies of place to reason about hot and cool parts of the city. Finally, I close with an analysis of Aaron's final model of urban heat island effect which did not contain any of his ideological framings of the city. I close with a discussion about the relationship between ideologies of place and reasoning about space.

THEORETICAL FRAMEWORK

The broader goal of this project is to build on studies which investigate the relationship between ideology and STEM learning. I conceptualize learning as a sociotechnical process where people interact with each other and their material surroundings to "generate new understandings, extend navigational possibilities, and adapt meaning-making practices to new forms and functions." (Roseberry, Ogonowski, DiSchino, & Warren, 2010, p. 324). In this section, I connect this perspective on learning to theories of ideology. First, I draw from cultural studies (Hall, 1986) and the learning sciences (Philip, 2011) to conceptualize ideologies and relate them to learning. Then, I draw on from critical geography (Cresswell, 1996) to conceptualize ideologies of place and relate these ideologies to reasoning about space.

Ideology and Reasoning

Stuart Hall defines ideologies as "the mental frameworks – the languages, the concepts, categories, imagery of thought, and the systems of representation – which different classes and social groups deploy in order to make sense of, define, figure out, and render intelligible the way society works." (Hall, 1996, p. 26). Hall's definition highlights the social, historical, and axiomatic nature of ideologies. However, this

definition does little to surface how ideologies are used, in interaction, to reason about the world. For this, I turn to Philip's framework ideology in pieces (Philip, 2011).

Ideology in pieces blends diSessa's theories about conceptual change (1993, 2002) with Hall's theories about ideology (1982, 1996). This framework explains that ideologies are dynamically co-constructed as people reason about the natural or social world. While there are many tenets involved in ideology in pieces, I explain three that I find most useful for this study:

- First, people draw on taken-for-granted assumptions or commonsense ideas to initiate reasoning about the social (or spatial) world. Philip calls these assumptions or ideas naturalized axioms. In interaction, people initiate reasoning by posing a naturalized axiom. For example, when participants were asked to explain what causes urban heat islands in Austin, Texas, they often began by listing out the ideas they knew to be true about the city of Austin.
- Second, naturalized axioms are cued by specific contexts and are not applied globally. Naturalized axioms are cued when people interact with others (social interactions) or with materials in the classroom (technical interactions). For example, students may reason differently about urban heat islands when reading a map that visualizes racial demography, then when reading map that visualizes class demography. Therefore, changing the social or material conditions of an interaction may engender shifts in what naturalized axioms people draw upon.
- Third, people over time stabilize or converge on sets of naturalized axioms for explaining the social or spatial world. As mentioned before, individuals do not know or contain entire ideologies in their minds. Rather, they draw on pieces of ideologies (naturalized axioms) in moments to reason about the world. However, over time certain ideological framings of the world can become sedimented,

converged upon, and empowered if they are repeatedly taken up by others. In later studies, Philip et. al. (2018) referred to this process as ideological convergence.

I use Philip's ideology in pieces framework to attend to the moment-to-moment construction of ideologies in STEM learning environments. However, I make two adjustments. First, Philip paid analytical attention to people's talk as the primary modality through which ideologies were drawn upon, contested, and co-constructed. By viewing learning as a sociotechnical accomplishment, I aim to expand analytical attention to focus on participant's talk, interactions with each other, and interactions with the materials they use in class. Second, Philip focused on ideologies in general. However, I aim to focus on a particular type (van Dijk, 2008) of ideology which are called upon when people reason about space: ideologies of place (Cresswell, 1996).

Ideologies of Place and Reasoning about Space

In his book *In and Out of Place: Geography, Ideology, and Transgression* (1996), Tim Cresswell analyzes events where people violated societal and spatial norms. For example, he discusses grafitti artist 'tagging' streets in New York City, hippies attending a music festival at Stonehenge, and Feminist nuclear disarmament protesters on the outskirts of a military base. By analyzing each these transgressive events, Cresswell showed how dominant ideologies about place are reproduced and used to judge people, materials, and actions as being natural or unnatural in certain spaces.

Ideologies of place are the collection of social meanings which are attached to particular places. Similar to Hall's definition, ideologies of place support people in reasoning about space. Cresswell specifies four axiomatic components of an ideology of place:

- First, ideologies define and classify places. Classification is a core ideological strategy which explains what places exist (including their spatial extent and boundaries) and what places do not exist.
- Second, ideologies of place describe how one place is different from another place. That is, ideologies of place differentiate places in the world. These differences can relate to their affective judgements of place (good/bad), aesthetic judgements of place (beautiful/ugly), or quantitative judgements of place (hotter/cooler).
- Third, ideologies of place specify what people or materials are natural within these places. That is, they frame some people and materials as 'in place' and others as 'out of place.'
- Fourth, ideologies of place specify what actions or practices are natural or unnatural within a place. That is, they connect spaces with acceptable social actions.

In this study, I use Cresswell's four elements to search the data for moments when participants were reasoning about space (i.e. urban heat island) while drawing on ideologies of place. In the next section, I discuss my methodology for mining the data to find these moments.

METHODOLOGY

This empirical study is part of a broader research project which explores how ideologies mediate reasoning about and modeling spatial phenomena. The data for this study was collected from a group of six preservice secondary STEM teachers enrolled in a project-based teaching methods course. The preservice teachers participated in a six-lesson series where they were asked to create a model which explained how urban heat

islands form in their local city, Austin, Texas. Guided by the principles of progressive refinement of hypotheses (Engle, Conant, and Greeno, 2007), data analysis and research questions unfolded simultaneously, resulting in many smaller cases of interest. I report on one of those cases here.

This qualitative case study (Stake, 1995) focused on one student, Aaron, and his efforts to reason about and model urban heat island effect. Aaron was selected because he as spoke frequently in class and sometimes interrupted students to make sure his remarks were heard. When reasoning about where urban heat islands may form in the city, he discussed knowledge about a variety of neighborhoods in Austin. Furthermore, many of Aaron's remarks about these neighborhoods were overtly ideological (Cresswell, 1996). Aaron viewed the west half the city as 'the good part' and the east half of the city as 'the slums.' This view of the city was voiced many times throughout the lesson series and ultimately shaped how he reasoned about and modeled urban heat island effect.

As a reminder, the primary research question guiding this analysis is: How do ideologies of place mediate reasoning about and modeling a complex spatial phenomenon? In the specific case of Aaron, I ask the following:

1. What ideologies of place does Aaron draw upon to make sense of Austin?
2. How does Aaron use these ideologies of place to make sense of urban heat island effect?
3. How do these ideologies relate to his group's efforts to model urban heat island effect?

This section is organized as follows. First, I describe the context of the research. By context, I am referring to: (a) the institution and course in which the study takes place; (b) the focal participant; and (c) the design of the lesson series. Second, I describe and justify the process of data collection, organization, and transformation. Finally, I explain

the process of analyzing the data to surface how ideologies of place mediated Aaron's efforts to reason about urban heat island effect.

Context

This research was conducted within a secondary teacher education program at a large university in the Austin, Texas. Preservice teachers enrolled in this program obtain an undergraduate bachelor's degree in a STEM field and simultaneously work towards a secondary STEM teaching credential. This research occurred during the Spring of 2021 in a course titled project-based instruction (PBI). The PBI course was designed to provide preservice teachers with: (a) a general understanding of the theoretical foundations of the PBI teaching method; (b) opportunities to participate in secondary STEM lessons; and (c) opportunities to plan secondary STEM lessons. This researcher took place in the context of the second goal of the course: providing teachers with opportunities to participate in secondary STEM lessons themselves.

Participant

The broader research project focused on a class of six preservice secondary STEM teachers enrolled in the PBI course. The course was led by an instructor, Dr. Kate Barry (a pseudonym). I acted as both the teaching assistant for the course and the researcher investigating the urban heat island lesson series. In the data, I refer to Dr. Barry either with the initials KB or simply as 'the course instructor.' During the lesson series, the course instructor divided the class into two groups. The first group was comprised of three students: Aaron, Drew, and Jordan (pseudonyms). The second group was comprised of Elias, Julius, and Judy (pseudonyms). This empirical study focused on

a single student: Aaron. However, at multiple points in the analysis I refer to others who interacted with Aaron.

Aaron is a White, cis-gender, male student enrolled in the preservice teacher education program. He was older than the other students enrolled in the course and the course instructor. He had previously earned a bachelor's degree in a STEM field and returned to complete coursework for a teaching credential after many years working in a STEM career. Aaron was an active participant in the course, spoke frequently, and often spoke first whenever questions were asked of students. In many instances, Aaron would speak over other students, sometimes interrupting students in the process.

I focus on Aaron for three reasons. First, Aaron's frequent participation in class dramatically shaped both whole-group and small-group class discussions. As mentioned, Aaron spoke first and more frequently than other students. In many instances, the course instructor and myself would make efforts to call on other students to speak. Despite these attempts, Aaron's contributions to the classroom conversation took center stage. Second, Aaron had lived in Austin longer than any of the students and the course instructor. Because of this, Aaron had many things to say about the history of Austin and the various neighborhoods in the city. Finally, many of Aaron's remarks about the city of Austin, various neighborhoods in Austin, and the causes of urban heat island were overtly ideological. By ideological, I mean he presented information about Austin as 'commonsense' (Hall, 1982) that did not need further justification. For these reasons, Aaron stood out as rich case to investigate the relationship between ideologies of place and reasoning about complex spatial phenomena.

Lesson Series

The lesson series was collaboratively designed by myself (MS) and the course instructor (KB) to provide preservice teachers with the opportunity to engage in the model-based learning cycle (Louca & Zachariah, 2005); a pedagogical approach to using models in science classrooms. The goal of the model-based learning cycle is for learners to create models which represent natural or social phenomena. By creating models, learners make visible how they think about and represent the structure and relations they see as part of a phenomenon.

The urban heat island lesson series spanned six class periods, each lasting approximately an hour and fifteen minutes. The purpose of the lesson series was for students to read about the causes of urban heat island effect, explore local neighborhoods using Google StreetView, and design a model which represents how urban heat islands form within cities. A detailed description of the six-lesson series is provided in Table 6.

Lesson	Description
1 (01/27/21)	Students were introduced the urban heat island effect, explored maps of Austin, and explored an agent-based model of urban heat island effect.
2 (02/04/21)	Open Exploration: Students chose a neighborhood in Austin, engaged in a virtual walking tour using Google Street View, and generated ideas about causes of UHI.
3 (04/05/21)	Geographic/Geological Exploration: Prior to class, students read about the variety of geographic causes to UHI. In class, students went to the neighborhood to explored for structural features which contribute to UHI.
4 (04/12/21)	Historical Exploration: Prior to class, students read about the historic causes of UHI (Wilson, 2020). In class, students went back to the neighborhood and explored for historical features which contribute to UHI.
5 (04/14/21)	Students worked to create a model of urban heat islands to show the change in their thinking and reflect new understandings about the causes of urban heat island effect.
6 (04/16/21)	Students presented their urban heat island models to the class.

Table 6. Brief description of the urban heat island six-lesson series

Data Collection

To examine how ideologies of place mediate reasoning about urban heat island effect, I collected three forms of data: whole-group video data, small-group video data, and final models of urban heat island. Because this research took place during the Spring 2021 semester during with the COVID-19 pandemic, no participants were physically present throughout the lesson series. Instead, participants in this course attended a biweekly virtual and synchronous class using the Zoom video conferencing platform. All lessons were recorded using the Zoom platform. Whole-class activities were recorded by the researcher and saved onto a cloud server. Small-group activities were recorded by one of the participants and uploaded to a cloud server. In the sections below, I describe each form of data which was collected and discuss how I used it to explore the broader research question.

Video Recordings

Whole group videos captured conversations between the course instructor and all the students. These conversations involved the course instructor and students reviewing assigned readings or sharing out what students learned from working with maps, models, or engaging in the virtual neighborhood. On the first (01/27/21) and last day (04/16/21) of the lesson series, students and the course instructor stayed in the whole-group configuration for the entire class. This totaled 1 hour and 15 minutes of video footage per class. On days 2, 3, 4, and 5 of the lesson series; students were in the whole-group activities at the beginning and end of class. This totaled approximately 30 minutes of video footage per class.

Small group videos captured conversations between group members (3 students per group) and sometimes the course instructor (if they joined the break-out room). These

conversations involved students working with maps and models of urban heat island, discussing readings about urban heat island, and engaging in the virtual neighborhood tours with Google StreetView. There were no small group activities on the first (01/27/21) and last day (04/16/21) of the lesson series. On days 2 (02/03/21), 3 (04/05/21), 4 (04/12/21), and 5 (04/16/21) of the lesson series, students were in small-group activities in the middle of class. This totaled approximately 45 minutes per class. In total, 5 hours of whole-group video and 3 hours of small-group video were collected.

I collected video data to better understand how ideologies are cued in interaction and used to reason about urban heat island. This involved viewing what participants were seeing, hearing, and saying. For example, throughout the lesson series students would view maps of Austin, identify patterns in the maps, and discuss their knowledge of areas on the map. Therefore, it was necessary to document what aspect of the map students were pointing to as they reasoned about patterns and explained their local knowledge of place.

The Final Urban Heat Island Model

The goal of the lesson series was for participants to create a model which explained how urban heat islands form in Austin, Texas. Students were provided with an initial NetLogo model for inspiration, but both groups ultimately created their own representations of urban heat island. These models were collected from students at the end of the UHI unit in the form of screenshots of their work. The final urban heat island model is used to analyze how participants think about urban heat island at the end of the six-lesson series.

Data Analysis

The broader goal of this research is to understand how ideologies of place mediate reasoning about urban heat island effect. Guided by the principles of progressive refinement of hypotheses (Engle, Conant, & Greeno, 2007), data analysis and research questions unfolded in tandem until I had identified Aaron as an illustrative case. I extracted a series of episodes where Aaron drew on ideologies of place to reason about urban heat island. I analyzed each of these episodes with a two-phase analysis procedure. First, I applied Cresswell's (1996) four elements of ideologies of place to describe each episode. This helped me render Aaron's ideologies of place more clearly. Second, I used tools from critical discourse analysis to probe these episodes further to see how Aaron represented the people, materials, and actions associated with urban heat island effect (Fairclough, 2004; van Leeuwen, 1993, 1996).

In the sections that follow, I explain my analytical process. I begin by describing how I qualitatively and inductively analyzed the video footage from the six-day lesson series. Then, I discuss how and why I selected Aaron as the focal student for this case study. Finally, I discuss how I analyzed Aaron's participation in the lesson series to understand how ideologies of place related to reasoning about urban heat island effect.

Step 1: Creating Content Logs

First, I viewed the video footage and created one content log for each day of the six-lesson series. Each content log contained a biographical description and a proto transcript. The biographical description recorded: the general goal of the lesson, the participants present, the materials used (slides, maps, models, readings, etc.), and the configuration (whole group activities, small group activities, or a mixture of the two). The proto transcript recorded minute-by-minute descriptions of what participants were

doing (i.e. creating models, summarizing a reading), saying (i.e. naming causes of urban heat island), working with (i.e. screen shots from their virtual neighborhood tours), and who or what they were interacting with (i.e. classmates, the course instructor, the reading). Creating content logs familiarized me with the data and helped me to notice patterns in how participants talked about place and urban heat island.

