

Undergraduates Learning Public Engagement through Designing and Sharing Games:
Undergraduate Research Engineers Enacting the Roles of Public Engagement with

Science

by

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ABSTRACT

This study is a qualitative exploration into the roles and social identities that Research Engineering Undergraduates (REU) enacted while engaging the public through designing serious games. At present, the science communication field is searching for ways to train the next generation of scientists to practice public engagement with science in a way that fosters dialogue with the public, however, little research has been done on training undergraduates in this regard. This exploratory study seeks to determine what opportunities a game design project in a summer program in solar energy engineering research provides undergraduates to that end. The project includes REUs designing games through a facilitated design process and then sharing them with the public at arts festivals. Through discourse analysis, data was analyzed through the lens of cohesion in order to interpret what roles and social identities REUs enacted as well as members of the public who play the games. Based on the analysis of 12 REUs and 39 player participants, findings indicate REUs most often enacted the science game designer social identity and science educator role during the public event. Less often, REUs enacted a sociotechnical role to determine the player's relationship to science/solar energy. Also, less often did they position themselves directly as scientists. For the most part, REUs reproduced the dissemination model of science communication in an interactive way and with an element of reflexivity. However, during public engagement events, dialogue with the public occurred when REUs enacted open-ended roles that enabled members of the public to contribute to the conversation by assuming a range of roles and social identities rather than positioning them into a single role. Dialogue was also supported when REUs were responsive and shifted their role/ social identity to correspond with the public's

enactment. Some players enacted a local Arizonan social identity in response to the open-ended role and game content about Arizona's solar energy. The project afforded REUs the opportunity to learn illustration and reformulation to communicate science concepts. Also, REUs referenced their game during illustration and reformulation, using it as a tool to teach science, be a science game designer, and other enactments. More research is needed to determine how science, technology, engineering, and math (STEM) undergraduates learning science communication can design serious games and conduct player reflections in such a way to promote dialogue to a greater degree than observed in this study.

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CHAPTER 1

INTRODUCTION

Science communication scholars continue to criticize the scientific community for not doing enough to engage the public with science-related issues (Cooter & Pumfrey, 1994; Trench & Bucchi, 2014). The most oft-cited concern is that too often scientists take part in what has been called the *dissemination* model of science communication, which characterizes scientists as the bearers of truth and non-scientists as laypersons who either are lacking knowledge or are simply “empty vessels” to fill with information (Davies, McCallie, Simonsson, Lehr, & Duensing, 2009, p. 342). Originally conceptualized as a critique of how scientists communicate with those outside of academia, the dissemination model is produced by practices and processes in which scientists enact the role of the paternal, authoritarian expert while the rest of society performs the role of non-experts who have no legitimate claim to knowledge and, at times, are incapable of understanding science (Cooter & Pumfrey, 1994; Wynn, 1991). Moreover, scholars making this argument view this relationship harshly, considering it an unequal one that gives the public-at-large an inferior position from which they are not meant to question the authority of the scientific community. Additionally, the media, particularly science journalists, have often adopted the role of “bridge” between these two sides, seeking to translate and interpret the scientific discourse into everyday language, or recontextualize it into the public discourse (Bensaude-Vincent, 2001, p. 100; Dornan; 1990). However, this role reproduces the same unequal positionalities, further entrenching old habits and not ameliorating the gulf between scientists and the public.

In response, critics and politicians have called for a new relationship between scientists and the public in this regard, one in which the former are experts who are in dialogue with the latter in a two-way interaction; hence the formation of the *dialogue* model of communication (Davies et al., 2009; Trench & Bucchi, 2014). This model, and others that are more participatory, seek to give scientists and non-scientists opportunities to interact as equals who communicate in ways in which both sides can contribute to the conversation, and the interaction is mutually beneficial (Baram-Tsabari & Lewenstein, 2017; Trench & Bucci, 2014). This raises the issue which is that scholars are not certain that the scientists and institutions that do public outreach events and generate various forms of media for the public are in fact communicating in ways that can be characterized as dialogue (Stilgoe, Lock, & Wilsdon, 2014; Trench, 2008). As such, this suggests that accomplishing dialogue is still an elusive goal for science communication practitioners. As will be explored in the literature review, Davies et al. (2009) recommend distinguishing between large scale dialogue events and events that seek to shift public opinion of the entire public compared to a smaller scale, or non-policy informing dialogue event centered on dialogue between experts/ facilitators and individual or small groups of the public. Even so, such small scale events still tend to reproduce the same unequal relationships between experts and members of the public in the sense that the former possess a privileged position based on their knowledge of science and the latter can take part in discussion in limited ways, primarily as a passive audience. As a result, it is still unclear which formats and how scientists and other practitioners of science communication can conduct a public engagement event so that it promotes dialogue.

Another issue, and the one that pertains directly to this study, is the limited ways that universities train graduate and undergraduate students to take part in public engagement with science (Brownell, Price, & Steinman, 2013). In spite of the attention placed on the need for scientists to engage the public through dialogue, institutions provide few opportunities for undergraduates to engage in communication practices with the public, and those that are offered have been characterized as only dissemination models (Baram-Tsabari & Lewenstein, 2017; Brownell, Price, & Steinman, 2013). Moreover, as previously noted above, scholars are not clear what students should be learning to do in order to encourage dialogue, how they should conduct an event and interact with members of the public since professionals themselves are not certain. However, it is clear that if the scientific community is expected to engage with the public in more dialogic ways, then universities must begin asking themselves in what ways they can include students in communities of practice that are actively engaging the public, thereby students can develop the thinking, being, and doing of scientists who value public engagement (Gee, 2002; 2014a). Baram-Tsabari and Lewenstein (2017) have taken a bold tentative first step toward assembling learning goals in this regard, arguing for undergraduates to be afforded hands on, authentic experiences in “fostering fruitful dialogue with diverse audiences” about science, among other science communication-related goals (p. 288). In order to achieve this, students will need to work with practitioners who can scaffold and guide them towards greater degrees of participation in the practices and processes of public engagement (Halliday & Hasan, 1989; Lave & Wenger, 1991; Vygotsky, 1980) by developing social identities as scientists who actively take part in such activities in ways recognized by the community (Gee, 2003; 2014a).

These enactments, which are considered to be social roles performed by students, can be derived through discourse analysis in which participant verbal interactions can be interpreted through a sociolinguistic lens (described in detail in Chapter 2) (Erickson, 2008; Gee, 2014a; 2014c; 2017; Gee & Green, 1998; Hicks, 1996).

The primary purpose of this research is to contribute to the scholarship on the teaching of future scientists in public engagement by exploring in what ways undergraduate science students enact social identities and relate to the public by designing and while sharing these games. This study approaches this problem through discourse analysis and sociolinguistic lens to examine the student-public interactions as well as the facilitated game design process in order to explore how such an educational experience does or does not give students chances to do and be like a scientist who engages with those outside of their field in dialogue and other productive ways. To these ends, I intend on addressing these research questions:

- 1) Given the challenge of designing a game to engage the public with science, what social identities and roles do undergraduate engineering students enact during the facilitated design process?
- 2) During the public engagement event(s), what social identities and roles do these students and members of the public who play the game enact through the player reflection?

An overview of the study begins with **Chapter 2**, Literature Review, which covers the foundational models of science communication and how they are currently viewed within the science communication field. This chapter focuses on the criticism that the dissemination model receives and the field's response via the dialogue model.

Moreover, Chapter 2 considers what ways universities are currently training the next generation of scientists to engage the public and where the research is still lacking, particularly for undergraduate science and engineering majors. In addition, it describes learning from the situated learning perspective and how discourse analysis can be used to examine student interactions as enactments of roles and social identities.

Chapter 3, Method, covers the methods used in this study and outlines the setting of the study as well as the author's positionality. First, the prior research which informed this study is described, then the design of this study. Next it covers discourse analysis and how cohesion in language is the window in which to interpret what a speaker does through language and what they mean and who they are attempting to be in a social context. This study takes place within a 9-week summer program within the Solar Energy Center (SEC)¹, where 12 Research Engineering Undergraduates (REU) worked with graduate student mentors to conduct solar energy engineering research in a lab. This study focuses on a public engagement project, which ran parallel to the lab research, in which REUs designed games about solar energy through a facilitated process. They then shared their games at two arts festivals open to the public, where members of the public played the games and then the REUs discussed with them their player experience during a player reflection. The facilitator who guided REUs through this process is the author of this study, meaning he has a role as teacher to the students and researcher. This limited

¹ All organizations, such as the Solar Energy Center (SEC), individuals, and proper places will be referred to by pseudonyms given to them for anonymity.

the author in how and when he could collect data, influencing this study's data sources. Over the 9-week program, audio recordings were collected during game design meetings, consultations, and player reflections. This data was analyzed using the discourse analytic method of cohesion in which the cohesive features of the language (reference, substitution/ellipsis, conjunctions, and lexical cohesion) were used to interpret what roles and social identities participants (REUs and players) enacted during the encounters in order to address Research Questions 1 and 2. Moreover, these enactments imply relationality between participants as they assume corresponding roles and identities.