Step 2: Writing Analytical Memos about Place

Second, I read the content logs and created analytical memos for each day of the lesson series. In these analytical memos, I summarized how students talked about place while reasoning about urban heat island effect. I noticed that students talked about place in a four binary-ways.

- ***Specific/General***. First, participants spoke about place either specifically or generally. Specific instances of place talk dealt with locales that can be referenced on a map. For example, students may have talked about Hyde Park (a neighborhood in Central Austin) or a grocery store they shop at. General instances of place talk dealt with non-specific locales. For example, students may talk about 'cities' or 'towns' without making specific reference to *a* city or town.
- ***Local/Extra-local***. Second, participants spoke about place either locally or extra-locally. Because the lesson series involved reasoning about urban heat islands in Austin, Texas; most participants talked about places in the city. I refer to these as local instances of place talk. In some instances, participants brought up places outside of Austin which they knew. I call these moments extra-local instances of place talk. For example, Aaron frequently discussed his experiences in Seattle, Washington.

- ***Experience/Understanding***. Third, participants spoke about either their experiences in places or their understandings of places. By experiences in places, I mean moments when participants talked about memories of a particular place. For example, many students recounted walking around particular neighborhoods to think about which parts of the city were warmer or cooler. By understandings of places, I mean moments when participants talked more generally about what they know about a place. For example, students would talk about: (a) the history of places; (b) the aesthetic qualities of places (beautiful or ugly); (c) the moral value of places (good or bad); and (d) the composition of places (resident demographics).
- ***UHI Reasoning/No UHI Reasoning***. Fourth, participants either spoke about place by itself, or while reasoning about urban heat islands. Much of participants talk about place had nothing to do with urban heat islands. Instead, students would talk about memories of places, connect certain places to others, and reveal their attitudes towards places. Other instances of place talk occurred in tandem with their efforts to explain how urban heat islands form in cities.

These four binaries emerged as useful tools for describing different ways of talking about place while reasoning about urban heat island effect. After having defined these binaries, I returned to the content logs for the next step.

Step 3: Extracting Segments from the Content Log

Working with the content logs, I extracted segments where students were either reasoning about heat and place together or reasoning about place by itself. I described each segment by the participants involved, the date and time of the segment, the materials used, and the four binaries of place-talk. I reviewed the corpus of segments and searched

for patterns in how and when participants were talking about place (either alone, or while reasoning about heat).

Through iteratively describing and analyzing these segments, I noticed that Aaron spoke about place frequently and in overtly ideological ways. Aaron talked about the history of Austin, the various neighborhoods in the city, and the racial and class compositions of each place. Aaron also spoke about other places outside of Austin. He frequently connected certain neighborhoods in Austin to neighborhoods in Seattle and even parts of Europe. Furthermore, Aaron frequently evaluated places aesthetically and morally. He described places as beautiful or slum-like, good or bad, and high-quality or low-quality. He cited his long-term residence in the city as evidence of why he believed these ideas to be true. For these reasons, I decided to further analyze moments when Aaron discussed place throughout lesson series.

Step 4: Transcribing and Analyzing Aaron's Talk about Place

With Aaron's content log segments in hand, I returned to the video footage to transcribe and analyze each instance to better understand how ideologies of place and reasoning about urban heat island occurred in tandem.

I transcribed each instance using the Jeffersonian transcription technique (Jordan & Henderson, 1995). In some instances, I paired transcripts with materials which were used in class. These materials were: (a) various maps of Austin; (b) assigned readings; or (c) screenshots from students' virtual neighborhood tour. Then, I analyzed each transcript in terms of Cresswell's four components of place ideology (Cresswell, 1996). I identified moments in each transcript when Aaron: (a) classified places; (b) differentiated places; (c) discussed the natural or artificial qualities of place; and (d) connected certain places to practices.

By analyzing Aaron's instances of place-talk, I learned two important details: First, Aaron drew on an ideology which I refer to as 'the slums and the good part' to make sense of Austin. In this ideology, Aaron classified East Austin as the 'slums' and West Austin as the 'good part.' Second, Aaron used this ideology to explain why 'the slums' were hotter and 'the good part' was cooler. While Cresswell's four components of place ideology were helpful for seeing this, they do not explain how Aaron made sense of the people, materials, and actions which create urban heat islands. To render these clear, I turned to critical discourse analysis.

Step 5: Using Critical Discourse Analysis to Clarify Aaron's Ideologies of Place

With transcripts and initial analyses of Aaron's episodes of place-talk in hand, I turn to critical discourse analysis to render clear how he represented various people and actions related to urban heat island. Specifically, I focus on how Aaron represented social actors.

Social actors are any individual people, groups of people, or institutions which are capable of performing actions or receiving actions in the real world. In talk or text, social actors are typically indexed as nouns, pronouns, or direct objects. Symbolically, social actors can be represented by drawings or symbols. How a person (in this case, Aaron) represents a social actor in talk, text, or symbol can reveal broader social or spatial ideologies.

Take as a hypothetical example, two newspaper articles about a recent protest. One article's title reads "police responded violently towards protestors" whereas the second headline reads "protestors erupted in violence." Although both articles aim to represent the same social event, they do so in dramatically different and ideologically important ways. The first headline includes both police officers and protestors as social

actors (indexed by nouns). In this headline, police are given the action of 'responding violently' and protestors receive the action of being 'responded violently to.' The second headline includes only protestors. The police are excluded from view. In this headline, protesters are given the action of 'erupting' in violence. By focusing on which social actors are included in a text and how they are represented in texts, it becomes clear how authors (i.e., speakers or writers) draw on differing ideologies to frame the social world.

Critical discourse analysis, particularly a method called sociosemantic inventory (van Leeuwen, 1993, 1996) specifies 11 dimensions for analyzing the representation of social actors. In this study, I draw on four dimensions discussed earlier (Table 2). By selectively applying these four representative dimensions to Aaron's talk about place and urban heat island, I aim to clarify further the ideologies about place he drew upon to reason about space. In the next section, I present the findings of this analysis.

RESULTS OVERVIEW

Aaron drew on an ideology of Austin which I refer to as 'the slums and the good part.' This ideology framed Austin as being divided into two parts by a major highway. To the east of this highway is the area he refers to as 'the slums' and to the west of that highway were the areas he refers to as 'the good part.' Aaron drew on this place ideology at multiple points in the lesson series to make sense of maps, models of urban heat island, assigned readings, and the virtual walking tour. Furthermore, this ideology came to bear on his group's final model which explains how urban heat islands form. Rather than presenting a sequential analysis of the six-lesson series, I structure my analysis into three parts.

First, I explain Aaron's ideological geography of Austin, Texas. By ideological geography, I am referring to the meanings which he attached to places in Austin. I

present data from moments when Aaron (and sometimes his groupmates and the course instructor) are discussing the nature, qualities, or perceived histories of two areas of Austin. These moments occurred frequently throughout the six-lesson series and were often separate from reasoning about urban heat islands.

Second, I provide examples of how Aaron drew upon these ideologies of place to reason about urban heat island effect. Specifically, I present two constructed stories where he reasoned about areas where urban heat islands are more severe (i.e. hotter parts of the city) and areas where urban heat islands are less severe (cooler parts of the city). I do this to demonstrate how Aaron recruited ideologies of place, in interaction, to explain how urban heat islands are formed.

Finally, I close with a description of his group's model of urban heat island. I do this to see what 'showed up' in their final explanation of why urban heat islands occur, and whether the various ideologies of place mediated their final explanation of what causes urban heat islands to occur.

RESULTS 1: AARON'S IDEOLOGICAL GEOGRAPHY OF AUSTIN

Before presenting Aaron's ideological geography of the city, I describe the geography of Austin Texas as produced by three boundaries: the Colorado River and two highways. The Colorado River flows from Northwest to Southeast through downtown Austin and divides the city into its northern and southern regions. Two highways further segment the city. The first highway is Interstate Highway 35, or I-35 for short. The second highway is Texas State Highway Loop 1, known locally as Mopac. Like I-35, MoPac also runs North and South through the city. However, unlike I-35, MoPac is not an interstate highway, and eventually merges with other Texas state highways.

These two highways and the lake divide the city into seven regions. East of I-35 is referred to as East Austin (north of the lake) and Southeast Austin (south of the lake). Collectively, the two regions are often described as 'East Austin' more generally. Between I-35 and MoPac is referred to as Central and North Austin (north of the lake) and South Austin (south of the lake). West of Mopac is generally referred to as West Austin, with the portion north of the lake being referred to as Northwest Austin.

In the figure below, I present a schematic which demonstrates the geography of Austin, as created by these three major boundaries. In red, I highlight the area Aaron referred to as 'the slums' and in green I highlight the area Aaron referred to as 'the good part (Figure 9).

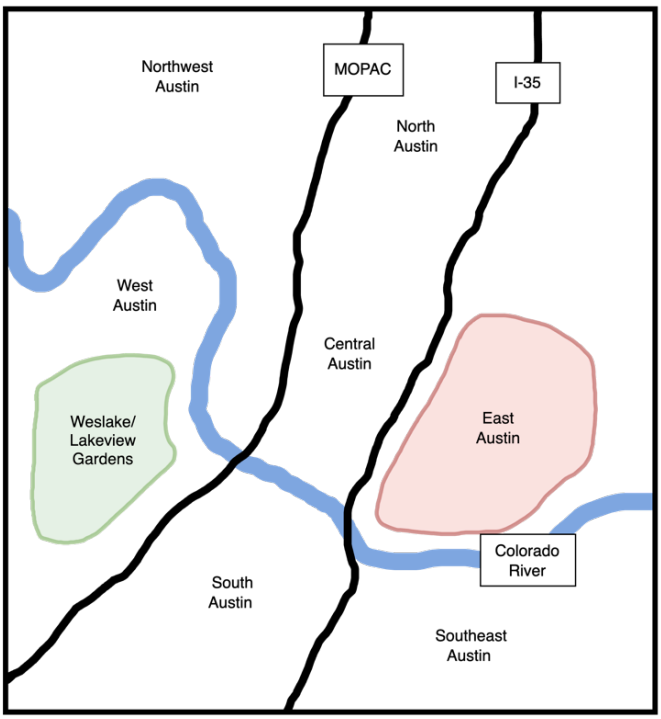

Figure 9. Map of Austin, Texas labeled with the cardinally named sections. Red-highlighted area was referred to as 'the slums' and the green highlighted area is referred to as 'the good part.'

The Slums: Negative Framings of the City

Two episodes were identified where Aaron discussed East Austin and framed this area negatively. Both episodes occurred on the first day of the lesson series while the course instructor was introducing the concept of urban heat island effect and showing students various maps of Austin. In the first episode, Aaron discussed East Austin alone. In the second episode, Aaron discussed East Austin in relation to West Austin.

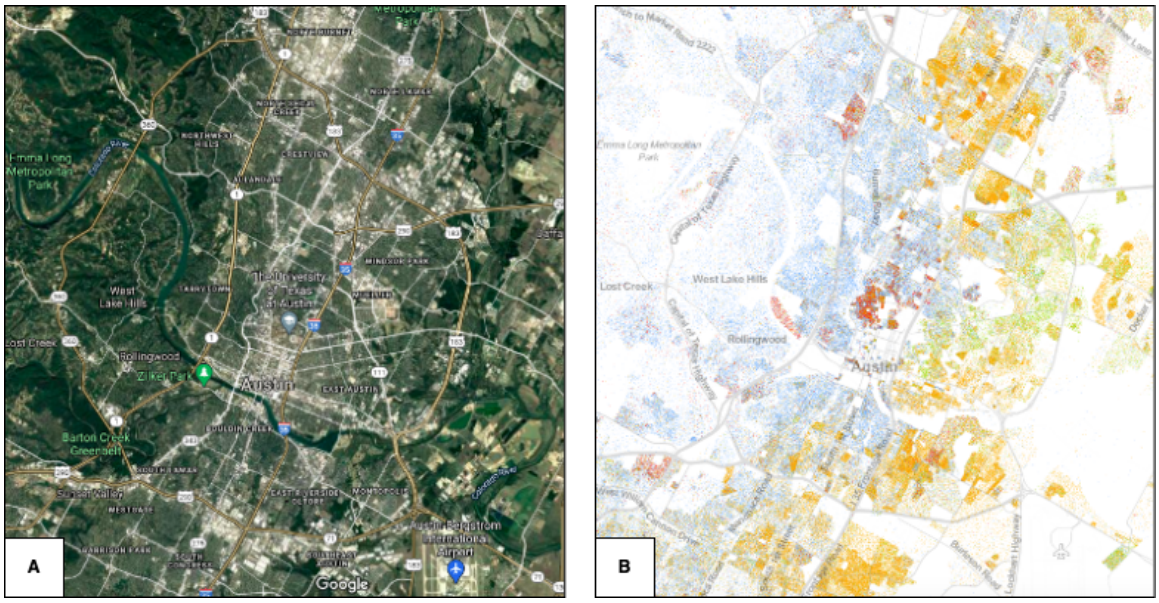

Figure 10. (A) Satellite Map of Austin, Texas; (B) Race-Dot Map of Austin, Texas (Cable, 2013)

Episode 1: East Austin.

The first episode occurred while students were discussing a satellite map, taken from Google Maps, depicting the center of Austin, Texas (Figure 10, A). The course instructor began by orienting students to the map by pointing out the university, specific neighborhood names (Downtown or Central Austin), some shopping areas, and the major boundaries (the Colorado River, I-35, and MoPac). Then, she clarified what the colors on

the satellite image meant: She explained that the 'lighter areas' on the map were 'developed areas' (such as buildings, concrete, or roadways) and the 'darker green areas' as on the map were natural areas (such as parks, forests, bodies of water). Finally, she asked students to reflect on differences they saw on either side of I-35, one of the two major highways that bisects the city into East Austin and the other cardinal areas of Austin. Aaron was the second student to respond, and said the following:

1.1 1.2 1.3 1.4 1.5 1.6 1.7	06:10	Aaron	"Honestly it's what we would consider the slums = Or you know when I first came here that area was kind of the slums of Austin = You hate to put it that way but it was (.) .hhh Yeah that = Yeah that is where you had built up areas = but it's where it's where the poorest = those were the poorest neighborhoods right in the area you are pointing to right now (.) .hhh east of 35 right ne- right east of downtown"

In this response, Aaron named East Austin as 'the slums', located poor neighborhoods within East Austin, and described it as 'built up.' Immediately after, the course instructor and a student (Elias) responded to Aaron's classification of East Austin as 'the slums':

2.1 2.2	06:34	KB	Historically these are (*tracing cursor, more slowly, over the East Austin area*) (.) uhh (.) yes like a lower:: uhh (1.0)
2.3	06:43	Elias	SES
2.4 2.5 2.6 2.7 2.8 2.9 2.10 2.11 2.12	06:44	KB	Ye:ah (.) .hhh Um a- all along the east side of 35 (traces cursor up and down on East side of map) (.) and now- I mean now what you seeing = and this isn't really part of the conversation of our unit = but what you are seeing (traces cursor over East 7th street, West to East, then draws circle within East Austin) is around here now is a lot of gentrification going on (.) in Austin (.) taking advantage of those low property (.) um (.) values (.) Uh but (.) yes (.) historically we've got lower (cursor moving randomly, on

2.13 2.14 2.15 2.16 2.17 2.18			East side of Map) (.) people who are in a lower SES class living east of 35 and more expensive property on the west (cursor moving randomly, on West side of Map) (.) and particularly as you get closer and closer to Mopac (traces cursor on Mopac, back and forth, North to South) (.) your prices are going way up(.)