Chapter 4, Findings, presents the study's findings in two parts, the first covering data generated at the public engagement event and the second covering data generated during the game design process. The reason for presenting findings from the public engagement event first, even though sequentially it happened later in the project, is that the event was the culminating phase for the project. What enactments learners and members of the public attempted and how they related to one another in a real setting was illustrative of the ways that the project was, or was not, an opportunity for learners to do public engagement with science. The first key finding from part one is that the science game designer social identity and science educator role were the most commonly enacted roles by REUs during the public engagement event. Moreover, players enacted the playtester role when REU's acted as science game designers and the learner role when the REU assumed the science educator role successfully. One REU enacted a sociotechnical role in which she sought to establish the player's relationship to science and/or solar energy. She also enacted the interviewer role (limited). These roles have been singled out because it leaves the player's role and social identity open to how the

latter relates to science and/or solar, meaning they can speak as a person curious about solar energy, critical of the solar energy field, a consumer, a professional, or a member of the local Arizona community. Another finding is that the questions that REUs used to conduct the player reflections were how REUs first asserted a role or positioned themselves in the above enactments (see Table 4.1). In addition, cohesive chains, which are a type of cohesion, often occurred concurrently with these questions and enactments mentioned above, further illustrating how language functioned in the encounters.

Part two of the findings focuses on data generated during the game design process and follows two focal participants who were chosen in large part based on findings from part one. The first focal participant, Howie, enacted roles typical of most REUs during the player reflections. Moreover, he was a gamer who both identified with the project and took part in the design process fully, making him an exemplar participant. The second focal participant, Vic, was chosen because she enacted the science educator role in a way different from the other REUs and she enacted the sociotechnical role, a role which few other REUs enacted. Moreover, Vic was not a gamer and haphazardly completed the design process, making her a counterpoint to Howie's enactments both in the design process and the public engagement event. Analysis followed Vic and Howie through the 1) introduction to the project, 2) brainstorming, 3) prototyping, 4) Young Scholar critique, 5) consultation with Howie, 6) consultation with Vic, 7) playtest, 8) playthrough, 9) (covered in part one), and 10) group reflection.

Findings for part two indicate the facilitator positioned the REUs as scientists first and then progressed from positioning them as scientists who do public engagement to the more specific role of science game designer. While the two focal participants accepted

this positioning, two REUs rejected this role. Towards the end of the project, the facilitator positioned Vic, Howie, and the REU's as scientists doing public engagement face to face using their game. Both focal participants accepted these positionings, enacting them as the progression occurs, except in the case of enacting public engagement face to face, which they enacted later than when first positioned. In short, Vic identified herself as a rapper and involved with music and having experience engaging the public with science. She enacted the science game design role through this association with music through a rap battle concept for a game. After discarding her game concept, she enacted the science game design role by designing a new concept and prototype based on science concepts. However, she merged her game with another group's game. To participate in the public engagement event, the facilitator guided her through an impromptu modification of a different REU's game. At the event she enacted a science educator role and sociotechnical role primarily. Upon reflection, she considered the public engagement event as an opportunity for her to take on the sociotechnical role and establish a positive relationship between players and science who have had bad experiences with science in the past. Moreover, she did not enact the science game designer social identity during the public engagement event and dropped it by the end of the project.

During the facilitated design process, Howie made a bid to be taken as a person experienced with being an expert engaging the public in science. Moreover, he associated with the game design project as a gamer and enacted the science game designer social identity by way of thinking as a designer brainstorming game mechanics, expressing a design aesthetic, troubleshooting, and doing an iterative design process with his game.

His game's overall goal is to educate players on solar energy, which is a part of his design aesthetic. Moreover, for him, the public engagement event fed into his design process, giving him feedback to work with to improve his design. Based on this analysis, for the most part the roles and social identities that the focal participants enacted during the design process (Research question 1) were also available during the public engagement event (Research question 2). Moreover, the public engagement event also provided many more additional roles and social identities for the REUs to enact that were not available during the design process (see Chapter 4).

Chapter 5, Discussion, begins with an overview of the findings and then compares those of the focal participants to the other REUs. Then it considers how the study's findings speak to the science communication education literature as well as the implications they have for training the next generation of scientists. Recommendations for improvements for similar REU programs with public engagement projects are made.

CHAPTER 2

REVIEW OF LITERATURE

This chapter examines criticisms of how scientists have communicated with the public historically and how such criticisms have led to the development of science communication models and subsequent research into what roles, relationships, and identities are possible for science, technology, engineering, and math (STEM) undergraduates learning public engagement with science. First the criticism and the development of the dissemination and dialogue models of science communication are explored to illustrate some of the key ways that STEM undergraduates are expected to do public engagement. Then the current approaches to teaching science communication at the undergraduate level is examined as well as the fundamentals and what this level of student is capable of doing. In addition, the genres of communication (written/ verbal) are also explored at this level. Also, this chapter will introduce non-policy informing dialogue events as an appropriate space to practice public engagement face to face. Then this chapter describes situated learning (Lave & Wenger, 1991, Gee & Green, 1998), the theoretical framework used in this study, as a framework which treats learners doing the public engagement project as taking part in roles and identities associated with the practice of public engagement as it is performed by practitioners in an actual engineering research center. Next, the chapter explains how discourse analysis (Gee, 2014a; 2014c; Gee & Green, 1998) through cohesion (Gee, 2014c; Halliday & Hasan, 1976) is used as an analytical lens to describe learners taking part in the identities, roles, and relationships that make up the practice of public engagement with science.

The Development of Science Communication Models

Scientists sharing their ideas outside of their discipline is a form of communication that puts into contact multiple worlds – one of which works professionally to develop new ideas in a particular field and others that have members of a special group interested in the topic or a more generalized audience encountering the communication through the news, entertainment, or various media. How scientists relate and communicate with their audiences has evolved over hundreds of years based on socio-historical, philosophical, and technical influences.

At present the communication of science to the rest of society is characterized as a process of popularization, in which scientific knowledge moves beyond the walls of academia and the lab and becomes approachable to wider audiences (Lewenstein, 2008). This definition does not include the many ways that non-scientists and scientists can interact or collaborate because, as will be explained below, the relationship between the two worlds is in flux, particularly with theoretical changes in science and opportunities that digital technology present. Moreover, while many intermediaries such as science journalists, public relations specialists, museums, and institutions play an important role in spreading scientific ideas (Lewenstein, 2008, p. 667), this literature review is limited to how scientists themselves engage with their audiences as individuals communicating through modes such as writing and speech and/or somehow involving non-scientists in some aspect of their research. This chapter reviews the traditional approach to science communication, a set of practice conceptualized as the dissemination model, and the dialogue model which grew out of the criticism of the former, as well as intervening models that inform how public engagement is conceptualized.

Generally speaking, there are four models to describe how scientists communicate with those outside of their field – *dissemination (deficit)*, *contextual*, *dialogue*, and *participation* (Bucchi & Trent, 2014). The dissemination model was originally coined “deficit” because it emerged out of some scientists critiquing the ways that the scientific community had characterized the rest of society as not only lacking scientific information, but incapable of producing its own knowledge equal to that of science (Wynn, 1991). This approach to communication was a one-directional flow of information from its source (science) to its audience (society), which was a placeless, faceless container of facts. In response Wynn and other critics took an approach, which was later labeled the *contextual model*, in which it valued the local audience who would be receiving and using the knowledge the scientists were sharing (Bucchi & Trench, 2014). Similarly, the *dialogue model* was born out of the call by politicians and the media for scientists to engage in two-way communication with the citizenry (Trench, 2008b). While it was considered a step in the right direction, many scholars of science communication felt that dialogue and engagement were only buzzwords and that real reform in how scientists communicated with society required genuine participation. In their eyes, non-scientists should be treated as co-equals with scientists and approaching science on more neutral terms in which both sides could engage in multi-directional, mutually beneficial interactions. As a result, the *participatory model* to science communication is considered the ideal form of interaction, however, scholars note that any interaction can be interpreted as reflecting more than one model of science communication at the same time (Miller, 2001).

Popularization – Dissemination/Deficit Model

Of course, not all popularizations of science take a condescending tone or position science as the end all voice when it comes to explanations of the universe. Richard Dawkins and Steven Hawking, for example, share their fascination with complex theories that they try to explain in such a way that non-scientists can enjoy and learn from them. However, some of the earliest examples of popularization contain elements of paternalism and “hegemony” between the scientific community and society (Cooter & Pumfrey, 1994, p. 240) that only intensified in the 20th century. For example, discoveries in the natural sciences were shared with non-experts as far back as the 17th century when Fontenelle popularized Cartesian thinking and scientific concepts among the nobility and bourgeoisie to educate them (Bucchi & Trench, 2014, p. 15). This approach assumed that non-scientists were susceptible to misinformation or irrationality and continues to this day as scholars and science journalists judge the success of science communication by how well their message has penetrated the public’s awareness. In this approach, surveys and questionnaires are used, much like an exam, to test if the audience learned the information or not. Cooter and Pumfrey (1994) argue that scientists and historians of science enjoyed a "hegemony" in terms of positioning themselves as specialists with the "belief that the productions of scientific knowledge were insulated from non-scientists and from the public at large," and that they placed themselves in a higher position and so resulted in a lack of "any study of the interactions between elite science and popular culture" (p. 239-240). As such, scientific knowledge was “boxed away from society, its production epistemologically privileged, its audience conceived as entirely yielding to new forms of natural knowledge." leading to the perception of lay audiences as “passive” receivers of what scientists could explain (p. 240).

It should come as no surprise, according to Cassidy (2014) then that some scientists still consider popularization as “dumbing down” their ideas and choose not to engage with the public for fear of losing the unequal relationship their discipline has within society. If scientists, and researchers in general, carry this attitude forward, they preclude any meaningful input or interactions with those outside of their field, believing that knowledge can only truly be discovered in the laboratory or by themselves.

To make the situation worse, science journalists and other mediators, have inserted themselves between scientists and the public. Science journalists “invented and reinforced the gap that they pretended to bridge... deliberately [disseminating] an image of science that reinforced the scientific authority of the experts,” in order to “self-legitimize” their role (Bensaude-Vincent, 2001, p. 100). In this view intermediaries claim to be translators of science and performing an important function in society, which could be argued that they do in many ways, such as writing articles about recent scientific discoveries. However, by leaving the work of communication to intermediaries who have turned it into a profession, researchers may come to the conclusion that they have no business trying to share their work on their own; they do not have the training to do so, they might reason. Moreover, Dorman notes that scientists and scholars of science communication tend to believe that the primary purpose of communication is to transfer as much information as efficiently as possible to their audiences (1990). This approach to educating audiences is problematic for many reasons. In terms of genres available for researchers to use, it diminishes the value that creative writing, such as speculative fiction, and other forms artistic expression, can have in the sharing of scientific ideas because their emphasis is less about disciplinary content (Bell & Turney, 2014). Just as

important, it assumes that learning means reproducing identical conceptual constructs in the minds of the public, a point of view that will be critiqued shortly. As a result of these positivist convictions and socio-historical positioning and attitudes of the scientific community, and accompanying involvement of intermediaries, scientists have only a few select reasons to share their research with those outside of their field and fewer ways to do so.

The Contextual Model of Science Communication

One of the two ways that researchers studying science communication critiqued this traditional approach to popularizing science came as a result of the “social turn” and other theoretical shifts that occurred in sociology and the sciences in the latter half of the 20th century. Interpretivist thinking as well as the development of the sociology of science through the work of Latour and others had a profound influence on how some scientists began to interact with non-scientists in the course of their research. One such researcher, Wynn (1991), made an important contribution through his article, *Knowledges in Context*, in which he made a radical shift from empirical, positivist methods to interpretivist approaches that emphasized context and the local construction of understanding among those interacting with researchers, leading to what would later be called the *contextual model* of science communication. He examined the findings of two research projects in which researchers worked with communities possibly exposed to radiation from the Chernobyl disaster and another dealing with patients and their families at risk of high cholesterol. In the former case, while scientists tried to inform locals about radiation exposure and evaluated what measures they would need to take with their farms and herds, Wynn and colleagues used small-scale interpretivist methods, such as

interviews and linguistic analysis. These methods of analyses differed from the usual large-scale surveys and quantitative methods used to determine if the locals understood the scientific concepts germane to the dissemination/deficit model. Reflecting on the initiative's approach, Wynn explains that science communication and scholarship:

represent in themselves a point of entry to the real-world encounters within which scientific knowledge is reconstructed to make [science] fit real situations in all their rich complexity (or rejected if it cannot). Understanding this general process of contextualization is crucial to understanding the social authority (or lack of authority) of science. The other important departure was that these researcher teams framed "the public understanding of science [as] an interactive process between lay people and technical experts rather than a narrowly didactic or one-way transmission of information" (p. 114).

Wynn (1991) makes many important epistemological and ontological changes in this approach. Science is not being moved or translated from its source to its audience, as in the traditional approach to popularization. Rather, he frames learning as a socially based sense-making activity in which communication involves the reformulation of the ideas by the audience members, who learn based on their own reasons and needs.

Wynn (1991) is also criticizing the scientific community's monopolistic control on where knowledge is generated and who may possess it. People living in farming communities for example have their own knowledge systems about their work which scientists need to be sensitive too because it could impact their own conclusions and recommendations. Moreover, this idea of non-academic knowledge systems may sound foreign to us now, but at various points in history, they were not only recognized, but

encouraged. In Ancient Greece, lay knowledge systems and those produced by philosophers (early scientists) were considered different, but both important (Bensaude-Vincent, 2001). The story of Thales falling into a well because he was looking up at the stars, and a country girl helping him out, represents the value of the practical knowledge of living in the world. Moreover, during the 19th century, non-professional scientists undertook experiments, published articles in non-academic journals, and held conferences in what is known as popular science. Active communities of amateurs worked in parallel to the professional scientists, maintaining mutual respect until shortly after WWI when the scientific community positioned itself as the only source of not just science, but knowledge worth having in the modern world. The same indifference to amateur and lay knowledge systems could also go for non-Western philosophies and non-positivist research. Such an attitude, that has rightly been called hegemonic (Cooter & Pumfrey, 1994; Wynn, 2007), would also limit the direction of communication as well as what roles non-scientists could play in that communication.

The Dialogue Model of Science Communication

By and large the scientific community and intermediaries remained unchanged in their approach to science communication (Dornan, 1990), remaining steadfast in the face of theoretical developments by Foucault, Habermas, and other 20th century thinkers in the decades leading up to the 20th century. In fact, Cooter and Pumfrey (1994) argue that Latour and the constructivist perspective on the process of scientific discovery perhaps reinforced their adherence to positivism and the traditional approach to science popularization. Criticism of the dissemination approach came to a head in the UK in 2000 when the House of Lords issued requirements for greater involvement and dialogue

between the scientific community and citizens (Bucchi & Trench, 2014). Holding to the one-directional flow of information and hegemony of the scientific community grew less and less tenable, with a call for a dialogue approach to communication came (Trench, 2008b). Issues such as genetically modified foods, cancer research, and other issues brought concerned citizens and scientists into a public debate that occurred in various forms of the media. The goal was for non-scientists to influence policy, not just be informed about the scientific concepts. One bright spot of progress occurred at the smaller scale when the European Science Communication Network organized around the purpose of designing and implementing training workshops to teach scientists and early career researchers to communicate with the public and the media better (Miller, Fahy, & ESConet Team, 2009). They included a module in teaching the participants to write press releases to be able to share their latest findings with the media, which we can consider an attempt to make scientists the primary communicator of their own research.

In addition to rejecting old approaches, including the dissemination model, and trying new ways for scientists to communicate their ideas, scholars have also reconceptualized how audiences receive and interact with the scientific information. Cooter and Pumfrey (1994) argue that when the public is in contact with the scientific information, they are engaging in "grafting, appropriation, and transformation" (p. 249), which is akin to how anthropologists describe a weaker culture interacting with a dominant culture. In this view the public has not only agency and choice, but the desire to reproduce that knowledge in other forms. For example, radiation and their effects on the human body have entered into the popular imagination, yielding comic books, movies,

and popular entertainment over many decades. Moreover, the public, they argue is a part of the overall web of social relations that connect the scientist with the audience:

Whether given a weak interpretation ('science *in* culture') or a strong one ('science *as* culture'), studies in this tradition have shown how the shape and success of the sciences have depended on a complete set of social relations linking different scientific communities with various allies, audiences, publics, consumers and reproducers; with powerful elites who bestow legitimacy and material support; and also with 'lower' social groups whose willingness (or resistance) to engage with science is an equally important determinant of scientific culture (p. 240)

So even non-experts play a role in shaping what the scientist is doing. Cooter and Pumfrey go as far as to say that when scientists gain new connections, it will rearrange how science fits in society, indicating that the cultural landscape is far more diverse and relational than a gap or hegemonic relationship would lead us to believe.

Science communication scholars have also recognized that “the public” can be characterized as diverse and fragmented (Bucchi & Trench, 2014; Kahan, Scheufele, & Jamieson, 2017). There is a broad consensus across the field that digital technology and the ways people consume and interact with media has led to a fracturing of audiences. Audiences are far more diverse than previously assumed, not just divided by interests, gender, age, and other demographics, but also by how they organize around important societal issues. Each is a specific context with its own concerns, interests, and makeup that researchers must engage with if they are to get out their message.

Speaking of plural form “publics” to describe the heterogeneity of society, and therefore audiences, brings to mind Dewey’s definition of publics as a group that “consists of all those who are affected by the indirect consequences of transactions to such an extent that it is deemed necessary to have those consequences systematically

cared for” (1927, p. 15-16). In other words, a public is a collection of citizens affected by an issue in common, formed out of necessity and a potential site for change. DiSalvo (2009) explains that for Dewey, the constitution of this kind of group was based on “the ‘facts’ of everyday life” (p. 48) and that his characterization of society is still relevant today as it “links with contemporary world conditions through its pluralistic stance, endorsing a public that is broad, inclusive, and multiple (p. 48). In the same way that Dewey saw citizens gathering around issues of the day and DiSalvo around design projects, publics form within society around scientific issues, making temporary groups tied to a particular issue, such as with the gay community to address HIV AIDS and farmers to stand against genetically modified foods (Irwin & Michael, 2003). When an audience is not treated as a passive receiver of knowledge, they perform remarkably well in tackling difficult concepts and show a great degree of initiative in acquiring new knowledge argues Wynn (1991) in the case of locals grappling with complex scientific ideas, which we can extend to well-motivated publics. In such cases, he recommends that audiences receive supplementary information and greater context to the concepts to make them easier to understand.