The course instructor responded first by tracing her cursor over the East Austin neighborhood while pondering a different word to describe the area. She paused, drew out her speech, and started to say that East Austin is a "like a lower::" but trailed off. Elias filled in almost immediately with the acronym "SES" (socioeconomic status). The course instructor followed up immediately with a longer response, adding three new ideas about East Austin: First, she mentioned that East Austin is presently undergoing a process of gentrification. Second, she indicated that 'historically' East Austin had been the primary place of residence for 'lower SES class.' And finally, she continued to explain that 'historically' there was a pattern where property cost increased as you moved from east to west across the city, "particularly as you get closer and closer to Mopac" (2.14-2.15).

I interpreted this interaction as ideological because it involved negotiating various classifications and differentiations of East Austin. Aaron began by classifying East Austin as 'the slums' and justified this based on his personal experience having lived in the city for many years. He differentiated it from other parts of the city by explaining that East Austin had 'built up areas' and is the part of the city where the 'the poorest neighborhoods' were present. This can be contrasted by imagining areas of the city with less 'built up areas' or 'richer neighborhoods.' He closed his remarks by re-affirming the location of 'the slums' as being "east of 35" and "right east of downtown." In response to Aaron, KB and Elias provided an alternate ideological framing of East Austin. Together, they re-classified East Austin as 'lower SES' rather than 'the slums.' However, neither

KB nor Elias outright denied Aaron's use of the term 'the slums.' KB went on to further differentiate East Austin by discussing property value. With her cursor and her words, she drew a gradient across the city while explaining that property values increase from East to West.

By focusing on the representation of social actors and actions in Aaron's remarks, we can see important differences in the ideological framings of East Austin. In Aaron's initial statement, I focued on two social actors: (a) East Austin; and (b) the 'Public Consensus.'

East Austin is not explicitly stated as a social actor but is referenced by Aaron's use of two pronouns (it and that) (1.1, 1.3) and a definite article and noun (that area) (1.4). By using pronouns, definite articles, and nouns, Aaron made the entire area of East Austin into a single social actor which can be classified and differentiated. This is what van Leeuwen (1993) refers to as the spatialization. Spatialization is a representation strategy where a group of people is represented by the place/space they live in. By spatializing a group of people, a speaker can attribute qualities or actions to a space rather than to the people who live in the space (or, to people who live elsewhere but have an impact on the space).

The public consensus is not explicitly stated as a social actor but is referenced by Aaron's use of the pronouns 'we' and 'you' (1.1). Aaron began by saying 'it's what we would consider the slums' (1.1). Shortly after, he says 'you hate to put it that way but it was' (1.3). Both 'we' and 'you' are what van Leeuwen refers to as generalized representations of social actors. Generalized representations of social actors do not refer to specific people in the real world, but instead refer to abstract or hypothetical groups. I interpret these generalized social actors to represent some form of 'public consensus' because both words refer to a hypothetical body of people who would agree about the

statements Aaron is making. Eliciting a public consensus to justify classifying East Austin as 'the slums' is an ideological strategy which made Aaron's remarks seem natural and is a hallmark indicator that ideological geographies are being established through talk.

Episode 2: East and West Austin.

The second episode occurred while students viewed and discussed the race-dot map (Cable, 2013) Austin, Texas (Figure 10, B). The Race-Dot Map is a thematic map which uses data from the 2010 census to visualize one dot per individual within the census block group they live in. The dots are colorized to represent the five racial/ethnic categories used on the U. S. Census: blue dots represent White people, green dots represent Black people, red dots represent Asian American people, yellow dots represent Hispanic people, and Brown dots represent other racial or ethnic groups. The course instructor began by orienting students to the map. Then, I explained the U. S. Census categories and how they were used to make this map. The course instructor opened the floor for students to make connections between the satellite map and the race-dot map. Drew responded first, followed by the course instructor and finally Aaron.

3.1 3.2 3.3 3.4 3.5	02:50	Drew	There's like (.) you can clearly see I-35 (.) um and to the left um its all White or Asian American and to the right its all Black or Latinx so [like] and that very clearly like (.) that racial divide happens to also be like the divide between the left side of I-35 on this map is way more green than the right side.
3.6	03:02	KB	[Yeah]
3.7	03:16	KB	Indeed ((knowing and formal tone))
3.8 3.9	03:19	Aaron	There is a strong correlation between uh identification and SES (.) sorry but that's how I see it

Drew began by identifying I-35, explaining some of the patterns they noticed from the race-dot map, and making connections to the previously viewed Satellite Map. Using the categories from the map, Drew explained that west of I-35 the dots were primarily representing White and Asian American people, and East of I-35 the dots were primarily representing Black and Latinx people. Drew then connected this to the previously established pattern that west of I-35 has more trees or is "way more green" (3.5). The course instructor agrees briefly by saying "indeed" (3.6) in what I interpreted to be a formal and 'knowing' tone, as if Drew explained the pattern KB was hoping to see. Aaron followed Drew's remarks by adding that there is a correlation between identification and SES. He closed his remarks by apologizing for idea.

In this short sequence, a variety of ideological moves were made. Drew began by drawing upon the I-35 boundary to classify the city into two regions, East and West. Then, Drew used the dot colors to differentiate East and West by describing the general composition of racial groups in each area. Despite there being many boundaries between racial groups on this map, the boundary of I-35 was repeated as an important line to differentiate the city. Finally, Drew made a connection between the racial compositions and the previously differentiated pattern of West Austin having more greenery than East Austin. Drew did not provide any causality in this description of the two patterns, but the course instructor indicated agreement with these remarks.

Aaron's response layered some new ideological meanings onto the pattern which Drew established. Aaron, adding to the East-West differentiation, explained that there existed a correlation between identification and income level. Although Drew didn't mention SES in their description of the map, it seemed Aaron was referring to the conversation moments before where the course instructor and Elias re-classified East Austin as 'lower SES' rather than 'the slums'. Aaron then drew a connection between the

racial divide along I-35, and the perception that East Austin is lower SES and West Austin is higher SES. With this remark, Aaron further differentiated East Austin as lower SES, with primarily Black and Latinx residents, and having less greenery than West Austin.

By examining the representation of social action in Aaron's short remark, one can see further the ideological nature of Aaron's understanding of East Austin. Aaron began his remark with the verb phrase "there is." Critical discourse scholars refer to this as an existential process, where the speaker is bringing something into existence that needs no further justification. The use of the phrase "there is", therefore, makes natural the statement that follows: racial identification and SES are correlated. Aaron goes on to complete his sentence by saying "sorry but that's how I see it" (3.9). I interpreted the use of apology here to indicate that Aaron believed this fact to be true, although potentially uncomfortable or even controversial for the class to hear.

In summary – in interaction with his classmates, two maps of Austin, and the course instructor – Aaron reproduced an ideological geography that classified East Austin as 'the slums' and differentiated it from other areas of the city by describing that it has low SES areas/residents, has less tree cover, and is populated by primarily Black and Latinx residents. He naturalized these statements by evoking public consensus with generalized phrases such as "It's (East Austin is) what we would consider the slums." (1.1). Aaron also naturalized the connection between identification and SES with existential verb phrases. As I will show in the second results section, these existing impressions of East Austin are recruited again, to explain why urban heat islands are more present in East Austin.

The Good Part: Positive Framings of the City

Aaron framed a variety of places west of I-35 positively. Here, I focused on the times when Aaron discussed the town of Westlake (a suburb of Austin) and Lakeview Gardens (a neighborhood within Westlake). I focused on these two places because Aaron and his group members chose this area to investigate to explore potential causes of urban heat islands. Therefore, Aaron's ideological framing of Westlake and Lakeview Gardens will be important to understand to see how he reasons about urban heat islands.

Episode 1: Choosing Westlake.

On the second day of the lesson series, students were tasked with choosing a neighborhood in the city to explore with Google Street View. The purpose of exploring neighborhoods in Google Street View was to provide participants with the opportunity to see actual spaces/places throughout the city. We hoped students would read about the geographic and historic causes of urban heat island and make connections to actual spaces in the city.

Aaron's group decided to explore the area in West Austin known as Westlake. The students initially thought of this area as a neighborhood, but later discovered that Westlake is in fact its own city. On the second day of the lesson series, Aaron and his group mates had just entered a break-out room to begin exploring Westlake. Jordan was sharing her screen, showing the map view of Westlake. The students were deliberating which area to explore within broader Westlake when Aaron said "that's the good part (smiles and laughs) (3.0) So:: what part in particular within Westlake/because Westlake is kind of a big area?" (02/03/21, 00:22). Here, Aaron differentiated Westlake as 'the good part' of Austin. He followed this remark by smiling, laughing, and asking his group mates what area within Westlake they should explore. This is Aaron's first ideological

framing of Westlake as 'good'. I interpreted this as an ideological opposite to his previous framing of East Austin as 'the slums.'

Shortly after labeling Westlake as 'the good part', the group members go along to select a smaller portion of the area to explore: Lakeview Gardens. Lakeview Gardens is a neighborhood within Westlake which borders the Colorado River and a tributary creek. Jordan 'drops in' to street view mode and began moving forward through the streets of Lakeview Gardens. Aaron was talking aloud as they move through the space, taking notes about what spatial features he saw as important to contributing to or protecting from urban heat islands. The course instructor entered the room and joined the conversation. At this point, the course instructor asked "Is this similar to neighborhoods where yall live now? Or have lived ever? Like the way this is looking? Or is this way different?" (02/04/21, 04:12). Aaron responded:

4.1 4.2 4.3 4.4 4.5 4.6 4.7	04:17	Aaron	Uh::: the neighborhood I live in is similar (.) except more crowded (.) there are more apartment complexes where I live than (.) but yeah no this is definitely upscale (.) this reminds me of (.) a lot of (.) what I saw in Mercer – Mercer island (.) when I went to school in Seattle (.) that is where the rich people live (.) that is where Bill Gates and people like him lived (.) this is very similar to that.

In this response, Aaron made a few ideological moves. First, he classified Lakeview Gardens as an 'upscale' neighborhood (4.3). Second, he differentiated Hyde Park from Lakeview Gardens by framing it as "similar (.) except more crowded" (4.1-4.2). Third, he differentiated Lakeview Gardens from other areas in Austin by comparing to Mercer Island. He justified this comparison by drawing on his former experience living in the Seattle. He then goes on to classify Mercer Island as "where the rich people live" and where "Bill Gates and people like him lived" (4.5-4.6). Aaron provided a positive

ideological framing of Lakeview Gardens by classifying and connecting Lakeview Gardens and Mercer Island as similar, 'upscale' areas, "where rich people live."

Probing a level deeper, there are similarities and differences between how Aaron represented Lakeview Gardens/Mercer Island and East Austin. In this quote, I focused on three social actors: Lakeview Gardens, Mercer Island, and 'Bill Gates and people like him.' Lakeview Gardens was not explicitly mentioned in the text, but instead was referred to twice with the pronoun 'this' (4.3, 4.6). Mercer Island was mentioned both by name in the text and with the pronoun 'that' (4.5). Similar to East Austin, both Lakeview Gardens and Mercer Island are spatialized social actors. As a reminder, a spatialized social actor is when a group of people are collapsed into a singular entity and represented by the space/place they live. Spatializing social actors makes it possible to talk about attributes of the space/place (East Austin as the Slums, Lakeview Gardens and Mercer Island as 'upscale' and 'good') without discussing the people who inhabit these areas.

However, at the end of Aarons' response, he mentioned that Mercer Island is where the rich people, like Bill Gates, live. Here, Aaron elicits a new social actor. First, he mentions a generalized social actor 'rich people' (4.5). Then, he provided a specific and nominalized social actor, Bill Gates (4.6). By drawing on Bill Gates and the rich people like him, Aaron is further laminating the notion that Mercer Island and Lakeview Gardens are affluent places. I interpreted this connection between spaces/places and 'rich people' like Bill Gates to be an ideological framing of 'the good part' of the city.

Episode 2: Exploring Lakeview Gardens.

Later during the same lesson (Day 2, 02/04/21), the students and course instructor continued to navigate through Lakeview Gardens in Google Street View. After a short period of silence, the course instructor said, "this is a beautiful neighborhood" (02/04/21,

07:02). The following discussion between Aaron, the course instructor, and his groupmates occurred:

5.1 5.2	07:03	Aaron	Oh it is (.) Uhhm::: (.) Let me (.) I will also tell you that I couldn't afford to live there right now probably
5.3	07:13	Drew	Same
5.4 5.5	07:21	KB	So what / So I am curious (.) what is it about this neighborhood that is making yall feel like you couldn't afford to live there?
5.6 5.7	07:30	Aaron	Um (.) well look at the houses (.) look at how they are maintained (.) look at the cars/
5.8	07:35	Drew	/The lots have like/
5.9	07:38	Aaron	/Yeah/
5.10	07:38	Drew	There is a lot space between each house (.) it seems like?/
5.11 5.12	07:41	Aaron	Oh yeah (.) oh yeah land is costly (.) yeah yeah (*starts typing*) land is..
5.13 5.14	07:46	Drew	Like I live in a duplex (.) I literally share the building with another family (*laughs*)
5.15 5.16	07:52	Aaron	Uh (*continues typing*) there is – let's say this – there is a high – there is a high apparent SES
5.17	07:59	Jordan	A lot of the homes also have like (.) an entrance and gates (*laughs*)
5.18	08:03	Drew	Yeah
5.19	08:04	KB	Oh gates!
5.20	08:05	Aaron	And driveways and such (.) that's that's money

In this short sequence, Aaron, Drew, and Jordan pointed out aspects of the built and environment which indicate that Lakeview Gardens is an expensive place to live. These indicators were: cars, houses, lot sizes, and gated driveways. As students were talking, there was a general sense of humor and amazement at the neighborhood, which seemed to lighten the mood while talking about the perceived wealth of this area. Furthermore, the pace of the conversation quickened as the group in rapid-fire succession began to name aspects which they knew indicated the wealth of the neighborhood.

From an ideological perspective, the students were listing out and justifying why particular materials were located in this area. This is the ideological process of naturalizing the place. Naturalizing is any time when people or materials are connected to a place without need of further explanation or reasoning. For example, Drew noticed that "there is a lot of space between each house" (5.10). Aaron responds immediately that "land is costly" (5.11). This quick reasoning between Drew and Aaron established a 'commonsense' about why the physical space looks this way. Furthermore, the rapid pace at which this interactional sequence occurred and the level of agreement amongst the students indicates ideological convergence amongst the group of students. The students demonstrated agreement on a few things: Lakeview Gardens is wealthy, and it is evident by the materials that are present in the space.