Participation Model of Science Communication

After more than a decade of efforts to reform how the scientific community communicated with publics, Trench’s analysis of Burns, O’ Connor, and Stocklmayer’s (2003) review of both dissemination and dialogue communication models concluded that the movement was unsuccessful (2008b). He reasoned that terms like “engagement” and “dialogue” were just buzzwords and they lacked substantive change (Bucci & Trench, 2014). Some scholars in science communication made a concerted effort to devise and

experiment with new models that the scientific community could use to engender participation. One approach of the participatory model is to place the scientist in face-to-face contact with interested people usually in public places that give a “neutral ground” (Riise, 2008). This approach includes science cafes, in which interested members of a community are invited to chats with scientists sometimes at an institution and lectures conducted by the scientist themselves. Another example is “street science” in which an expert gives informal chats in public places like a mall, much like a poster session or mini-lesson to non-experts (Riise, 2008). The term “street science” also refers to a model of participatory science that includes the local community in a co-production of knowledge so that the latter is involved in the scientific process while knowledge is being made rather than at the very end when findings are disseminated (Corburn, 2005). The rationale for such an approach is that Corburn questions whether scientists working on behalf of the greater good or the well-being of society is accurate, especially when there is so little contact between scientists and local communities. This goes especially for disenfranchised communities in regards to environmental and health issues, but it is also worth considering for large scale endeavors such as alternative energy production. Corburn notes that professionals who judge the cost to local communities verse the benefit usually do not involve the local community in gathering data or opinion. However, he points how this approach falls short of its goal:

Lay people often are in a better position than professionals to make judgements over the democratic character of science because they experience how science impacts their everyday lives, from the repetitive mechanical tasks on the factory floor, to navigating inadequate mass-

transit systems, to substandard housing and inferior medical care... [lay people] ought to be considered "local experts" in their own right. (p. 40).

This notion of conceptualizing members of a local community as local experts recalls Wynn's idea of local knowledge, recognizing that there is more than one knowledge system or way for knowledge to be generated and shared. This is particularly relevant for when solutions and technologies are being researched for the benefit of said local community. In general, involving non-scientists to take part in a scientist's research project or enlist scientists in theirs, falls broadly in the arena of an expansive area of research called citizen science (Irwin, 1995). It has reshuffled the traditional arrangements and enabled non-scientists to on a few occasions become part of the scientific community in terms of researching and publishing academic articles. Though this study is focused on the communication aspect of science as opposed to knowledge production, citizen science as Irwin conceptualizes it assumes that locals have developed knowledge, or "contextual knowledge," that is rooted in their lived experience and local culture, which is separate from science (p. 132). What gets overlooked, argues Irwin, is how this knowledge can be considered expertise and that locals are in effect, local experts, in regards to living in their local community in an ecological and social sense. As both Wynn and Corburn have noted, Irwin also points out that science is predominantly privileged in relation to local expertise.

Another example of the participatory communication model is a *consensus conference* which invites selected non-experts to take part in panel discussions and deliberations with experts on potentially controversial developments in science and technology (Einsiedel & Eastlick, 2000). Early examples of this type of event were begun

by the Danish Board of Technology to elicit engagement with the public in emerging technology innovations (Andersen & Jæger, 1999). Who should be invited to take part and represent “laypeople” seems to have two options – “neutral” members of a community who do not have hard opinions about the issues under discussion or individuals with strong opinions who might be called activists or representatives of a public (Horst, 2008). In Horst’s analysis of a multitude of studies examining consensus conferences around the world leads her to see consensus conferences exhibiting both dissemination and dialogue as well as other forms of communication. She remarks that “negotiations between different parties, the identification of scientifically sound and socially robust knowledge [which] seems to be more contextually bound [and socially] robust knowledge... which gains credibility during the process.” (p. 272). Horst also points out that another key element is that during the event, the communication is neither one-way or two-way, but rather multi-directional as non-experts communicate with one another, experts communicate with one another, and the two communicate together as well. Coming back to scientists and writing, a consensus conference can be seen as taking the contextual model a step forward in that non-experts have been invited to take part in developing a text in the form of a statement that gives their collective opinion. However, critics like Jensen (2005) argue that requiring participants to agree on a single opinion defeats the purpose of a participatory conference because it leaves out diverse perceptions.

While participatory forms of science communication offer exciting possibilities in terms of public engagement with science, the current study intends on speaking to all of the models (dissemination, dialogue, and participatory), choosing to not conceptualize the

study as one model or the other. That being said, this study hopes that a public engagement event in which participants share their creative work with members of the public, as will be explained shortly, will be an opportunity for learners to interact with the public in ways that can be considered dialogue in the sense of both sides contributing to the conversation and benefiting from the interaction (Baram-Tsabari & Lewenstein, 2017).

Games, Debriefing, and Public Engagement

The recognition of local knowledge and the need to involve communities affected by an issue or scientific endeavor calls this shift in how science gets done is called “the participatory turn” as Jasanoff points out (p. 235, 2003). This includes involving local communities in decision making in the knowledge production process. In terms of using games for public engagement, Forlano and Halpern (2016) use a participatory approach to the game design process as a format for public engagement. As part of their study, Forlano and Halpern involve labor advocates in a gaming and prototyping workshop to create an opportunity for their reviews to be a part of the design process for thinking about socio-technical solutions that addressed their goals. In their discussion they note that if participants possibly had a more directed prompt in which to design under, then the advocate’s view may have been more concrete in the final product. However, the authors do see participatory design, where the local community is involved at the inception of the creative process, as a potential avenue of forming dialogue and social justice.

Scientists sharing board games and other kinds of analog games can also be used in public engagement events, such as a festival or fair, where there are many advantages to the face to face interaction. As Wilkinson and Weitkamp (2016) point out, researchers

can get immediate reaction and it is more personable and direct than other modes of interaction. Potentially, students would have invaluable feedback to both their game and the player experience as well as how they explain science concepts and get reactions about how this community thinks and feels about solar energy, an avenue of research that the students are at least exploring in terms as potential career directions.

In addition, after a player has played a game, a teacher or facilitator can conduct a *debriefing* whereby the player discusses their experience in order to draw conclusions and learn from it (Lederman, 1992). The debriefing is a methodical process conducted by a facilitator or possibly a teacher which is designed to “review and describe the experiences through which [players] have come to assess the implications of the experiences and the meanings attributed to them (p. 151). Debriefing has been primarily used as a teaching tool in connection with students playing simulations and used in connection with serious games (Crookall, 2010), which are games designed with a purpose other than just to entertain (Michael & Chen, 2005). More recently, within science communication, debriefing has been used to teach students and adults about climate change (Wu & Lee, 2015). Students play a card game, board game, or non-digital game and then the teacher or facilitator leads a debriefing where they take part in a “reflection and discussion” (p. 415) about the game and game experience. Debriefing as a concept in science communication is a useful one for public engagement. However, this study chose to work with the non-policy informing dialogue events, described in the next section, as its conceptualization of scientists sharing a game because of its emphasis on promoting dialogue, rather than disseminating knowledge or educating the public.

Formats for Dialogue Events and Non-policy Informing Dialogue Events

As the literature review above hints, putting into practice the dialogue model, or any approach that attempts public engagement with science, is a tall order to achieve. Scholars and practitioners of science communication use the term *dialogue event* for any kind of public outreach or other kind of event in which scientists speak with members of the public, for example a science café or public lecture at a library (Davies et al., 2009; Lehr, McCallie, Davies, Caron, Gammon, & Duensing 2007). Such events are defined as “adult-focused, face-to-face forums that bring scientific and technical experts, social scientists, and policy-makers into discussions with members of the public about contemporary scientific and socio-scientific issues related to the development and application of science and technology” (Leher et al., 2007, p. 1469). This study will explore the educational value of a dialogue event primarily for the REU conducting the event, though learning is still an important aspect of dialogue events for members of the public. Moreover, this study will refer to a dialogue event as a *public engagement event* in this context, but the latter should be taken as synonymous with the former.

Davies makes a considerable contribution to the research in this regard through her studies on public engagement events, particularly an ethnographic work on a science center that held dialogue events or public engagement events (2008; 2013a; 2013b; Davies, et al., 2009). Davies (2008) researched dialogue events at the Dana Center, a now defunct science center in London, where facilitators and scientists held debates, Q & A sessions, and informational lectures open to the public. These dialogue events used formats that guests could recognize and already know, such as talk shows, news interviews, and lectures. Davies (2008) explains that, in her observations of public

outreach events at the Danah Center, the ways in which the facilitator conducted the events framed the way audiences participated in the event and so shaped the experience for the latter. Facilitators did so most often by asking audiences if they had questions, comments, and points they wanted to make about a topic or what a technical expert had said:

While we could argue that this in itself acts to limit types of valid contributions from audience members - it would seem to disallow, for example, 'stories', 'memories', 'feelings' or anything else that doesn't fall neatly into the narrowly intellectual concepts of specific questions and focused comments - it appears that, in practice, the 'questions' category is the one that is most frequently assumed or imposed. (Davies, 2008, p. 215)

So facilitators play an important role in shaping what is allowable and possible at the events, the way they invite the audience to participate, the types of questions they ask affects what the audience members get to talk about, the experience.

Davies (2008; 2013a) describes this in terms of the roles of the participants (facilitators, scientists, members of the public) that are determined by the genre, or format of the event, but also through how the participants enact these roles. For example, members of the public in Davie's study took on the role of audience member in a passive way in that they only listened to the experts speaking on the stage and did not speak until given permission by the facilitator. They never took the floor, to sort of speak, on their own initiative. On the other hand, the scientists were introduced as speakers, or expert speakers, always had the right to speak, and never needed to ask for permission from the facilitator. Moreover, the focus of the conversation was on science content and

information, which presumably could be an opportunity for audience members to learn and follow up on their curiosities. However, this framing could persist even during events that had a debate format, as Davies (2008) explains:

While some of the surface language of Dana Centre events seems to encourage genuine audience engagement and two-way debate, many participants naturally slip into language that implies that the speakers are indeed merely present as an 'expert resource' and that audience involvement should be limited to asking them questions. (p. 216)

As such, the facilitator and speakers play an important role in defining what dialogue is in the context and the ways that the audience is allowed to relate and interact with science.

Moreover, as Davies (2013a) notes:

While other roles and positions are occasionally presented (a participant speaks as a patient, for example), ultimately, scientific authority is final (Davies, 2009).

Indeed, audience members are frequently complicit in maintaining hierarchies of expert–lay knowledge, reproducing “deficit models” of lay publics in their talk or positioning themselves as deferent to the expertise of the invited speakers. (p. 74)

Based on these conclusions, even a well-meaning public engagement event can present roles to its participants which do not achieve dialogue in the sense of both sides contributing equally to the interaction.

Of the various forms that dialogue events can take place, Davies et al. (2009) make a point of drawing a distinction between those that are tied to influencing public opinions on policy issues and those that are not. In the case of the latter, Davies et al. categorize *non-policy informing dialogue events* as public engagement efforts that are not

designed to “directly influence policy processes,” which in other words, means these events are not attempting to shift public opinion on a particular science-related issue, such as climate change or genetically modified foods (p. 339). Non-policy informing events seek to engage publics in dialogue that is “symmetrical” in the sense that both the scientist and members of the public are informed by the interaction (p. 340). For example, small group discussions at science centers and science cafes where members of the public are invited into institutions for Q&As and lectures are the types of informal conversations between scientists and members of the public that would offer the mutually beneficial dialogue that Trench and Bucchi (2014) call for in public engagement. Such events are not designed to persuade audiences to believe or form an opinion on a particular issue, rather they are meant to facilitate “discussion of contemporary issues in science and technology in a relaxed and informal environment” (Davies et al., 2009, p. 340) and either side can draw their own opinions.

Another key aspect of non-policy informing dialogue events is that they are usually at a small scale, even at level of a single scientist speaking to one person in public, which is markedly different than institutions, with their agenda’s and need for measurable impact, engaging with entire communities and the nation at large. The advantage of small-scale face to face events is that it offers scientists direct and personable interaction (Riise, 2008) whereby scientists can see what those outside of their field think about their research. As Wilkinson and Weitkamp (2016) suspect, a face-to-face format may make it “easier to develop rapport or to empathize with people...and to avoid things being misconstrued as can occasionally be the case when communicating electronically” (p. 58). Moreover, these authors argue that the format can make the

scientist more personable, “less remote and more grounded in reality” and, from the scientist’s perspective, the members of the public as “fellow individuals” (p. 58). The last advantage that they point is that the scientist can react “flexibly” to the other side during an interaction that may be difficult to do in an online format or impossible through traditional media. Davies et al. (2009) note the value of non-policy informing dialogue events is how they can be enlightening in the sense that differing views from the scientist and members of the public can be presented, converge, or at least be acknowledged.

In short, scientists, members of the public, and facilitators who organize the dialogue event take on roles discursively as they participate in the event and these roles are shaped and in a sense, possible, through not only the format of the event, but how the facilitator organizes it. Moreover, non-policy informing dialogue events are of small scale and do not carry the expectation of changing public opinion, but rather work at the individual and small scale between scientists and members of the public. This conceptualization of what a public engagement or outreach event can be is important to the current study as it is the type of setting that was designed for and enacted by students in this study who were learning to enact roles, relationships, and identities associated with public engagement. The next section of this chapter takes up this topic, which is of central importance to the research questions of concern to this study.

Teaching Science Communication to STEM Undergraduates

As noted above, by 2008 scholars in the science communication field and many in the scientific community were aware of the lack of dialogue in public engagement and seeking ways to remedy the situation. However, Miller (2008) concluded that little communication was occurring between those who practiced science communication and

trained scientists on the topic on one side and scholars researching this issue on the other. So likely even if a university programs wanted to implement new curriculum or a researcher wanted to evaluate the effectiveness of a program, it was not clear what exactly the former was supposed to be teaching graduate and undergraduate STEM students. To further complicate the picture, the current practices of scientists left much to be desired in terms of engaging the public as they continued to replicate the dissemination model as noted above. Even more recently, though scholars continue to place attention on the need for scientists to do a better job in engaging the public, institutions provide few opportunities for undergraduates to engage in communication practices with the public, and those that are offered have been characterized as only dissemination models (Brownell, Price, & Steinman, 2013; Baram-Tsabari & Lewenstein, 2017).

This lack of science communication education at the undergraduate level and how scholars have attempted to address the issue is demonstrated well in the work of scholars in Australia. One study indicates that in terms of communication education for STEM undergraduates, over half of the tasks students are asked to perform in the curriculum are for presenting scientific results and writing lab reports, almost none of which is created for non-academic audiences (Stevens, 2013). Mercer-mapstone and Kuchel (2015) cite this as one strong indication of a lack of training for science communication taking place in Australia's research institutions. Mercer-mapstone and Kuchel note that research suggests some of the likely reasons for why science communication training is not taking place is because it is left to professors who may not have time to do public engagement themselves or may lack experience with it. Moreover, with pressure to do research and

publish, they argue, science communication is a neglected aspect of a young scientist's training. To address this issue, Mercer-mapstone and Kuchel (2017) extrapolated key skills or fundamentals that undergraduate science students need to learn based on existing literature and then conducted surveys of current practitioners of science communication, such as scientists in various fields and scholars in science communication, for their feedback. Their review of the literature indicates that practitioners predominantly characterize science communication in terms of informing non-experts in such a way that both sides come to an understanding or as van der Sanden & Meijman (2008, p. 90) call it, an “exchange (negotiation) of knowledge between scientists and the lay public in order to achieve a reciprocal understanding.” Mercer-mapstone and Kuchel's study concludes that practitioners maintain that these are the top four fundamental skills for science communication:

- 1) Identify and understand a suitable target audience
- 2) Use language that is appropriate for your target audience
- 3) Identify the purpose and intended outcome of the communication
- 4) Consider the levels of prior knowledge in the target audience

One of Mercer-mapstone and Kuchel's (2017) findings that is relevant to the current study is how highly practitioners ranked the ability to “Use language that is appropriate for your target audience” (p. 194). The idea of “appropriate” relates to using language that is understandable to those outside of the discipline and fits the situation and also relates to recontextualizing disciplinary knowledge. What is also relevant to this study is the low ranking by the practitioners of promoting public engagement with science and dialogue, ranked 10th and 12th out of twelve, respectively. The authors

suspect that the wording of the survey may have made the promoting public engagement with science option sound like disseminating knowledge because of the way it is phrased. However, they also suspect dialogue might be ranked low because it is difficult to teach students to generate a two-way form of communication, that undergraduates may not need to be able to communicate in that way with the public because “during their undergraduate education they are still developing their own views of science” (p. 194), and so it is a skill deemed by practitioners as more appropriate for postgraduate students. As a result, Mercer-mapstone and Kuchel maintain:

it may be that dialogue is more appropriately embedded in a postgraduate science education, advanced undergraduate courses or activities, or in programmes aimed at educating professional communicators—the graduates of which are more likely to engage in true dialogue approaches and need to consider differing values and views of science. Engaging audiences in a dialogue about the nature or process of science is a specialist skill to teach and learn which may be better placed beyond the undergraduate curriculum. (p. 194)

In short, the authors conclude that communicating with the public in such a way that a back and forth of ideas and information occurs between the student and member of public is not recommended for all STEM undergraduates. Their reasoning is that “true dialogue” is difficult to achieve and would requires students to consider their views on the role of scientists and what they value in regards to the relationship between the scientific community and those outside of academia. However, knowledge transfer and more attuned approaches to disseminating knowledge in which the context is given careful consideration are considered realistic goals for undergraduates. That being said, Mercer-

mapstone and Kuchel note that dialogue could be a learning outcome for “advanced undergraduate courses or activities” (p. 194).

These authors are not alone in classifying dialogue or public engagement as either advanced or too difficult for undergraduates. Baram-Tsabari and Lewenstein (2013) developed learning goals for both undergraduate and graduate students learning about how to do science communication through writing. They conclude similarly with Mercer-mapstone and Kuchel (2017) that dialogue is an advanced practice and describe it as being able to, “Acknowledge and show respect to multiple worldviews” (p. 60). Moreover, while implementing a science communication course that applies Baram-Tsabari and Lewenstein’s learning goals, Sharpe & Blanchfield (2014) intentionally left dialogue out of their rubric. They state that “the category of ‘dialogue’ was judged not relevant to this level of student, but is more suited to the advanced science practitioners” (p. 37). As a result of these decisions in research and curriculum, there is a paucity of research on undergraduates learning public engagement or dialogue. Hence, the focus of research continues to be on teaching undergraduates practices involved with transferring knowledge and shaping a message to be suitable for an audience and its context.