Focusing on the representation of social actors and actions reveals more about the ideologies of place. Curiously, in this sequence there are no mentions of the people who live in this neighborhood as being part of the reason why the neighborhood looks this way. For example, when Aaron described the homes, he mentions that they are "are maintained" (5.6-5.7). The social actor responsible for maintaining the house (either the homeowner themselves or perhaps a caretaker) is excluded from view. Furthermore, "houses" are treated as a social actor by Jordan when she mentioned that "houses also

have like (.) an entrance and gates" (5.17). In this instance, the people who own a house are obfuscated and spatialized into simply 'houses.' The only time residents are mentioned is when Drew is describing their own experience living in a duplex with neighbors. At this point, it is worth noting that descriptions of the people who live in these neighborhoods (whether Lakeview Gardens, East Austin, or any other place) are few and far between.

In summary – in interaction with his classmates, two maps of Austin, and the course instructor, and the initial day of the walking tour – Aaron presented an ideological geography that classified West Austin generally and Lakeview Gardens specifically as 'the good part.' Through a variety of ideological moves, Aaron and his classmates differentiated it from other areas of the city by describing that it had higher SES areas, had more greenery and tree cover, and contained a variety of materials which are naturalized in the neighborhoods. Important to note, while race was elicited once in a discussion about the ideological geography of East Austin (by Drew), race was not elicited at all when discussing the ideological geography of West Austin and Lakeview Gardens. Instead, there was a heavy emphasis on socioeconomic status.

RESULTS 2: REASONING ABOUT HOT AND COOL PARTS OF THE CITY

In this section, I constructed two stories which illustrate how Aaron reproduced ideologies of place when reasoning about the causes of urban heat island. I used data from Aaron's reading reflections, interactions during whole-group instruction, and interactions during small-group instruction to construct these stories. By construct, I am referring to the process of crafting these stories to seem like salient, temporally bound moments in the classroom. However, ideologies are not so clear-cut. Rather, ideologies are "cued in specific contexts, applied locally and do not require global consistency."

(Philip, 2011, p. 305). In this lesson series, ideologies of place were cued anytime Aaron viewed maps, made sense of readings, or virtually toured neighborhoods. These instances happened frequently, were short in duration, and were distributed throughout the 6-day lesson series. Therefore, by repackaging these instances into contrasting stories, I hope to show how ideologies of place are sedimented and repeated as Aaron reasoned about urban heat island effect.

First, I present a story where Aaron reasoned about where he believed urban heat islands were more severe. I call this story, 'reasoning about hot neighborhoods.' This story is reconstructed from two episodes. Then, I present a story where Aaron reasoned about where he believed urban heat islands would be less severe. I call this story 'reasoning about cool neighborhoods.' This story is reconstructed from 3 episodes.

Story 1: Reasoning about Hot Neighborhoods

This story occurred on the fourth day of the lesson series when students were learning about the relationship between historic redlining and present-day urban heat islands. Prior to class, the course instructor assigned a journal article for students to read and write a short reflection about. The assigned reading was an empirical research article which explored the relationship between formerly redlined portions of four major U.S. cities and present-day urban heat islands (Wilson, 2020). I refer to this reading as 'the Wilson article.' In class, students were given time to discuss the reading, explore the historic redlined maps of Austin (Digital Scholarship Lab, 2019), and virtually tour their selected neighborhood. In this story, I review two episodes from the fourth day of the lesson series (04/12/21). I began by analyzing Aaron's reading reflection to contextualize how he understood the relationship between redlining and present-day urban heat islands. Then, I analyzed a short episode where the course instructor asked Aaron to explain how

landlord and tenant interactions produce urban heat islands. I close by summarizing the ideologies of place Aaron reproduced while reasoning about hotter parts of the city.

Episode 1: Reflecting on the Wilson Article

KB began class by reviewing the Wilson article and showing a slide with quotes from students' reading reflections. KB named that students were generally on the same page and Aaron immediately responded:

6.1 6.2 6.3 6.4 6.5 6.6	03:55	KB	What I saw from your reading reflections was fantastic (.) i'm really liking the way this is working out for us as a class because I get to see what you're thinking, and then we can kind of combine it all (.) into a quick-quick discussion because we were all pretty much on the same page because it's pretty straightforward paper and more like using it for the same purpose here.
6.7	04:15	Aaron	What? That didn't give you heart burn? (*laughs*)

The course instructor claimed there was a consensus among the reading summaries. However, this was not true. Prior to class, the course instructor and myself had reviewed the reading summaries to find that Aaron had expressed significant frustration with the reading. His response to KB indicated that he was in fact not 'on the same page.' In his reading response, Aaron had taken issue with the notion of 'redressing' urban heat islands caused by historic redlining. Aaron wrote:

> "I also want to strenuously dissent over the notion that we should somehow "redress" such issues now since the ultimate logic of such 'redressal' is the forcible and involuntary confiscation of property and perhaps even civil liberty for the supposed "greater good"." (Aaron's Redlining Reading Reflection, 04/11/21)

In the article, Wilson did not explicitly state what 'redressing' urban heat island entailed. However, Aaron imagined that redressing the consequences of redlining would

involve some excluded social actor forcibly confiscating both property and civil liberty. It is unclear why Aaron interpreted 'redressing' in this manner, and the course instructor decided to shy away from asking Aaron. Although Aaron disagreed with the notion of redressing the effects of redlining on present day urban heat islands, he did agree with the methods and findings of the research. He wrote:

> "There seems to be a strong, statistically significant correlation between zones that were typically reserved for 'less desirable' (read minority and underserved) elements of society and higher rates of Urban Heat today. As the paper itself notes this is probably due to a wide variety of factors including (but not limited to) the use of cinder-block, asphalt, and other heat retaining and cheap materials, along with a dearth of canopy coverage, and I would add an unfavorable H/V ratio because of overcrowded buildings." (Redlining Reading Reflection, 04/11/21)

In this quote, Aaron summarized Wilson's claims about the relationship between urban heat islands and redlined zones of U. S. cities. From an ideological perspective, this is a departure from his previous discussions of place. Previously, Aaron reasoned about specific places in Austin. He cited his personal experience having lived in the city to classify this East Austin as the slums and differentiate it as being a poor neighborhood with mostly minority residents. Here, Aaron reasoned about general places in the U. S. He discussed the "zones that were typically reserved for 'less desirable' (read minority and underserved elements of society" and differentiates these places by describing their built environment. The transition from specific to general discussions about place was 'forced' by requiring Aaron to reflect on the Wilson article. This provided an opportunity to see how Aaron draws on more general ideologies of place to reason about urban heat islands.

By focusing on the representation of social actors, we can clarify the general ideologies of place Aaron drew upon to reason about urban heat islands. We can see who are in these places (zones with less desirable elements of society) and how they are

related. Aaron began by acknowledging a correlation between "'less desirable (read minority and underserved) elements of society" and urban heat islands. At first glance, there is one social actor represented in this sentence: elements of society. Elements of society is a generalized representation of a social actor, meaning it does not point to any specific or nameable person. Furthermore, 'elements of society' is a depersonalized social actor. Depersonalization is the process of converting human social actors into the non-human materials. In this instance, 'people' are converted into the material phrase of 'elements of society.'

While seemingly rudimentary to convert humans into elements, Aaron modified 'elements of society' in two important ways. First, 'elements of society' was modified by the phrase 'less desirable.' This indicated that someone is responsible for desiring certain elements of society and not desiring other elements of society. However, the social actor responsible for 'desiring' is excluded in this sentence. With this modification, Aaron acknowledged that some social actor is responsible for placing certain people into these zones but does not say who. Second, 'elements of society' is modified in parentheses with the words "minority and underserved." Here, Aaron is equating 'less desired elements of society' with two other groups: minority people and underserved people. This is an acknowledgement that 'those who desired' (people who made redline maps) did so based on racial identity.

Aaron then went on to summarize a variety of variables which contributed to urban heat islands, including building materials, canopy coverage, and height-width ratio of buildings. However, he did not in any way connect these variables to the practice of redlining, the people who created redline maps, or the people affected by redlining. Aaron did acknowledge that race is important to the creation of redlining maps but did not explain how redlining maps relate to the present disparities in heat within a city. This

general ideology of place would surface again, when Aaron was asked to further explain what he believed caused urban heat islands in general throughout the U.S.

Episode 2: A General Explanation of Urban Heat Island

After a few other students shared their thoughts on the redlining reading, KB pivoted to Aaron and said: "I think I have you next (.) um (.) you were talking about the use of materials [and the] materials are dispersed around town (.) so can you give us a little bit more" (04/12/21, 06:36). This remark is interesting because although Aaron expressed significant frustration with certain aspects of the reading, the course instructor focused exclusively on the parts he did agree with. When asked to share out his thoughts, Aaron responded by saying:

7.1 7.2 7.3 7.4 7.5 7.6 7.7 7.8 7.9 7.10 7.11 7.12 7.13 7.14 7.15 7.16	06:44	Aaron	Sure (.) basically: uhh: (.) tenant (.) your landowners (.) uh (.) if you would try to build for their tenants and minority groups and disadvantaged groups would often be poor (.) and honestly wouldn't get the first call resources (.) so the the worse or poorer your neighborhood (.) the cheaper (.) yeah yeah (.) the material was put into it (.) So you'd have cinderblock asphalt and other materials that tend to retain heat going along with your (.) lower (.) rated (.) you know (.) neighborhoods and yes (.) the neighborhood were rated (.) yeah at certain categories (.) that that's a fact (.) And in addition to which they were also be (.) uh (.) less emphasis of canopy because you'd want to get as many people (.) or rather think about it (.) as many your tenants (.) you know (.) for that rent coming in (.) to these lots (.) as you could (.) and that would also affect your geographic area (.) calling back to last time.

Similar to his reading reflection, Aaron continued to draw on general ideologies of place, rather than specific ideologies of Austin. In this quote he focused on “lower

rated neighborhoods" (7.8) which he classified as "worse" or "poorer" (7.4-7.5). He stated that these neighborhoods were comprised of predominantly "minority groups and disadvantaged groups" (7.2-7.3). He then went on to differentiate these neighborhoods as areas constructed out subprime materials (cinderblock and asphalt) with fewer trees.

By focusing on the representation of social actors, we can clarify more about the general ideologies of place Aaron draws upon to reason about urban heat island. Now, we can see who are in these places (poor neighborhoods), how they are related, and how these relationships produce urban heat islands. I focused on two social actors included in this quote: tenants and landowners.

Tenants and landowners are generalized social actors. As described before, generalization represents social actors as categories of people who could exist anywhere, rather than specific people tied to a place and time. Generalizing social actors contributes to Aaron's general explanation of urban heat islands and towards a more general ideology about "poor," "worse" or "lower rated" places.

Tenants and landowners are also functionalized social actors. Functionalized social actors are represented by the action they conduct. For example, tenants are people who rent properties and landowners are people who own land and lease properties. Although tenants are primarily functionalized, they are also identified as being "minority groups and disadvantaged groups" who are often poor. The racial and economic identities of landowners, however, is unstated. Functionalizing social actors narrows the discussion about who is involved in creating urban heat islands. In this quote, only landowners and tenants are involved in creating urban heat islands. Those who created redlined areas are backgrounded from this discussion.

Furthermore, landowners are repeatedly activated in this quote. Landowners are responsible for building properties, selecting materials, removing trees, wanting more

tenants, and wanting more income. Tenants on the other hand are hardly activated as doing or receiving any actions in this quote. Other social actors (banks, municipal governments, neighborhood associations) are fully excluded in this explanation of urban heat islands.

Summary:

To summarize, Aaron understands urban heat islands in "poor," "worse," or "lower rated zones" to be primarily caused by the actions of landowners. Landowners, wanting more rent money, attempt to pack as many residents onto properties as possible. In the process, they cut down trees and cut costs on building materials. He foregrounds the racial and class identities of tenants but removed the racial identities from landowners themselves. Furthermore, despite having acknowledged in his reading reflection that some social actor is responsible for 'desiring' certain racial groups and not others when creating redlined areas, Aaron does not include these social actors in his explanation of how urban heat islands form.

Story 2: Reasoning about Cool Parts

Most of Aaron's time spent reasoning about urban heat islands was in the context of virtually touring Westlake and Lakeview Gardens. However, this area of the city is significantly cooler than East Austin. Therefore, in this story, I focused on how Aaron reasoned about cooler parts of the city. I reconstructed this story with three episodes from the lesson series. First, I analyzed an episode from the second day of the lesson series (01/27/21) where Aaron is reasoning about cooler neighborhoods in the city, before having read the Wilson article. Second, I analyzed an episode from the middle of the fourth day of the lesson series (04/12/21) when Aaron and his groupmates were reasoning

about cooler neighborhoods after having read the Wilson article. Third, I analyzed an episode from the end of the fourth day of the lesson series (04/12/21) where Aaron summarizes how he views the relationship between redlining and air temperature in cooler neighborhoods. I close by summarizing the ideologies of place Aaron reproduced while reasoning about cooler parts of the city.

Episode 1: Cooler neighborhoods, before reading the Wilson article.

On day two of the lesson series, students were given the opportunity to select a neighborhood in Austin and explore that neighborhood using Google Street View. At this point in the lesson series, students had not read any literature about the potential causes (either geographic or historic) of urban heat island. Therefore, students aimed to explore a neighborhood of their choice and point out features they believed might lead to excessive heating or cooling. As mentioned before, Aaron and his groupmates selected the town of Westlake and Lakeview Gardens. After having explored Westlake and Lakeview Gardens for some time, the course instructor asked Aaron "what does this make you think about the model?" (02/04/21, 23:28). By model, she was referencing the final model of urban heat islands which students were tasked with creating by the end of the six-day lesson series. Aaron responded:

8.1 8.2 8.3 8.4 8.5 8.6 8.7	23:36	Aaron	Well actually (.) so far (.) I think that uh: (.) I want to know what the actual heat map for Westlake is compared to the rest of Austin but I suspect that vegetation and population density are uh going to have a big impact (.) um (.) the SES affects the population density (.) If you've got money – you are not going to live as close together or share houses (.) that's just (.) you know the way that goes.
8.9 8.10 8.11	24:00	Drew	I (1.0) think it is interesting that like (.) um (.) a lot of these trees are all on top of each [other] (*referring to Jordan's screen which is focused on a cluster of trees together*) but like where I

8.12 8.13			live is more like one tree per front yard (.) so I feel like it would be a lot cooler with a bunch of trees in one area versus/ (10.0)
8.14 8.15	24:21	Aaron	[right so] (1.0) [a tree-to-tree interaction] (*speaking simultaneously as KB*)
8.16 8.17	24:21	KB	So in the model you could add [patches of clumps of trees] (*speaking simultaneously as Aaron*)
8.18 8.19	24:28	Aaron	Yeah I I I so we need to add a tree-to-tree interaction (.) maybe (.) depending on
8.20 8.21	24:32	Drew	I don't think it is as much tree-to-tree or more that a patch can be multiply interacted with (.) with different trees
8.22	24:37	Aaron	Ah (.) okay good point

In this episode, Aaron, his group mates, and the course instructor discussed possible additions to their final model of urban heat island. Aaron was first to speak. He explained some variables that were important to mitigating urban heat islands (vegetation and population density), explained the relationship between SES and population density, and closed by naming how people with "money" build their houses. Drew responded by discussing their own neighborhood vegetation in comparison to what they were seeing in the virtual neighborhood tour. Throughout the final few turns at talk, the group decided that their final model should include the effect that clusters of trees have on mitigating urban heat islands.