One noteworthy example of scholars sharing their experiences teaching public engagement to undergraduates is Goldina and Weeks (2014) course for fourth year science students called Science Café in which students organize and implement public outreach events. The educational goal is for students to “use their science background, ability to interpret scientific literature, and communication skills learned in the preceding years to communicate scientifically complex concepts in an engaging, easy to understand manner to non-scientists” (p. 14). During class sessions, students practice talking about

developments in research and science concepts without jargon, e.g. recontextualizing, and do the same by writing news articles for the general public. They also conduct surveys to determine what topics the public would like to discuss and then organize outreach events for audiences ranging in age from elementary school children to adults. Goldina and Weeks describe the events as opportunities for undergraduates to engage in dialogue:

During these events, students have the opportunity to contribute to increasing public interest in and understanding of science, to stimulate dialogue between scientists and the public, inform the general public about scientific topics, while countering common myths, distortions and misinformation associated with a wide range of scientific topics (p. 15).

While these events sound promising for undergraduates to take part in authentic experiences doing dialogue, these descriptions are based on author observations experienced as teachers, but not examined through research. Also, note that only fourth year students who have developed a background in science and already learned to speak as a scientist and work with the complex concepts of the discipline are then allowed to take this course. In this way, these educators of science communication follow the trend of reserving dialogue for advanced undergraduates.

Another trend in undergraduate science communication is that most programs focus on teaching students to use forms of media typical of journalists (Brownell, Price, & Steinman, 2013). Sharpe and Blanchfield (2014) are an example of this approach as their students create journalistic videos and news reports. A second example is Australian National University's science communication curriculum which has the largest such program in the country (McKinnon, Orthia, Grant, & Lamberts, 2014). There students

write blogs, opinion pieces, and translate a science journal article into a piece for the general public. Moreover, students participate in a conference where they present their research for public audiences.

In summary, dialogue continues to be an elusive construct to put into practice in public engagement. At the same time how undergraduate STEM students can learn it is an under-researched element of science communication scholarship for the reasons outlined above. As a result, a study such as this is exploratory in its asking undergraduate STEM students to engage in a practice little understood, though is expected of them as future scientists.

Before moving on to the learning theory section of this literature review, this study will highlight the learning goals that Baram-Tsabari and Lewenstein (2017) developed as they are at the time of this writing the most comprehensive in scope and take a sociocultural approach to learning, which aligns with the current study's theoretical approach to education. Baram-Tsabari and Lewenstein propose six strands (affective, content knowledge, methods, reflection, participation, and identity) as learning objectives which are not specifically designed for one level of student, but should be adapted to the context as appropriate. The first strand is *affective* in which the authors suggest learners to adopt a positive attitude towards the practices and goals that make up science communication. Learners also need *content knowledge* of the models of science communication, its history, and other concepts associated with it. *Methods* includes using various modes of communication, such as verbal, written, and visual to “for fostering fruitful dialogues with diverse audiences” (p. 291). This is an important aspect of this strand and relevant to the current study in that it treats dialogue as a goal of creating and

sharing artifacts, not just one directional flows of information or replicating journalistic uses of media. Moreover, the methods strand includes the student learning how to conduct face to face communication with audiences, particularly a subsection on conducting public engagement events:

- Use informal science education and public participation venues (such as science museums, science festivals, science cafes, public meetings, consensus conferences)
- Knows how to manage and facilitate public discussions
- Engages with the public through hands-on activities
- Develops communication strategies and artifacts that support inquiry and active learning (p. 292).

This particular subsection of the methods strand illustrates what a scientist competent in the practices of science communication can do. It includes using public engagement events, which presumably includes non-policy informing events, where the scientist can be in a two directional flow of information with the public, taking part in a conversation equally (Davies et al., 2009; Baram-Tsabari & Lewenstein, 2013; 2017). In addition, the last bullet points out the creation of techniques as well as tools or artifacts that a scientist can use to help the public learn. These two aspects make up an important part of public engagement practices that will be explored in the current study.

Next, the *reflection* strand is where learners consider science communication and their role in the process. In addition, the last two strands, *participation* and *identity*, are also key aspects to the sociocultural roots of these learning goals. Participation refers to learners taking part in science communication activities and using various mediums to

craft a message for non-experts in an authentic way that also promotes dialogue. Lastly, the identity strand advocates for learners to consider themselves as persons who do and are capable of science communication.

These six strands and their attention to directing STEM students to foster dialogue in genuine settings give useful goal posts any science communication learning experience for undergraduates. Moreover, Baram-Tsibbarai and Lewenstein's sociocultural approach places attention on learners taking part in science communication practices in authentic settings. This aligns well with situated learning, which is this study's guiding educational framework.

Situated Learning

Situated learning is the guiding framework for this study, first coined by Lave and Wenger's book by the same name (1991) in which they argue that learning is a matter of taking part in practices of a discipline or profession in ever greater ways until they become experts in the practices themselves. In their example, an apprentice tailor learns the craft of tailoring by being in a shop, trying their hand at simple jobs of a tailor, and work their way up to completing more complex garments and doing what the expert does until they are experts and possibly open their own shop. This organization in which the learner enters is a *community of practice* where a key aspect is that learners work under the guidance of the expert. Learning is demonstrated by changes in the execution of those practices until they are as capable as the expert which can be visualized as *legitimate peripheral participation* in that a beginner takes part in the discipline at its edges and gradually progresses to a fuller or central participation. Another way to describe participation is for the learner to be recognized by the organization or discipline as a

member, and the learner demonstrates the values, priorities, and ability to be productive as that type of person, utilizing the resources available to that discipline (Wenger, 2010). Gee would also add that among those resources is readying the learner “for future learning and problem solving” in the world (2003, p.24) as a foundational goal of education in general. In effect, situated learning requires an authentic learning environment in terms of giving a learner opportunities to become the profession and do or type of person does.

Situated learning builds from Vygotsky’s (1980) conceptualization of education which is that learning is a social endeavor mediated by intellectual tools, such as language, allowing for an interaction between the social and the individual’s mind to take place. He argues that the social-individual interaction facilitates psychological development occurs. Moreover, language is both a cultural and psychological tool in that it “forges,” as Mercer and Howe (2012, p. 13) state, these new properties in the mind. Another way of conceptualizing change in the learner is how Moje and Lewis (2007) characterize participation as being an embodied experience that involves all of a person’s senses, not just mental, and leaves a mark, or a history. They elaborate on Roger’s notion of a person having "histories of participation" (2002) by explaining:

people bring their histories of participation to bear on each new act or moment of participation. Thus, learning can be conceived of as always being situated in participation, but not necessarily synonymous with or reduced to participation. Learning goes beyond the moment of participation to constitute a history and to shape a future act of participating (p. 16).

What is compelling about this framing of learning as participation is that it acknowledges that learners change and carry forward those changes in their journey towards becoming a particular kind of person, such as a scientist. Undergraduates learning public engagement, for example, can build on initial participations in the practice, starting a foundation that continues into graduate school and their overall career trajectory.

No doubt there are changes in the individual learner in terms of mental processes and memory. However, Erickson notes that “if social interaction is seen as crucial for learning [as is maintained by Vygotsky and socioculturalism], we must not leave unexamined the notion of social interaction itself” (2008, p. 30). Borrowing from Gumperz’s (1982) notion of reflexivity, Erickson points to how in verbal interactions speakers construct a social situation in terms of what is happening, who is speaking, and how they act through words, even while the context shapes what the speakers are saying. So in an educational setting the learner is in dialogue with, internalizes and responds to the context which they are also responsible for shaping discursively (Hicks, 2008). Hicks argues that the learner is not absorbing a representation of an objective reality and then reproducing it through language. Rather, the learner is co-constructing a context with other participants, one that is a reproduction but still created nonetheless. In a situated learning sense, this means as a learner is participating in practices of a discipline, they use language in ways that reproduce the social situation, perhaps only partially at first, in ways that can be recognized as belonging to the social group or community.

As the next section will elaborate upon, participating in a practice is done through enacting social identities by way of discourse, or language in use, by that social identity

in interaction with others in the situation. Moreover, the reflexive relationship between language and context will also be explained below.

Social Identities and Roles

A key aspect of situated learning is the notion of the learner becoming or transforming into a more capable person and expert of the discipline (Lave & Wenger, 1991). In fact Lave and Wenger argue that authentic learning amounts to a shift in identity. This study uses Gee's definition of identity as "different ways of being in the world at different times and places for different purposes" (2014a, p. 228). He makes the point of calling these "different ways of being" as *social identities* to distinguish them from a *core identity* that is relatively stable and fixed or a psychological construct of the self. These social identities are historically formed and embodied in cultural practices. They are associated with social groups that have knowledge systems, their own way of speaking (specialized language), and a host of values and norms that make up and define what can be called a Discourse. The upper case "D" is to distinguish it from little "d" discourse which is used to refer to only language in use and not the social group and its associated aspects. So social identities are made possible and situated within a context which learners are responsible for reproducing as they participate in them.

Moreover, as Gee notes, social identities are "ways of being a 'good student,' [or] an 'avid bird watcher,'" (p. 228) the adjectives implying that there are more than one type of the same social identity and that there are likely desirable versions of them. In regards to science communication education, learners should have the chance to act as a scientist who is an expert in their field as well as participate in activities in ways that encourage the public to take part in a two-way conversation. In other words, the kind of scientist that

this study hopes to support is one that supports dialogue with the public, rather than simply disseminating knowledge.

Also, an important aspect of social identities is that they must be accomplished (Gee, 2014a). Organizing one's language, dress, actions, body language, and other tools into a performance that convinces others in the interaction to accept them as that kind of person is how one accomplishes or achieves the social identity. A speaker can position themselves or the listener in the sense of designing their language so that the listener thinks, feels, or believes something as well. Gee states:

This means that the speaker/writer seeks to invite or hail the listener/reader to assume a particular identity, to be a particular type of recipient that the speaker/writer wants," and so invite them to act in a particular way as well (p. 21).

Of course, the person being positioned can accept, reject, or otherwise negotiate this social identity. This further contributes to the notion that social identity is performed and negotiated in a context. A person cannot do a social identity on their own. Moreover, a situation in a specific time and place presents opportunities to enact social identities (Goffman, 1961; Erickson, 2004). As Erickson (2004) points out, speakers enact social identities that are obvious and pertain to the situation at hand and they can enact more than one identity in a single stretch of conversation, as in one moment a person can speak as a "businessman" and the next as a "father" (p. 148; See also Goffman, 1961). That being said, speakers attempt to accomplish these goals and make bids to be accepted as belonging to an identity, but it is not a given (Erickson, 2004; Erickson & Shultz, 1982).

So far, social identities have been described as ways of thinking, doing, and being within a context (Gee, 2014a). A related construct that is similar to social identities are

roles. Roles are a temporary way of being and can be defined by rights and responsibilities (Bloome & Katz, 1997) in that there are expectations for how a person performing a particular role is to behave in the situation. Like social identities, roles need to be enacted, negotiated, and available in the situation, but are different in the sense they do not require or imply belonging to a social group or community. For example, a doctor presumably is a part of the medical profession, went to medical school, introduces herself as a doctor, and does other actions that are expected of a doctor. But a mother who checks her daughter for a fever, gives her medicine, and tells her to get some rest is not being a doctor *per se*. In the latter case, she is performing the role of caretaker or simply helping her daughter, a role that is normal and one of the ways a mother performs her social identity as a mother.

The distinction between social identities and roles needs clarification as this study wishes to speak to the science communication literature. For example, Davies notes that members of the public who attend a public engagement event act as audience members (2008; 2013a). On the other hand, Gulich notes that medical professionals use language in particular ways to not just transfer knowledge, but to enact the role of the expert when speaking to non-experts. This study conceptualizes the situation as the medical professional as a social identity and being an expert also as a social identity as it is a recognizable way of being and acting in the world. However, the patient speaking with the doctor can be considered a role as it is not tie that person to belonging to a social group. However, if the patient is a cancer survivor, for example, then perhaps they identify with that social identity and it is how they position themselves in the world in a social sense.

A final crucial aspect of social identities and roles is that of how those enacting them relate to one another in the situation. For example, in a classroom, a teacher has his ways of thinking, doing, and acting as that social identity and the students of the class have theirs, and so between them is a relationship that is based on what they are mutually attempting to accomplish. The teacher acts to impart knowledge and has the authority to discipline students if they do not do so or disrupt that learning process. It is the students' responsibility to learn what is being taught. Of course, this is an over-simplification and it can be said that each has additional goals they are attempting to accomplish, such as the teacher getting a paycheck or finding personal fulfillment in meaningful work. However, the point is that they form a teacher-student relationship during a class that is unequal in terms of authority and ability to determine what happens in the classroom. Moreover, the student is not expected to contribute to the class in such a way that the teacher's worldview shifts or suddenly discovers a new passion or potential career. Perhaps it should, but they enact a relationship through their interactions that suggest it unlikely.

In terms of public engagement with science, a scientist might be enacting the social identity of a scientist and taking on the role of an expert speaker at a forum. In this case, what does that make members of the public who attend the event? Moreover, is non-expert or lay person a social identity or a role? Because neither is associated with a social group or discipline or recognized way of being (Gee, 2014a) then the answer is neither and/or cannot be determined without data. What social identities and roles the public enact can only be answered by analyzing the social interactions and context. What are the participants of the public engagement event attempting to accomplish and what might that suggest in terms of enacting roles/ social identities? Answering such a

question would also clarify the relationship between the scientist and the members of the public.

To assume that members of the public who attend a public engagement event automatically assume *any* role or social identity is part of the problem of science communication research in that it does not recognize that such social relations must be enacted, performed in order to happen (Goffman, 1961; Erickson & Shultz, 1982; Gee, 2014a). Perhaps because members of the public who attend public engagement events often *only* enact the role of audience members (Davies, 2008; 2013a) and no social identity of their own is part of the problem with the format of the public engagement event.

In order to determine what social identities and roles and their attenuating relationships the public as well as undergraduates learning science communication enact, their interactions must be examined through a methodological approach that interprets how language functions in the interaction. For this reason, the next section explores how discourse analysis can interpret language in use to interpret the enactment of social identities, roles, and relationships.

Discourse Analysis and Social Identities and Roles

Approaching undergraduate science communication education from a situated learning perspective entails certain epistemological convictions. It requires the interpretation of modes of communication, particularly language, in order to come to conclusions as to what social identities, roles, and relationships are being enacted in a given situation. This section covers how discourse analysis, specifically Gee's (2014a)

version of critical discourse analysis, is an appropriate approach to address such a line of inquiry.

In general, discourse analysis is a sociolinguistic methodological approach to interpreting discourse, or language in use, to make claims about interaction as a meaning making process as well as one in which speakers attempt to accomplish a myriad of goals through language (Johnstone, 2008). Also, discourse analysis is a set of techniques and approaches that focus on “close and systematic attention to particular situations and particular utterances” (p. xiv), depending on the problems or constructs under investigation. So discourse analysis is not interested in language as simply an abstract set of rules, but how people use it in actual places and times. Potter notes that other key assumptions of this method is that it does not attempt to interpret an objective reality, but what worlds and meanings the speakers discursively create together through natural talk (1997). Moreover, discourse analysis shares the assumption that what a person says has a reflexive relationship to the context in that the former builds the latter even while the latter influences the former, as noted above (Gumperz, 1992). In addition, Johnstone notes that one way of approaching discourse analysis is for the analyst to asks themselves a series of questions such as “who the participants in the situation are and how their roles are defined [because this] clearly influences what gets said and how” (p. 9). This study considers the reverse of that question in that analyzing what is stated and how it is stated in a conversation can allow an analyst to interpret who is speaking, in social identity terms, and what roles they are performing.

Overall, discourse analysis can be divided into descriptive and critical discourse analysis (Johnstone, 2008). Pure descriptive discourse analysis is the attempt to describe

discourse in terms of generalizations that could possibly be applied more narrowly to specific contexts, but hopes to explain the nature of language use as broadly as possible. On the other hand, critical discourse analysis seeks to address problems, shed light on inequality and injustice, and improve a situation somehow that is affecting parts of society (Rogers, x-xi). Both are heavily influenced by Halliday's development of *systemic-functional grammar* which assumes that language is a system of meaning making resources that offer choices to speakers in terms of what they want to convey (Halliday, Matthiessen, & Matthiessen, 2014). This is what undergirds many of the previously stated assumptions that speakers can assume different social identities and roles, as well as position others, by using some words instead of others. As Gee (2014a) would say, speakers design their language, whether consciously or unconsciously, to accomplish goals discursively as well as enact social identities.

Another important assumption about sociolinguistic analysis that this study takes is provided by Goffman who points out (1981), during a conversation, a speaker responds to what came before, and refers to what is just said by the other or to an earlier point in the conversation. He states, "And what conversation becomes then is a sustained strip or tract of referencings, each referencing tending to bear, but often deviously, some retrospectively perceivable connection to the immediately prior one" (p. 71). Moreover, a speaker's utterances have immediate importance as speakers indicate through their words "something he wants assessed, appreciated, understood, *now* (p. 72). So even as a conversation progresses forward in time, it points back to what has been said, giving conversation elasticity, pulling and stretching between ideas, directives, questions, etc. Moreover, the speakers are not bound to respond in a deterministic way. They have

“choice” as Goffman maintains, even as their conversation coheres (p. 73). In turn, this freedom extends to how a person enacts a role or identity and what version, to sort of speak, they will enact. Also, speakers enact roles that are relevant and available in the situation as well as address concerns at hand in the moment as well as those that are distant physically and temporally (Erickson, 2004). These arguments about reference and cohesion are operationalized in this study by applying Halliday and Hasan’s (1976) approach to cohesion, which will be described in Methods.

This study chooses to follow the critical discourse analysis tradition because it attempts to explore ways to improve STEM undergraduate science communication in order to address the lack of dialogue between scientists and the public. There are many approaches to critical discourse analysis, however, Gee’s approach to discourse analysis has been chosen because it forefronts the use of language to enact social identities and its relation to context in terms of the immediate situation of the conversation as well as sociological implications (2014a). According to Gee, language is used to accomplish the task of identity as well as six more tasks that make up reality or how the participants in a conversation experience a social situation (2014a; 2014c). These tasks are significance, practices (activities), identity (social identities and roles), relationship, politics, connections, and sign systems and knowledge. While this study focuses primarily on how language is used to enact identities and roles and form relationships in the process, the seven tasks are interrelated and are worth mentioning. This is because, for example, a speaker positioning themselves as a local person may make connections to the local environment discursively, base arguments on local knowledge systems, and place

important on any or all of these things in addition to using the identity tasks. The speaker's perspective constitutes and is constituted by numerous tasks.