Aaron's opening turn at talk revealed how his ideology about place supported his reasoning about why Westlake may be cooler. First, Aaron began by expressing interest in knowing the heat differences between Westlake and the "rest of Austin" (8.2-8.3). This remark is ideological because he classified two specific places by name: Westlake and the "rest of Austin." These two places became the subject of comparison and reasoning for the rest of the turn at talk.

Second, Aaron posed three variables he believed might be important to heat differences between the two places: vegetation, population density, and SES (8.3-8.5). Aaron reasoned that vegetation and population density would "have a big impact" on heat, and that "SES affects population density" (8.4) This remark is ideological because he differentiated Westlake from the "rest of Austin" using these three variables. Aaron's past ideological framing of Westlake allows us to interpret that he believed Westlake to have more vegetation, lower population density, and higher SES than the rest of Austin. This supported his understanding that, even without a heat map, he understands Westlake to be cooler than "the rest of Austin."

Finally, Aaron explained that "if you've got money" you are not going to "live as close together or share houses" (8.5-8.6). This remark is ideological because he connected people and practice to Westlake. Aaron connects people (wealthy people or "people who have money") with the practice of building far apart and situated both to Westlake. To summarize, Aaron understands Westlake to be cooler than "the rest of Austin" because Westlake has wealthy or high SES people who want to build further apart. The emergent effect of people building further apart allows more vegetation, which produces cooler parts of the city.

By focusing on the social actors in Aaron's opening remark, we can see deeper into how Aaron's ideology of place supported his reasoning about heat in Westlake. I focus on Aaron's repeated use of the word "you" on lines 8.5 through 8.7. "You" is a personal pronoun, but each use of 'you' in Aaron's first turn at talk signifies a different social actor. First, Aaron began by saying "If you've got money – you are not going to live as close or share houses" (8.5-8.6). Here, Aaron's use of the word 'you' was representing high SES people or wealthy people. This use of 'you' was generalized because Aaron was referring to wealthy people in general, and not to specific people he

knows. Furthermore, using 'you' allowed Aaron to reason from their perspective. He posited that wealthy people 'have money' and because of this are 'not going to live as close or share houses.' Second, Aaron ended his first turn at talk by saying "that's just (.) you know the way that goes" (8.7). Here, Aaron's use of the word 'you' represented a general consensus or public understanding. This positioned all the remarks he made previously as common sense, which further solidified the ideological nature of this turn at talk.

In summary, Aaron's opening remark sedimented an ideology of place in tandem with reasons about space. What happens next, however, is noteworthy. Drew responded to Aaron by discussing the difference in vegetation between their own home and Westlake. Then, Aaron, Drew, and the course instructor engaged in a few turns at talk where they settled on an aspect that needed to be included in their final model: a tree-to-tree interaction. This tree-to-tree interaction would explain how multiple trees cool off a location more so than a single tree. What is striking about this conclusion is its simplicity. Despite Aaron having reproduced an ideology of place and using this ideology of place to reason about how people behave, the aspect which they chose to include in the model was simply 'tree density.' This demonstrated that ideologies were important for reasoning about urban heat island but become invisible as the students consider what to 'put into' their final model about urban heat island.

Episode 2: Cooler neighborhoods, after reading the Wilson Article

On the fourth day of the lesson series (04/12/21), students were tasked with using the Wilson article to think about how redlining may have influenced urban heat island formation in their chosen neighborhood. The students were provided with a digital map which showed which portions of Austin had historically been redlined (Digital

Scholarship Lab, 2019) and were given time to continue virtually touring their neighborhood. However, Aaron and his groupmates had already established that Westlake and Lakeview Gardens were not yet built when the redlining map of Austin was created. Knowing this, the conversation went as follows:

9.1 9.2	02:21	Drew	Okay (.) so (.) we don't really have a sort of (.) redlined area to go off of (.) um/
9.3 9.4 9.5 9.6 9.7 9.8 9.9 9.10 9.11 9.12	02:28	Aaron	/let me go ahead and put that (*inaudible*) first (.) we don't have historical (.) yeah (.) (*starts typing and talking out loud*) Westlake (4.0) but I was going to say uh it might be (2.0) worth comparing to historic 'A' neighborhoods given its current uh affluence (5.0) alright so that is the first thing that I have in mind (1.0) honestly the things we've already talked about (.) um (.) we covered H versus V (.) building materials (.) (*inaudible*) It is kind of hard to tell the ethnic (.) uh (.) makeup of Westlake (.) of course we basically know what it is (.) it is primarily uh you know you know White uh in uh Westlake
9.13 9.14 9.15 9.16 9.17 9.18	03:47	Drew	Um (2.0) okay so (1.0) (re*ading from instructor's discussion questions*) the questions that we are being asked are what grade is your neighborhood (.) so we don't have a grade – what do you notice about it now – so I guess upon reading this paper we need to like (.) do google street view through (.) through Westlake/
9.20 9.21	04:05	Aaron	I don't understand what uh uh uh it is definitely an affluent neighborhood
9.22 9.23 9.24	04:12	Drew	Well yeah and I mean (1.0) we know that (.) even outside of the google street view (.) just um from our own experiences living in Austin
9.25	04:20	Drew	Um
9.26 9.27 9.28	04:22	Aaron	Yeah well just by taking our tour we can tell immediately that this uh yeah (2.0) those houses we walked by are uh weren't cheap

Aaron and Drew were trying to make sense of the task. Aaron began by suggesting that they compare their neighborhood (Westlake) with a neighborhood that would have been graded as an 'A' neighborhood on the historic redlining map. Then, Aaron listed out the many variables he saw as important to causing or mitigating urban heat islands. He closed his initial turn at talk by naming that they do not have data about the ethnic make-up of Westlake but do know that it is primarily White. Finally, Drew and Aaron together named reasons why they knew Westlake was an affluent neighborhood.

Similar to the previous episode, Aaron began by ideologically framing Westlake and using this framing to contextualize his explanation of why it is cooler. First, Aaron suggested it might be worth comparing Westlake to neighborhoods which were historically graded 'A' because of its "affluence" (9.7). This remark is ideological because he classified two places: Westlake and historically graded 'A' neighborhoods. This remark is also ideological because he drew a connection between the two based on the perceived affluence of Westlake and perceived affluences of historically graded A neighborhoods. This is interesting, because HOLC zoning practices were based around class and racial make-up of neighborhoods, and not class alone.

Second, Aaron suggested a range of variables that his group already determined were important: H/V ratio and building material (9.9). This remark is ideological because it further differentiated the spatial makeup of Westlake and neighborhoods like it (particularly those which were historically graded as 'A' zones). Aaron did not explain what the H/V ratio or building material composition of Westlake are, but in previous episodes he explained that H/V ratio and building materials were favorable.

Third, Aaron explained that, even without data, they know the ethnic make-up of Westlake is predominantly white (9.12). This remark is ideological because it connected people to place. Even without data, Aaron knew Westlake to be a predominantly White

neighborhood. Aaron did not elaborate on what the racial make-up of Westlake meant, but it may have been brought up to draw further connections between present-day Westlake and neighborhoods which were historically graded as 'A' zones. Aaron's turn at talk did not further elaborate an explanation about urban heat island. Rather, Aaron reminded his group members about the variables that make Westlake cooler and further connected these to the affluent rendering of Westlake.

The rest of the episode involved Drew and Aaron, together, laminating the notion that Westlake is an affluent neighborhood. First, Aaron explained that "it is definitely an affluent neighborhood" (9.20-9.21). This remark, again, classified Westlake as affluent. Second, Drew responded to Aaron by explaining that "we know that (.) even outside the google street view (.) just from um our own experience [living] in Austin" (9.22-9.23). Drew provided evidence to Aaron's statement by naming that the students know this from google street view and from their personal experience living in Austin. Therefore, affluence is something that can be seen (is material about a place) and something that is generally known (is commonsense about place).

Finally, Aaron called back to the neighborhood tour from the second day of the lesson series (02/04/21) and reminded his group that "those houses we walked by are uh weren't cheap" (9.26-9.28). This repeated Drews' evidence that affluence is something that can be seen in the material structure of Westlake.

In summary, this episode reinscribed Aaron's ideology about Westlake: Westlake is wealthy or affluent, built from better materials, has a favorable H/V ratio, and is cooler than other places. Some new ideological framings about Westlake were also provided: Westlake is similar to historically graded 'A' neighborhoods and is predominantly white. However, not much was elaborated in the way of explaining new causes or clarifying previous causes of urban heat island. Rather, Aaron and his group mates tended to view

this as more evidence of what Westlake is cooler than other parts of the city. In the final episode, we see how Aaron's final attempt to explain urban heat island in relation to historic redlining.

Episode 3: Final reflections about redlining about cool neighborhoods

At the end of class on day four (04/12/21), the course instructor gathered both groups of students together and asked a volunteer from each group to share out their new ideas after having read the Wilson article, examined the redlining map, and completed their final neighborhood tour. Aaron volunteered to share out for his group, and the following episode occurred:

10.1 10.2 10.3 10.4 10.5 10.6	59:30	Aaron	Honestly for me it reinforced (.) uh (.) a lot of the notions that I already had (.) SES matters (.) you know (.) people that invest in neighborhoods are uh going to invest in better materials and that will be reflected in the urban heat island you know because they will tend to reflect less heat (1.0) yeah
10.7	59:52	KB	Who are the people who are investing in the neighborhoods?
10.8 10.9 10.10 10.11 10.12 10.13 10.14 10.15 10.16 10.17 10.18	59:57	Aaron	Well uh it's going to be the uh the ba- the banks primarily but its going to be the land owners you know ultimately (1.0) um (.) you hate to be blunt about it but uh basically the more property taxes you get out of a uh neighborhood probably the better the urban heat island is going to be just because you're going to get more return per tenet your going to get um: you know a better H versus V- you are going to get better materials (.) more canopy (.) you know uh it works its way together (.) I'm not saying there is a you know one causes the other but I'm saying one effects the other (.) there is a correlation
10.19	01:00:41	KB	Property taxes:
10.20 10.21	01:00:43	Aaron	Well property tax is a way you can measure how affluent a neighborhood is (.) the more property tax you get out the

10.22 10.23 10.24 10.25			more affluent that neighborhood is (.) for what I think should be obvious reasons (4.0) I also pointed out that school districts are funded primarily through property tax (.) so that comparison is not made casually
10.26 10.27 10.28 10.29	01:01:11	KB	Well and I think it is interesting to think about (.) that (.) and how that neighborhood was allowed to be developed in that way because it wasn't already taken up by giant roads or giant factories
10.30 10.31 10.32 10.33 10.34 10.35	01:01:24	Aaron	.hhh absolutely and and and one thing I did note in my section was Westlake deliberately self-incorporated (.) and I suspect (.) I'd have to go and do some research to prove it (.) but I suspect – my hypothesis is – that they did so to avoid being under the aegis of the Austin city council and their regulations

Aaron explained why certain neighborhoods do not have urban heat islands. He explained that 'people who invested in neighborhoods' chose better materials, and that these neighborhoods became cooler. The course instructor asked him to clarify who these 'people' were. Aaron clarified that banks and and landowners were the people who invested in neighborhoods. He then explained that higher property taxes were an indicator of affluent neighborhoods, and affluent neighborhoods would likely correlate with better urban temperatures (and schools). He finished his explanation by positing that Westlake likely self-incorporated (became its own city) to avoid being controlled by the city of Austin. This episode is dense in both conjectures about urban heat island and ideologies about place. First, I review some of the new ideologies about place that Aaron revealed in this episode. Then, I probe these ideologies deeper with the tools of critical discourse analysis.

In the previous two episodes, Aaron drew on specific ideologies about Westlake to reason about urban heat island. He classified Westlake as wealthy, differentiated it by its built materials and vegetation, and naturalized certain people (landowners/tenants) and

actions (building with better materials) which made this area cooler. In this episode, Aaron reasoned about neighborhoods more generally. He stops using the name 'Westlake' and pivoted to using more general terms like "neighborhoods" (10.3) and "affluent neighborhoods" (10.22). I interpreted this as a shift from using specific ideologies of place (ideologies about Westlake) to using more general ideologies of place (ideologies about wealthy places).

Aaron's general ideology about wealthy places was evident by how he classified places, differentiated places, and what people and actions he attached to these places. Aaron classified neighborhoods by affluence and used property tax to differentiate more affluent places from less affluent places. For example, in lines 10.20 through 10.22, Aaron stated "Well property tax is a way you can measure how affluent a neighborhood is (.) the more property tax you get out the more affluent that neighborhood is." Aaron framed this reasoning as commonsense when he closed the remark with "for what I think should be obvious reasons" (10.22-10.23). Aaron named banks and landowners as a natural part of what makes an affluent neighborhood cooler. For example, Aaron stated that "people that invest in neighborhoods are uh going to invest in better materials and that will uh be reflected in the urban heat island" (10.2-10.3). The course instructor asked Aaron to clarify who "people" were (10.7) and Aaron responded that people were "the banks primarily but it's going to be the landowners you know ultimately" (10.8-10.10).

Summary

To summarize, Aaron's ideology about wealthy places contained the following ideas: Certain neighborhoods are affluent because they have higher property taxes. Affluent neighborhoods have higher property taxes because they have wealthier residents and generate more taxed income. Banks are responsible for giving money to landowners,

and landowners invest in properties. This ideology of place supported the following explanation about urban heat island: Landowners in affluent neighborhoods invest better materials when building their properties. They build further apart (lower H/V ratio) and allow for more tree canopy. When landlords build like this, it emerges to make cooler neighborhoods.

To further examine Aaron's general ideology of wealthy places, particularly the people naturalized to these places, I focused on the representation of two social actors: banks and landowners. Banks are a generalized and institutional social actor. They are generalized because the word 'banks' did not refer to specific banks in Westlake or Austin, but banks more generally. They are institutionalized because banks are organizations of people, rather than individual people themselves.

Aaron included banks by explaining that they were "primarily" responsible for investing in neighborhoods. This indicated that Aaron understood that banks (historically and presently) provided loans to people to purchase homes or materials to build homes. However, Aaron did not discuss any other actions banks may conduct or receive. Pertinent to the discussion of urban heat island, Aaron did not mention that banks were responsible for granting or denying home mortgages to families, depending on their race the grade of their neighborhood (i.e., how it was graded on the A-D system.).

Landowners were a generalized and functionalized social actor. They were generalized because 'landowners' do not refer to specific landowners in Westlake or Austin, but landowners in general. They were functionalized because 'landowners' are identified by the function they conduct (owning land). Aaron included landowners by explaining that they are "ultimately" responsible for investing in land. This indicated that Aaron understood that landowners were the ones who spend the money to buy or build

properties. Landowners are where Aaron focused most of his explanatory efforts about urban heat island: landowners used better materials, and better materials reflect less heat.

RESULTS 3: MODELING URBAN HEAT ISLAND EFFECT

Finally, I turn attention towards the final urban heat island model which Aaron and his group submitted at the end of the lesson series (04/16/21). I do this to show what appeared in their model, what did not appear in their model, and draw connections to Aaron's broader ideologies of place. Although Aaron and his group mates created this model, I call it "Aaron's model" for simplicity's sake. I began by describing and comparing the initial urban heat island model (Figure 11) with Aaron's final urban heat island model (Figure 12). Then, I discuss how this model, and the explanation of urban heat island it affords, relates to Aaron's previous efforts to reason about various places in Austin, Texas.

The Initial Urban Heat Island Model

The initial urban heat island model was designed in NetLogo by a volunteer computer scientist. The model had two 'turtles': trees and people. Trees were represented by a tree-shaped icon, were scattered randomly on the model simulator, and were fixed in their location. The model user could control how many trees were in the simulation, on a scale from 0 to 1000. People were represented by human-shaped icons, were scattered randomly on the model simulator, moved around the screen in random patterns. The model user could control how many people are in the simulation, on a scale from 0 to 500. A number was fixed below each person which showed how hot the person is, on a scale from 0 (least hot) to 100 (most hot). The background of the model consists of square patches which were one of three colors: red, pink, and white. Red patches were the

hottest patches, white patches were the coolest patches, and pink patches had a medium amount of heat.

Figure 11. Initial Urban Heat Island Model provided to students for inspiration

The model functioned very simply. All patches begin as red. When trees were populated onto a patch, it 'cooled' the patch down. Therefore, a patch with many trees nearby became either pink or white. All people began with an initial starting heat value (set by the model user). As the people move around the simulator, they 'pick up heat' from patches. If a person steps onto a red patch, they pick up the most heat. If a person steps on a white patch, they pick up the least heat. Once people reached a heat value of 80, they would stop moving for a short period of time. This represented people experiencing heat exhaustion.

The model was designed as an intentionally simple prototype for students in the classroom to build from or change. The course instructor intended for students to re-

design the initial NetLogo model, however, Aaron's group decide to create a mathematical model instead.

Aaron's Model of Urban Heat Island

Aaron's model added and modified four features from the initial NetLogo model: asphalt, daily temperature cycles, ground temperature calculations, and people's walking behavior.

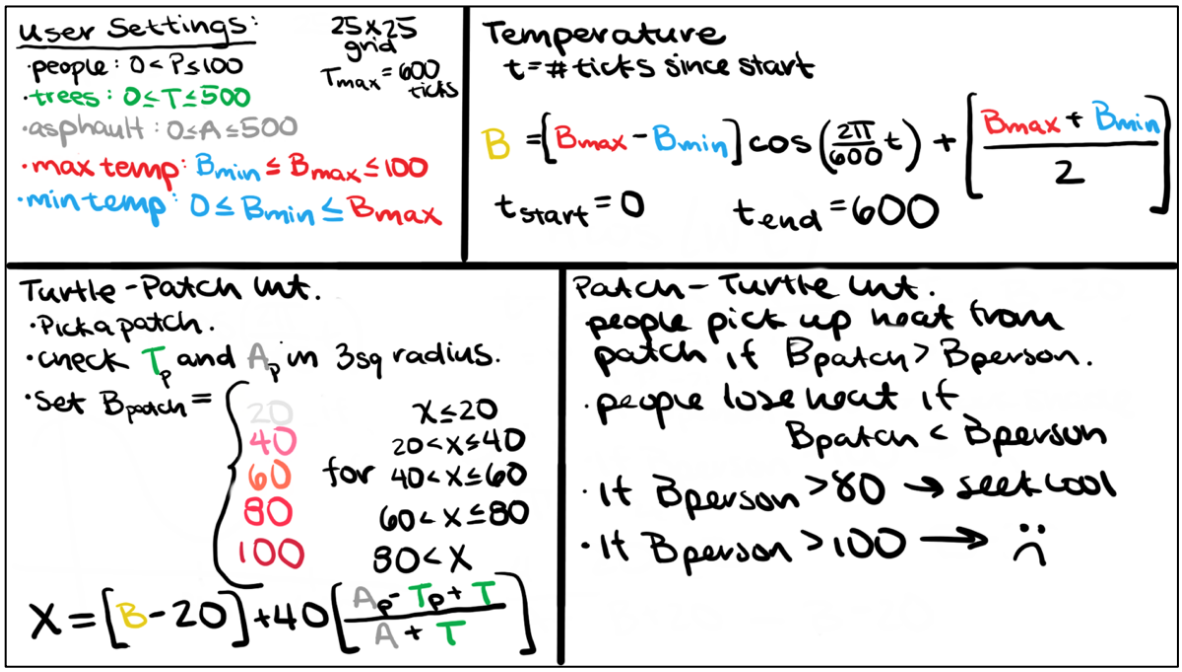

Figure 12. Aaron, Drew, and Jordan's mathematical model of urban heat island effect.

The first feature added in this model was a new turtle: asphalt (top left box, Figure 12). Similar to people and trees, asphalt could be set by the model user on a scale from 0 to 500. Asphalt, like trees was a fixed turtle which is scattered around the model randomly.

The second feature added in this model was a daily air temperature cycle. This was done to simulate daily temperature fluctuations, where morning and evening would be cooler than midday. The students created a variable named “B” which represented baseline temperature, or temperature at a specific time, ‘t’. Then, the students created a formula to calculate baseline temperature based on a maximum temperature (Bmax) and a minimum temperature (Bmin). The model user could set maximum and minimum temperatures, to simulate various climate types. The formula is represented in the top right box.

The third feature was a modification of how patches become hotter or cooler. In the original model, patches could only be one of three levels of heat (hot, medium, cool). In this model, students divided the patch into five heat levels. Then, the students created a variable, X, which represented how hot a patch could become. Patch heat was calculated by combining the baseline temperature and the number of trees and asphalt present in a 3-square radius from the patch. If a patch had more trees and less asphalt, it would be cooler. If a patch had less trees and more asphalt, it would be warmer. The formula for patch heat (X) is represented in the bottom left box.

The fourth feature included in the model was a change to how people behaved in the simulation. In the original simulation, people moved around randomly until they acquired too much heat and stopped. In this simulation, people would not move randomly. Instead, once people reached a heat value of 80, they would seek cooler places. If a person reached a heat value of 100, the person would die. This was represented in the bottom right box.

Aaron’s model of urban heat island presented slight but important deviations from the original NetLogo model. Some of the changes made the model more realistic. For example, people behaved more realistically in the final model. Rather than moving

around randomly, people in the model would seek shelter from the heat. If people could not seek shelter, they would die. This did not contribute to their explanation about how urban heat islands form, but it was a notable difference from the original model. Some of the changes made the model more complicated. The group understood asphalt to be an important contributing factor to urban heat islands. If an area had more asphalt, that area would be significantly warmer. The group also understood that air temperature and temperature on a specific patch were different and important. They created an elaborate formula to represent daily air temperature fluctuations. This formula was then tied to a second formula which calculated temperature on specific patches. The temperature at a patch was a combination of air temperature and the amount of trees/asphalt nearby the patch.

Ideologies of Place and Reasoning about Urban Heat Island

Aaron's model presented a general explanation for how urban heat islands form. By general, I mean that it can be used to explain urban heat island in any urban landscape. This explanation can be summarized with the following bullet points:

- Urban heat islands are a product of three interacting variables: air temperature, tree canopy, and asphalt coverage.
- Air temperature is a natural variable, meaning people do not impact this variable.
- Tree canopy and asphalt coverage are artificial variables, meaning humans do impact these variables.
- More trees, less asphalt, and lower air temperatures will make cooler spaces (less urban heat island effect).
- Less trees, more asphalt, and higher air temperatures will make warmer spaces (more urban heat island effect).

This explanation of urban heat island paralleled Aaron's ideologies about place. Aaron's ideology about place can be summarized with the following bullet points:

The Slums

- East Austin specifically and poor neighborhoods generally are classified as 'the slums.'
- The slums are differentiated by their built structure. They are built out of worse materials like asphalt and cinderblocks.
- Landowners are central social actors in these places. Landowners would build out of cheap materials because they wanted to save money on construction costs.
- Tenants (who are described as poor, disadvantaged, and minorities) are also central to these places had no actions ascribed to them but were naturalized as being residents of these neighborhoods.

The Good Part

- Westlake specifically and affluent neighborhoods generally are classified as 'the good part.'
- The good part is also differentiated by their built structure. The good parts are built from beautiful, aesthetic, and nice materials like stone.
- Landowners (who were funded by banks) would build neighborhoods out of better materials both for aesthetic reasons, but also to mitigate heat.

There are many missing elements in Aaron's explanation about urban heat islands. These missing elements reveal more about Aaron's ideologies about place. First, Aaron's final model contains no human social actors. This model only represented the materials which produce urban heat islands in a city. Without attending to Aaron's ideological work throughout the lesson series, we would not have been able to make visible Aaron's reasoning about how these spatial variations came to be.

Second, Aaron's model included no reference to institutional social actors. For example, Aaron's model did not include banks, the Homeowners Loan Corporation (HOLC), municipal government bodies, or neighborhood organizations. Each of these social institutions was discussed in the Wilson article and at length in class. However, none of these social institutions appeared in the final model about urban heat island. Furthermore, at no point in the lesson series did Aaron or his groupmates engage deeply with institutional social actors and their relationship to urban heat island. When asked by the course instructor why Aaron and his group mates did not include any reference to redlining or the people/institutions who conducted redlining, the following conversation unfolded:

11.1 11.2 11.3 11.4	01:15:10	Aaron	It came up (.) we talked about it (.) uh (1.0) but the way we figured it (.) the redlining would affect the surface cover (.) the canopy cover (.) in other words the effect would show itself in the other aspects (.)
11.5 11.6 11.7 11.8 11.9 11.10 11.11 11.12 11.13 11.14 11.15 11.16	01:25:00	Drew	yeah I know at one point we talked about having a slider for the different grades of redlining (.) I think (.) we ended up deciding (.) um if we had a slider that was A-B-C-D (.) it is not as customizable I guess (.) like (.) you could (.) look into the area itself and say yeah okay this area was a D and therefore it had this amount of tree cover and this amount of asphalt cover (.) and use that to determine it (.) um (.) thinking about it now (.) um (.) I think it would be interesting to have the model show (1.0) development over time in an area (.) of like (.) depending on which people are where (.) how the area has changed (.) but I feel like that is a lot harder to code.
11.17 11.18 11.19	01:32:12	Aaron	Uh yeah we talked about it (.) we considered it (.) as Drew was saying (.) but frankly to use an old computer term (.) we just marked it down as feeping creaturism (*laughs quietly*)."

In this interactional sequence, Aaron acknowledged that his group did consider including redlining in their model, but thought it was redundant. Aaron explained that redlining affected surface cover (asphalt coverage), and therefore there was no reason to show it in the model. Drew posited a possible way of including redlining in the model, but Aaron referred to this as 'feeping creaturism' (11.19). Feeping creaturism is a spoonerism of 'creeping featurism.' The phrase is used to describe when a digital object (a model, or a website) has gained too many unnecessary features which obfuscates its initial purpose. When pressed further about why redlining is 'unnecessary,' Aaron responded:

> "I honestly think that redlining is a secondary effect and I mean it in this way (1.0) .hhh Sure (.) it has an affect (.) Sure (.) it has been documented (.) but it has primarily been documented in the effects that we see it in our primary model (.) the asphalt coverage (.) the uh building structures and everything else (.)" (04/16/21, 01:38:00)

Here, we see Aaron's final explanation of why redlining is not important for modeling urban heat island. Aaron saw redlining as a background or 'secondary' effect which caused the spatial variation in tree canopy and asphalt coverage. The removal of human social actors, institutional social actors, and redlining from his final model furthers the ideology that some places are simply 'the good part' and other places are 'the slums.'

DISCUSSION

In this study, I set out to accomplish two goals. My first goal was specific to studies about ideology and learning. I aimed to show how ideologies are drawn upon, contested, and constructed through social and material interactions. My second goal was general to research in the learning sciences. I aimed to show how important it is to attend to students' ideologies about place when they are reasoning about space. In this

discussion, I review my progress towards achieving each goal. I close with a discussion about next steps for research about ideologies of place and reasoning about space.

Ideologies as Socio-technical Achievements

Previous studies about ideology and learning have "drawn attention to the micro-interactions through which ideological stances are taken by participants, taken up by others, and contested and co-constructed in interaction" (Philip & Gupta, 2020, p. 200). In research on teacher education, Philip (2011) traced the ideologies about race and class that a single teacher drew upon to reason about student successes and failures over the course of a semester. In research on computer science education, Philip, Olivares-Pasillas, and Rocha (2016) analyzed moments in high school classrooms were students and teachers made sense of data visualizations by drawing on broader ideologies social of race and more specific local knowledge. In research on engineering education, Philip, Gupta, Elby, and Turpen (2018) traced how the ideological categories of 'civilian' and 'terrorist' were interactionally constructed and converged upon throughout a single class period where students were learning about drone warfare.

Similar across these works is their close attention to people's talk as the primary medium through which ideologies are drawn upon, contested, and constructed. Each study relied on methods - such as stance analysis (Du Bois, 2007) - which describe, analyze, and connect participant's talk in interaction with broader social ideologies. From this perspective, ideologies are mental phenomenon which arise during social interactions.

However, ideologies are only partly discursive (Cresswell, 1996). Ideologies can also be drawn upon, contested, and constructed: (a) when people interact with materials; and (b) within materials themselves. By materials, I am referring to any artifact which

can contain meaning(s). For example, students in this study worked with satellite maps, thematic maps, agent-based models, readings about urban heat island, and technologies like Google StreetView. Students drew on ideologies to reason with these materials. But also, the materials themselves embody particular ideologies about the world. From this perspective, ideologies are a material phenomenon which arise during technical interactions. To illustrate this, I return to two examples from the findings of this study.

The first example illustrates how ideologies arose out of interactions with materials. On the first day of the lesson series (01/27/21), the course instructor showed students three maps of Austin: a satellite map, a race-dot map, and an urban heat hazard map. The course instructor asked students to reason about patterns they saw within each map. However, reasoning about patterns in a map is not a neutral affair. Rather, students drew on ideologies about place to make sense of the spatial patterns in each map. When reading the satellite map, Aaron pointed out areas in the western part of the city which he considered to be greener and naturally less developed. He framed these places positively as lush, good, and island-like. When reading the race-dot map, Aaron pointed out areas in the eastern part of the city which he considered to be built up, developed, and less green. He framed these places negatively as the slums, the worse part, or built from bad and cheap materials. This example illustrated that ideologies are cued in contexts with materials. Therefore, analytical accounts about ideologies and learning should pay attention to interactions between people, and between people and materials. Furthermore, these objects could be a site to transform STEM learning environments. Students' material interactions can be managed far easier than student's social interactions.

The second example illustrates how ideologies arose within materials themselves. On the final day of the lesson series (04/16/21), students presented their urban heat island models to the class. These models contained conjectures about how urban heat islands

form. However, they also contain (albeit, in an obfuscated manner), students' ideologies about place. Aaron's urban heat island model only included the distribution of materials: tree canopy and asphalt. His model excluded individual and institutional social actors who were responsible for distributing trees and asphalt cover throughout a city. Therefore, this model presents an explanation about urban heat island which foregrounds the seemingly 'natural' differences in the city's built structure, while backgrounding the historical and political reasons for why these differences exist. This example illustrated that ideologies can be canonized within materials themselves. Therefore, analytical accounts about ideologies and learning should pay attention to the ideologies built into material artifacts. Similar to the first example, interrogating the ideologies within artifacts provides a new site for transforming STEM learning environments. By attending to, and selecting different materials, instructors make certain ideologies available in learning environments – and exclude other ideologies.

In summary, this study demonstrated that ideologies are both mental phenomena which (cued in social interaction) and material phenomena (cued in technical interaction). Therefore, I consider ideologies to be sociotechnical achievements.

Ideologies of Place and Reasoning about Space

Previous studies about place-based learning (Gruenewald, 2003) have centered the use of paper and interactive maps to foster students' spatial and mathematical reasoning about critical issues of spatial (in)justice. These studies have largely been in the context of K-12 mathematics education. In research on high school mathematics, Rubel, Lim, Hall-Wieckert, and Sullivan (2016) investigated students' mathematical reasoning about the probabilities involved in playing the lottery, and spatial reasoning about places in their local community where people buy and sell lottery tickets. Findings demonstrated

that students were able to reason mathematically and spatially about local spatial contexts (i.e. neighborhoods), more so than city-wide or state contexts. In research on middle school mathematics, Rubel and Hall-Weickert, and Lim (2017) developed three tools for fostering spatial thinking at multiple spaces: an oversized floor map, interactive geographic information systems (GIS), and participatory maps. Findings demonstrated that interactions between these three tools provided opportunities for students to politicize their understandings about spatial life and mathematical practice. Rubel and Nicole (2020) integrated research on place and space to develop a framework for teaching mathematics for spatial justice. This framework describes how teachers and learners can use mathematics to identify and transform power relations inscribed in place.

Similar across these works is a close analytical attention to students mathematical and spatial reasoning in pursuit of understanding spatial injustice and advocating to spatial justice. However, the Rubel and colleagues offer a cautionary message for teaching and learning about spatial (in)justice. The authors caution that "familiarity with place can lead learners to privilege prior knowledge, precluding negotiation with disconfirming quantitative data (Enyedy & Mukhopadhyay, 2007; Wilkerson-Jerde & Laina, 2015)" (Rubel, Hall-Wieckert, & Lim, 2017, p. 650). In summary, people's knowledge about place (or ideologies of place) can hinder their ability to critically reason about space.

This case study about Aaron further demonstrated that people's ideologies of place mediate their ability to reason with spatial representations and reason about spatial phenomenon. At many points in the lesson series, I showed how Aaron's ideologies about place supported a non-critical reading about the causes of urban heat island in Austin, Texas. However, rather than interpreting people's ideologies about place in a purely negative light, I see these as opportunities to engage in what Philip et al. refer to as

ideological divergence (2018). By ideological divergence, I am referring to the process whereby people, in interaction, provide alternative readings of the (spatial) world. For example, Aaron's first attempt to classify East Austin as the slums was countered by the course instructor and a classmate (Elias). Together, Elias and Dr. Barry re-classified this East Austin as a low SES neighborhood, rather than the slums. Although this moment was short-lived, it provided hope for pathways forward.

In summary, if dominant ideologies of place tend to classify and naturalize places (and the people within them), they also inadvertently create templates for how to transgress (Cresswell, 1996) these expectations. Therefore, we should see dominant ideologies of place as sites to create critical and alternative readings of place.

Conclusion

To summarize, ideologies of place are important resources for reasoning about space. In this study, Aaron repeatedly co-constructed ideologies which frame Austin specifically and cities more generally as being comprised of 'the slums' and 'good parts.' He constructed these ideologies as he interacted with classmates, maps of Austin, readings, and virtual tours with Google StreetView. These ideologies mediated his efforts to reason about why certain parts of the city were cooler and hotter. And finally, these ideologies were inscribed into his final model about how urban heat islands form in cities.

Throughout this research, I explained how ideologies of place mediated reasoning about space. I choose the word mediate intentionally. Aaron's ideologies did not in any simple way cause or influence his reasoning about urban heat island effect. Rather, ideologies about place and reasoning about space were tandem and entangled processes. They occurred in ephemeral but important moments across the six-day lesson series.

To close, I offer a question posed by Tim Cresswell (1996) regarding the centrality and funciton of place in social life, and in this case, in learning.

> "While I agree that the social construction of place is an interesting question, other types of analysis are necessary. Harvey, Edward Soja, and others frequently assert that place is a powerful tool for manipulating social action. It still remains to ask, why is place such a powerful container of social power? More specifically, what is it about place that makes it an effective signified of ideological values?" (1996, p. 151).

This research demonstrated how Aaron, through social and technical interaction, constructed ideologies of place and used them to reason about space. However, this research did not reveal why place is such a powerful construct for containing ideologies or reasoning about space. In future research, I hope to take up this guiding question in the context studies about spatial reasoning.

Appendices

APPENDIX A: CONSENT FORM 1

Title of the Project: Exploring how preservice teachers enrolled in an elementary science methods course engage with computer science, modeling, and complex phenomena.

Principal Investigators: Max Sherard, Dr. Tia Madkins

Consent to Participate in Research

Invitation to be Part of a Research Study
You are invited to be part of a research study. This consent form will help you choose whether or not to participate in the study. Feel free to ask if anything is not clear in this consent form.

Important Information about this Research Study
Things you should know:

- The purpose of the study is to better understand how we can support preservice teachers in understanding how to integrate STEM and non-STEM disciplines (computer science, mathematics, social studies) and engage in the science practice of model-based thinking.
- In order to participate, you must be an elementary preservice teacher in the College of Education who has taken EDC 370E: Science.
- If you choose to participate, you will be asked to share your experiences from your time in EDC 370E - Science Methods course with us, including your course materials produced when you engaged in model-based learning last semester.
- Risks or discomforts from this research are not greater than everyday life.
- The possible benefits of this study include being able to help your instructors better develop the elementary STEM methods courses for future preservice teachers and support students in learning best teaching practices for elementary STEM classrooms.
- Taking part in this research study is voluntary. You do not have to participate and you can stop at any time.

Please take time to read this entire form and ask questions before deciding whether to take part in this research study.

What is the study about and why are we doing it?

The purpose of the study is to explore how we can best support you as a preservice teacher in understanding how to teach science and mathematics to elementary school children. Specifically, this study will explore how we can best support preservice teachers in understanding how to teach integrated STEM content in a manner that is situated in real world events and uses the science practice of modeling.

In order to understand how the course has impacted your learning, we would like to examine your course materials you produced while engaging in the model-based learning lesson series about the phenomenon segregation. These course materials include written artifacts (reflections and drawings of models) and transcripts from the video footage of class discussions. By sharing your experiences and insights about the course, you will support us in figuring out how to improve the next iteration of the course to best support preservice teachers taking it in the future.

What will happen if you take part in this study?
If you agree to take part in this study, you will be asked to:

1) Allow us to include your course materials as evidence to be further examined now that the course has been completed.

How long will you be in this study and how many people will be in the study?
This study is retroactive. We are seeking to analyze course materials produced from your previous enrollment in the Elementary Science Methods course. If you elect to participate, there will be no further action necessary from you.

What risks and discomforts might you experience from being in this study?
There are no risks or discomforts you might experience as this study will analyze course materials that have already been generated from your previous semester.

The researchers will let you know about any significant new findings (such as additional risks or discomforts) that might make you change your mind about participating in this study. Course instructors will not know of your participation in this study until after you have received the grade for the EDC 370E: Science.

How could you benefit from this study?
There are no direct benefits to you for your participation in this study. However, future EDC 370E students might benefit because your experiences will help to inform how to modify or re-structure the course to best support preservice teacher learning.

What will happen to the samples and/or data we collect from you?
As part of this study we will collect your course work submitted the previous semester in class (e.g., written reflections and drawings of models) and transcripts from the video

collected.

How will we protect your information?
We will protect your information by using pseudonyms for each of the participants, as well as course sections. Furthermore, video footage will be used to create transcripts, but will be destroyed after the transcripts are created. In addition, instructors will have no knowledge of who is and who is not a research participant until after grades are submitted.

Information about you may be given to the following organizations:
- The College of Education at The University of Austin; or
- Representatives of UT Austin and the UT Austin Institutional Review Board.

We will keep the list of participants' names and matching pseudonyms in an encrypted box system on the university server, UT Box (which is approved for the safe-keeping of confidential research data). All other data including notes from lessons, transcripts derived from video of class discussions, course artifacts, etc., will also be kept in the encrypted UT Box service.

We will share your data or samples with other researchers for future research studies that may be similar to this study or may be very different. The data or samples shared with other researchers may include information that can directly identify you. Researchers will not contact you for additional permission to use this information.

We plan to publish the results of this study. If we include any information that could directly identify you, we will use a pseudonym to protect your privacy.

What will happen to the information we collect about you after the study is over?
Your name and other information that can directly identify you will be deleted from the research data collected as part of the project.

How will we compensate you for being part of the study?
You will not receive any type of payment for your participation.

Your Participation in this Study is Voluntary
It is totally up to you to decide to be in this research study. Participating in this study is voluntary. Your decision to participate will not affect your relationship with The University of Texas at Austin, your instructors, or anyone involved with any of the teacher education programs in the College of Education. You will not lose any benefits or rights you already had if you decide not to participate. Even if you decide to be part of the study now, you may change your mind and stop at any time. You do not have to answer any questions you do not want to answer.

If you decide to withdraw before this study is completed, you may let Max Sherard or Dr. Tia Madkins know by contacting them through e-mail.

Is it safe to start the study and stop before you are finished?
You are always free to stop participating in the study if you would like. Your decision to stop participating will not affect any other benefit you would receive if you were not in a research study.

Contact Information for the Study Team
If you have any questions about this research, you may contact:
Max Sherard
Phone:
Email:

Dr. Tia C. Madkins
Phone:
Email:

Contact Information for Questions about Your Rights as a Research Participant
If you have questions about your rights as a research participant, or wish to obtain information, ask questions, or discuss any concerns about this study with someone other than the researcher(s), please contact the following:

The University of Texas at Austin Institutional Review Board
Phone: 512-232-1543
Email: irb@austin.utexas.edu

Please reference study number 2019-81-0021.

Your Consent

By signing this document, you are agreeing to be in this study. We will give you a copy of this document for your records. We will keep a copy with the study records. If you have any questions about the study after you sign this document, you can contact the study team using the information provided above.

I understand what the study is about and my questions so far have been answered. I agree to take part in this study.

_____
Printed Subject Name

APPENDIX B: CONSENT FORM 2

Title of the Project: Modeling in Science Preservice Teacher Education.
Principal Investigators: Max Sherard, Dr. Tia Madkins

Consent to Participate in Research

Invitation to be Part of a Research Study
You are invited to be part of a research study. This consent form will help you choose whether or not to participate in the study. Feel free to ask if anything is not clear in this consent form.

Important Information about this Research Study
Things you should know:

- The purpose of the study is to better understand how we can support preservice teachers in understanding how to integrate STEM and non-STEM disciplines (computer science, mathematics, social studies) and engage in the science practice of model-based thinking.
- In order to participate, you must be an preservice teacher enrolled in either EDC 370E: Science Methods OR EDC 365E: Project-based Instruction.
- If you choose to participate, you will be asked to share your experiences from your time in the course with us, including your course materials produced when you engaged in model-based learning last semester.
- Risks or discomforts from this research are not greater than everyday life.
- There are no benefits to participating in this study.
- Participating in the study help your instructors better develop the elementary and secondary STEM methods courses for future preservice teachers and support students in learning best teaching practices for elementary STEM classrooms.
- Taking part in this research study is voluntary. You do not have to participate, and you can stop at any time.

Please take time to read this entire form and ask questions before deciding whether to take part in this research study.

What is the study about and why are we doing it?
The purpose of the study is to explore how we can best support you as a preservice teacher in understanding how to teach science and mathematics to elementary and secondary school children. Specifically, this study will explore how we can best support preservice teachers in understanding how to teach integrated STEM content in a manner that is situated in real world events and uses the science practice of modeling.

In order to understand how the course has impacted your learning, we would like to examine your course materials you produced while engaging in the model-based learning lesson series about a complex phenomenon. These course materials include written artifacts (reflections and drawings of models) and transcripts from the video footage of

class discussions. By sharing your experiences and insights about the course, you will support us in figuring out how to improve the next iteration of the course to best support preservice teachers taking it in the future.

What will happen if you take part in this study?
If you agree to take part in this study, you will be asked to:

1) Allow us to include your course materials as evidence to be further examined now that the course has been completed.

How long will you be in this study and how many people will be in the study?
This study is retroactive. We are seeking to analyze course materials produced from your previous enrollment in the Elementary Science Methods course or the Project-based Instruction Course. If you elect to participate, there will be no further action necessary from you.

What risks and discomforts might you experience from being in this study?
There are no risks or discomforts you might experience as this study will analyze course materials that have already been generated from your previous semester.

The researchers will let you know about any significant new findings (such as additional risks or discomforts) that might make you change your mind about participating in this study. Course instructors will not know of your participation in this study until after you have received the grade for the EDC 370E: Science.

How could you benefit from this study?
There are no direct benefits to you for your participation in this study. However, future EDC 370E students might benefit because your experiences will help to inform how to modify or re-structure the course to best support preservice teacher learning.

What will happen to the samples and/or data we collect from you?
As part of this study we will collect your course work submitted the previous semester in class (e.g., written reflections and drawings of models) and transcripts from the video collected.

How will we protect your information?
We will protect your information by using pseudonyms for each of the participants, as well as course sections. Furthermore, video footage will be used to create transcripts, but will be destroyed after the transcripts are created. No identifiable information will be retained for this study. In addition, instructors will have no knowledge of who is and who is not a research participant until after grades are submitted.

Information about you may be given to the following organizations:

- The College of Education at The University of Austin; or
- Representatives of UT Austin and the UT Austin Institutional Review Board.

We will keep the list of participants' names and matching pseudonyms in an encrypted box system on the university server, UT Box (which is approved for the safe-keeping of confidential research data). All other data including notes from lessons, transcripts derived from video of class discussions, course artifacts, etc., will also be kept in the encrypted UT Box service.

We will share your data or samples with other researchers for future research studies that may be similar to this study or may be very different. The data or samples shared with other researchers will not include information that can directly identify you.

We plan to publish the results of this study. If we include any information that could directly identify you, we will use a pseudonym to protect your privacy.

What will happen to the information we collect about you after the study is over?
Your name and other information that can directly identify you will be deleted from the research data collected as part of the project.

How will we compensate you for being part of the study?
You will not receive any type of payment for your participation.

Your Participation in this Study is Voluntary
It is totally up to you to decide to be in this research study. Participating in this study is voluntary. Your decision to participate will not affect your relationship with The University of Texas at Austin, your instructors, or anyone involved with any of the teacher education programs in the College of Education. You will not lose any benefits or rights you already had if you decide not to participate. Even if you decide to be part of the study now, you may change your mind and stop at any time. You do not have to answer any questions you do not want to answer.

If you decide to withdraw before this study is completed, you may let Max Sherard or Dr. Tia Madkins know by contacting them through e-mail.

Is it safe to start the study and stop before you are finished?
You are always free to stop participating in the study if you would like. Your decision to stop participating will not affect any other benefit you would receive if you were not in a research study.

Contact Information for the Study Team
If you have any questions about this research, you may contact:
Max Sherard

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Contact Information for Questions about Your Rights as a Research Participant
If you have questions about your rights as a research participant, or wish to obtain information, ask questions, or discuss any concerns about this study with someone other than the researcher(s), please contact the following:

The University of Texas at Austin Institutional Review Board
Phone: 512-232-1543
Email: irb@austin.utexas.edu

Your Consent

By signing this document, you are agreeing to be in this study. We will give you a copy of this document for your records. We will keep a copy with the study records. If you have any questions about the study after you sign this document, you can contact the study team using the information provided above.

I understand what the study is about and my questions so far have been answered. I agree to take part in this study.

_____
Printed Subject Name

_____
Signature Date

APPENDIX C: SOCIOSEMANTIC INVENTORY

This appendix was created from examples and explanations borrowed from Theo van Leeuwen's writings about sociosemantic inventory (1993, 1996).

11 Dimensions for Representing Social Actors:

1. Inclusion: What social actors are present or absent in a text?*
2. Role Allocation: Which social actors conduct action (activated)? Which social actors receive action (passivated)?*
3. Genericization/Specification: Are social actors real people in the world (specified) or abstractions of people (genericized)?
4. Assimilation/Individualization: Are social actors left within their groups (assimilated) or extracted (individualized)?
5. Association/Dissociation: When many groups of social actors are mentioned, are they macro-grouped (associated) or split (dissociated)?
6. Indetermination/Determination: Are social actors identifiable by some feature (determined) or abstract, and unidentifiable (indetermined)?
7. Differentiation/In-Differentiation: Does the author take sides with social actors (differentiated)? Or are the alliances rendered invisible (in-differentiated)?
8. Nomination/Categorization: Are social actors named by individual or institutional names (nominated)? Or are they grouped by other features (categorized)?
9. Functionalization/Identification: Are social actors categorized by their behaviors (functionalized)? Or are they done so by species (identification)?*
10. Personalization/Depersonalization: Are social actors treated as human (personalized) or as non-human (impersonalized)?*
11. Single Determination/Over Determination: Are social actors reduced to a single trait or role (single determination) or given many traits or roles (over determination)?

*These are the four dimensions I use in the above three articles.

Inclusion Analysis

Inclusion refers to the process whereby a text selects certain social actors to include and represent and other social actors to exclude and hide. Texts include and exclude social actors to distribute power. Social actors can be empowered by being included, and thus present in the text; or disempowered by being excluded and hidden in the text.

Probing Question:

What social actors are present or absent in the text?

Variations:

1. Included
2. Excluded
    a. Totally Excluded
    b. Partially Excluded
        i. Backgrounded
        ii. Suppressed

Codes, Descriptions, Linguistic Markers and Examples:

Code	Description	Linguistic Marker	Example
Included	Social actor is named in the text	Nouns (common or proper) and pronouns used in the text.	"Australians feel they cannot voice legitimate fears about immigration." Australians are included
Excluded: Totally Excluded	No reference to social actor at all	No reference to social actor in any portion of the text. No trace of their existence in verb use.	n/a
Excluded: Partially Excluded - Backgrounded	Social actor is named in some other portion of the text	Social actor is absent in one portion of the text, but present in other portions, and therefore inferred.	n/a

Excluded: Partially Excluded - Suppressed	Social actor is not named, but there are clues that they are present. These clues usually relate to the use of verbs in a sentence.	**Passive Agent Deletion** When the social actor responsible for conducting the action of a verb is deleted.	"In Japan similar concerns are being expressed about a mere trickle of third world immigrants." Who expresses concerns? This social actor (citizens?) is being suppressed.
		Non-Finite Clauses Dependent clause which acts as a circumstance for another independent clause. The social actor is not present in the dependent clause.	"To maintain this policy is hard." Who maintains the policy? This social actor (government?) is being suppressed
		Dropping a beneficiary of action An action is conducted, but who the action is conducted to or for is deleted. (Similar to passive agent deletion; but passive beneficiary deletion).	"Japan's National Police Agency had to apologize recently for circulating an internal memo to police stations claiming that Pakistanis working in Japan 'have a unique body odour', and carry infectious skin diseases and tell lies 'under the name of Allah'. Who did JNPA apologize to? This social actor (the public?) is being suppressed.
		Nominalization Nominalization is when nouns are created from adjectives or verbs. Verbs would indicate that a social actor conducts or receives them, but nominalizing the verb, the social actor can be removed, and thus suppressed.	"The level of support for stopping immigration altogether was at a postwar high" "Support" and "Stopping" are treated as nominals, although they refer to activities wherein someone would be the person doing or receiving them. This social actor (Australians?) are suppressed.
		Processes realized as adjectives A process or a verb can be converted into an adjective to describe a noun. The process, in its original state, would require a social actor to do or receive it. By	"Australians feel they cannot voice legitimate fears about immigration" Who legitimizes the fear? This social actor (the public?) is suppressed.

		converting the process/verb to an adjective; the social actor is dropped and therefore suppressed.	
		Middle Voice Middle voice is neither active voice nor passive voice. The use of middle voice means there isn't a social actor named; although, in reality, a social actor is present. Therefore, the social actor in middle voice is suppressed.	"The door of the playhouse opened and the teacher looked in." The door opened is middle voice, but doors do not open themselves. Someone had to open it (the teacher?)

Role Allocation (Activation) Analysis:

For social actors that are included (or those who are partially excluded), they are given roles. Roles are the positions social actors are placed in, with regards to social actions. Texts allocate roles to social actors to ascribe agency differently. There need not be congruence between the roles that social actors play in texts, and the roles they play in 'the real world'. Authors can reallocate roles and rearrange social relations. Citations to read more about: Fairclough, 1989; Fowler, 1991; Fowler et al 1979; Kress and Hodge, 1979; van Dijk, 1991).

Probing Question:

What social actions are conducted in a text and who are they conducted by? Who receives the social action?

Variations:

1. Activated
2. Passivated
    a. Subjected
    b. Beneficialized

Codes, Descriptions, Linguistic Markers and Examples:

Code	Description	Linguistic Marker	Example
Activated	Social actors which conduct the action or verb within a sentence. Activated social actors are realized as 'agents' or as having 'agency'	**Transitivity Structures** ▪ Social actor is ACTOR in material processes ▪ Social actor is BEHAVER in behavioral processes ▪ Social actor is SENSER	Material Process Example ▪ "80 young white thugs attacked African street vendors" o Thugs are activated by material process 'attacked' Behavioral Process Example ▪ No example

		in mental processes ▪ Social actor is SAYER in verbal processes ▪ Social actor is ASSIGNER in relational processes	Senser Process Example ▪ "<u>They</u> <u>felt</u> 'besieged' by immigration." o They are activated by mental process 'felt' Verbal Process Example ▪ No example Relational Process Example ▪ No example
		Circumstantialisation Prepositional circumstantials with 'by' or 'from'. The action is placed in the circumstance of the sentence (details about where or when).	Preposition: By ▪ "They felt 'besieged' by <u>immigration</u>" o Immigrants are implied as social actors within 'immigration'. Therefore, immigrants are activated, because they conduct the verb 'besieged' Preposition: From ▪ "People of Asian descent suddenly received a cold-shoulder from <u>neighbors and co-workers</u>" o Neighbors and Co-workers are activated the implied idea that they 'give' a cold-shoulder
		Pre- or Post-Modification When an adjective is used to modify a verb, which indicates a social actor's presence (pre-mod) OR when a preposition/possessive pronoun is used to modify a noun, but implies a social actor (post-mod, possessivation)	Pre-modification: ▪ "The influx of Asians" o Asians are a social actor, they conduct the action of 'influxing'. Although, this phrase is treated more as a noun. Post-modification ▪ "Public support" o Although treated as a noun, public support implies that the 'public' is an activated group of social actors who conduct the action of 'supporting'. Possessivation ▪ "My teacher"

			○ Implies two social actors; me and teacher. Implies a social relation between them, one of ownership "me owns teacher' ▪ "Our intake" ○ Implies social actor (our, us, the public) and a verb/process (intake). Treated as a nominal group.
Passivated: <u>Subjected</u>	Social actors which receive the action of the verb in a sentence, and are treated as OBJECTS in a sentence. (CANNOT take a preposition) Social actors who are passivated-subjected are realized as 'patients' or having less 'agency'	**Transitivity Structures** ▪ Social actor is GOAL in material process ▪ Social actor is PHENOMENON in mental process ▪ Social actor is CARRIER in attributive process	Material Process Example ▪ Immigrants taken in in return for the skill or the money they bring. ○ Immigrants are passivated-subjected. They are treated as an object that gets 'taken in'.
		Circumstantialization When a social actor is passivated-sbjected by a prepositional phrase in the circumstance of a sentence.	Prepositional Phrase: ▪ "A racist backlash against ethnic Asians has been unleashed by those who resent the prominence of centrist candidate Alberto Fujimori" ○ Ethnic Asians are passivated-subjected by the 'backlash' with the prep phrase 'against.'
		Post-modification The use the preposition 'of' to modify a nominal group or phrase, which calls into being a social actor who is subjected.	Post-mod with "of" ▪ "An intake of some 54,000 skilled immigrants is expected this year." ○ Intake 'of' indicates that 54,000 skilled immigrants are passivated-subjected
		Pre-Modification When an adjective modifies a verb or a noun, in a way that calls into being a social actor who is	Adjectival pre-modification ▪ "Racial tolerance" ○ The social action of tolerance (conducted by the White public). The social group of "races"

		passivated-subjected.	(ostensibly non-White racial groups) are passivated-subjected by being tolerated.
Passivated: <u>Beneficialized</u>	Social actors which receive the action of the verb in a sentence, and are treated as A THIRD PARTY, which positively or negatively benefit from the action (CAN take a preposition) Social actors who are passivated-subjected are realized as 'patients' or having less 'agency'	**Transitivity Structures** ▪ Social actor is RECIPIENT or CLIENT in material clause ▪ Social actor is RECIEVER in verbal clause	Material Clause ▪ "22,000 Hong Kong Chinese arrived last year, bringing bulging wallets to cities like Vancouver" o Vancouver is passivated-beneficialized in this sentence in relation to the verb/process/action 'bringing'. Verbal Clause ▪ "I told Mark he needed to leave" o Mark is passivated-beneficialized because he is told something by "I"

Functionalization/Identification (Identification) Analysis

Social actors are likely to have or be a part of many identity groups. However, identity groups can be crafted from a range of relations to social practices. In some instances, a social identity can be derived from the actions that the individuals conduct. This is called functionalized identities. In other instances, a social identity can be derived from thinking of a group as a species within a larger group. This is the typical realization of identification. This only happens for social actors who are categorized.

Probing Question:

Are social actors' identities derived from their membership in a group (identification) or by their practices (functionalization)? A third type, which is less common, is when social actor's identities are appraised by the affective value they offer society.

Variations:

1. Functionalized
2. Identified
    a. Classified
    b. Relationally Identified
    c. Physically Identified
3. Appraisement
4.

Codes, Descriptions, Linguistic Markers and Examples:

Code	Description	Linguistic Marker	Example
Functionalized	When social actors are referred to by the actions or practices they conduct	When a verb is formed into a noun with the addition of suffixes like -er, -ant, -ent, -ian, -ee	Interviewer, Celebrant, Correspondant, Guardian, Payee, Comittee

		A noun formed into another noun which denotes a place or a tool closely associated with the activity	Pianest Mountaineer
		Compounding nouns denoting places or tools closely associated with the activity and highly generalized categories such as 'man' and 'woman.'	Cameraman, Camerawoman, Chair person, Police Man, Police Woman
Identification: Classified	Social actors are not represented by what they do (functionalized) but rather by what class, caste, or species they fall into.	Culturally-determined categories such as: age, gender, provenance, class, wealth, race, ethnicity, religion, sexual orientation, nationality, etc.	Asian American, Catholic, Gay, Rich, etc.
Identification: Relational	Social actors are not represented by what they do (functionalized) but rather by who they are related to.	Relationship-oriented words	Mother, father, brother, sister
		Possessives can modify the above category further.	"my friend" "my mother"
Identification: Physical	Social actors are not represented by what they do (functionalized) but by a physical trait they have.	Traits attached to the person, metonymized usually	Read head, blonde, tall, short, fat, bearded, dark-skinned *** these can easily flow between identification-classified category.
Appraisement	Social actors are identified by their value to another group, or their affective harge.	Appraising verbs or adjectives	80 Young white thugs Thugs is an appraisement, young and white are classifciations (age and race).

Personalization/Depersonalization (Personalization) Analysis:

Social actors in the real world are typically humans, collections of humans. However, in texts, they can be transformed into many other things. When social actors are conserved as humans, we call this personalization (or social actors are personalized). This is typically how social actors are referred to. In other circumstances, social actors can be made into non-humans: animals, characteristics, behaviors, objects, etc. We call this impersonalization.

Probing Question:

Is the social actor represented as a human person or collection of people? Or, is the social actor represented as something non-human?

Variations:

1. Personalized
2. Depersonalized
    a. Abstraction
    b. Objectivation
        i. Spatialization
        ii. Utterance Autonomisation
        iii. Instrumentalisation
        iv. Somatisation

Codes, Descriptions, Linguistic Markers and Examples:

Code	Description	Linguistic Marker	Example
Personalized	When social actors are attempted to be described accurately by some association or identity	All of the above	n/a
Impersonalized: Abstraction	When social actors are made to be not human, and instead made into an abstract or mental concept.	Making people into ideas, processes, mental concepts	"Australia is in danger of saddling itself up with a lot of unwanted problems." All of the people (Muslims, Immigrants, etc) are collapsed under the abstract concept of 'problems.' They are de-humanized.
Impersonalized: Abstraction – Spatialized	When social actors are made to be not human, and instead made into an object – specifically a spatial object.	Social actors are represented by means of reference to a place which which they are, in given context, closely associated. (this is confusing when you think about identified-classified.	"East Austinites"
Impersonalized: Abstraction – Utterance Autonomisation	When social actors are made to be not human, and instead made into an object – specifically an utterance or spoken object.	Social actors are represented by means of reference to their utterances	
Impersonalized: Abstraction – Instrumentalisation	When social actors are made to be not human, and instead made into an object – specifically a instrument or tool.	Social actors are represented by means of reference to the instrument with which they carry out the activity which they are represented as being engaged in	"A 120 mm mortar shell slammed into Sarajevo's Marketplace" The 120 mm mortal shell is the social actor, rather than the person who launched it.
Impersonalized: Abstraction -	When social actors are made to be not human, and instead	Metonymy or synedoche	"She put her hand on Mary Kate's Shoulder"

Somaticisation	made into an object – specifically a body part.		Shoulder is the social actor, Mary Kate is a modifier

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