In terms of *significance*, speakers in a conversation indicate that something or person is important or not so. A *practice* is the routine ways of doing or being that are enacted through specific actions or activities over time. Gee (2014a) states that, a practice is a "socially recognized and institutionally or culturally supported endeavor that usually involves sequencing or combining actions in certain specified ways" (p. 32). So a discursive action can be accomplished through a single utterance or talk turn and it can perform one aspect of a practice that is enacted over the course of several episodes or instances.

In terms of the building task of *identity*, speakers identify themselves directly or speak in ways to be taken as a kind of person or is performing a particular role. Gee (2014a) frames such an analytical question as asking, "What identity or identities is this piece of language being used to enact (i.e., get others to recognize as operative)? [and] What identity or identities is this piece of language attributing to others, and how does this help the speaker or writer enact his or own identity?" (p. 33). Moreover, socially recognized types of people, or identities, have their own specialized grammars with particular vocabulary, ways of thinking, syntax, which is called a *social language*, not to mention tools and behaviors associated with them. The building task of *relationship* is where speakers signal to others how they want to relate, which can also include between identities and roles. *Politics* is the identification of social goods and what is considered desirable to have or be in the situation based on cultural values and norms. *Connections* is determining what is relevant or not relevant to the situation. Finally, *sign systems and*

knowledge can be languages, social languages of disciplines and social groups, and visual communication such as equations, graphics, etc. This includes forms of knowledge and beliefs. In sum, speakers in a conversation experience reality through these seven building tasks. Which tools this study employs to interpret identity, and the other building tasks when relevant, will be explained in Methods.

Sociolinguistic Analysis in Science Communication

As this literature review has indicated, Sarah Davies (2008, 2013a) and Elizabeth Gülich (2003) have made notable contributions to the field of science communication in terms of describing how language is used by scientists and other experts interacting with the public. Generally speaking, both use sociolinguistics. Davies uses Hymes' ethnography of communication (2008) as well as critical discourse analysis (2013a) while Gülich (2003) uses conversation analysis. Their respective findings will be further considered in light of how discourse can be used to enact social identities, roles, and relationships.

Davies uses critical discourse analysis when interpreting the discourse from the perspective of power (Van Dijk, 1993) as it applies to scientists exerting control over members of the public during public engagement events, and how this manifests through conversation as well as spatial positioning and silences. Her work in non-policy informing dialogue events (2008; 2013a) concludes that during a face to face public engagement event, participants use language to position themselves and others in particular roles. For example, the facilitator introduces the scientist as an expert speaker in a panel to the audience. The audience not speaking until given permission by the facilitator also contributes to defining the role of audience as a passive participant. And

often the discussion turns to the scientist as expert espousing scientific knowledge in spite of the event's format that is supposed to foster dialogue, the two-way exchange of ideas.

Another important study related to role taking is Gülich's (2003) examination into the discursive moves medical experts make to explain medical information to patients and others in a face to face setting, a process she calls *reformulation*. Reformulation, a concept developed by Gülich and Kotschi, (1995, 1996), is where ideas are being shifted from one context to another, not unlike recontextualization. In Gülich's (2003) study, reformulation is from the scientific community Discourse to the non-specialized language of the vernacular for the patient to understand. Her argument is that experts use particular verbal techniques to transfer knowledge to the patient and that the role of expert/non-expert are discursively achieved, accomplished, which is an assumption this study agrees with. She borrows from Barton (1996, p. 303) in this regard, in that "Expertise has to be considered as a 'dynamic construct, one that is continually and repeatedly negotiated within the context of a medical encounter.' This is basic to the success of expert/non-expert communication." Her point is well taken that identity and roles are continuously enacted and negotiated. In her analysis, Gülich, uses a broad approach to her sociolinguistic methodology, however, references are a prominent aspect with which she interprets the discourse. She explains the technique of an expert doing the discursive action of reformulation as the doctor making a reference to an earlier statement, such as a medical term and then rephrasing it as a kind of "alternative" expression (2003, p. 237). This can involve paraphrasing the medical term or expression into the vernacular or simply use repetition to bring home the point. Moreover, doctors self-categorize

themselves as belonging to their profession through the use of a first-person pronoun plural “we” as in “we doctors” (p. 254). Moreover, they will categorize others by referring to them as “patients” or “doctors” (p. 254). These verbal techniques are similar to what Gee (2014a) calls the positioning of the self and others as being kinds of people.

In addition to reformulation, Güllich (2003) also outlines illustration as another verbal technique that experts employ to transfer knowledge. She identifies metaphoric language, exemplification, scenarios, and concretization as ways that experts express their disciplinary knowledge to a non-expert. Metaphorical language includes similes, metaphors, and comparisons. Exemplification is the expression of technical concepts into “ordinary everyday experience” (p. 241). Also, scenarios is a term borrowed from Brünner (1987) which is giving a situation or story to express the concept. Lastly, concretization is explaining abstract concepts in actual or non-abstract terms. These types of illustrations are used by experts to transfer knowledge from the expert context to the non-expert’s context for the purpose of informing the latter in terms they can understand.

Davies (2008) and Güllich (2003) use of sociolinguistic analysis to analyze how scientists and kinds of experts take roles and relate to those outside of their field is instructive in how to approach the problem of examining what is happening during face to face public engagement events. With the assumption that an “expert” is not an “expert” until they make talk moves to take that position is a starting point in defining what are learners of science communication supposed to be learning to do. The scholarship so far has focused on the scientist taking the role of expert who transfers knowledge. What discursive moves or verbal techniques do scientists use when engaging the public in dialogue is still unclear.

The current study assumes that in order for a two-way conversation to take place where both sides of the conversation contribute and benefit from the interaction does not rely on transferring knowledge. The scientist likely does not need to be “the expert” or at least the kind of expert whose purpose is to inform the non-expert audiences. What roles and how those roles are taken discursively to foster dialogue still needs to be explored. Moreover, what medium or tools or artifacts these scientists can use to aid in this endeavor are still yet to be identified. Moreover, in terms of teaching undergraduate STEM students to do public engagement, it is still considered challenging and possibly beyond the ability of this level of student to take on these roles and social identities. As a result, as the writing of this study, conducting a public engagement project with undergraduate STEM students to teach them how to foster dialogue is a highly exploratory undertaking. What roles and social identities they and members of the public are able to enact during a public engagement event needs to be described. Discourse analysis is an appropriate method in how it is able to interpret cohesion to describe enactments of roles and social identity. Another under researched aspect of science communication education is students using game design to use as the medium of communication as well as sharing those games as part of a public engagement event to encourage dialogue. As a result, a public engagement project in which STEM undergraduates design games to share with the public is a way of exploring this issue. Moreover, the design process and event should be facilitated by science communication experts to scaffold and lead the participants through the practice of public engagement and game design.

Research Questions

The primary purpose of this research is to contribute to the scholarship on the educating of future scientists in public engagement by exploring in what ways undergraduate science students enact roles and social identities with the public to foster dialogue. This study approaches this problem through discourse analysis through cohesion to examine the student-public interactions as well as their facilitated game design process in order to explore how such an educational experience does or does not give students chances to do and be like a scientist who engages with those outside of their field in dialogue and productive ways. To these ends, this study intends on answering these research questions:

- 1) Given the challenge of designing a game to engage the public with science, what social identities and roles do undergraduate engineering students enact during the facilitated design process?
- 2) During the public engagement event(s), what social identities and roles do these students and members of the public who play the game enact through the player reflection?

While this is an exploratory study, this study posits that during the game design process, students will position themselves as scientists as they decide on the content of their games and negotiate between the limitations of the tabletop game genre and their creative vision. Moreover, when they share their games with the public, they will position themselves as the role of expert of PV solar technology and social identity of scientist by explaining the implications and intended message(s) of their game while at times coming to realize the shortcomings of their design through player feedback. Moreover, this study

expects that discourse analysis is a viable lens with which to examine what roles and social identities are being enacted during the facilitated design process and face to face public engagement events.

CHAPTER 3

METHOD

In the previous chapter, a review of the literature indicated that the dialogue form of public engagement is the preferred model of science communication; however, researchers are not clear on how to make public engagement events with that dynamic. Moreover, even as science programs look for ways to teach science communication to STEM undergraduates, dialogue with the public is considered at the least an advanced practice for that level of student and perhaps beyond their ability. Moreover, situated learning was put forward as the theoretical framework to view learning and discourse analysis was the lens by which to interpret the learning in the form of students enacting roles and social identities in authentic settings. In this chapter, the prior research leading to this study is described, then the research design is detailed, followed by the participants and context. Then discourse analysis through cohesion will be explained as the analytical lens by which the research questions will be explored. Finally, this chapter details the data collection and analytic process taken by this study.

Prior Research/ Pilot Study

Prior to this study, the author of this study, hence forth referred to as “the researcher,” took part in an ethnographic study of the same solar engineering center in the summer of 2017. The researcher served two functions, first as an observer collecting data through ethnographic methods (Bowers, Jordan, Fischer, Holman, & Evans, 2019) and as a facilitator leading REUs through a public intellectualism writing project (Evans & Jordan, 2019). In the first capacity (Bowers, Jordan, Fischer, Holman, & Evans, 2019), the researcher took observations of REUs attending workshops, meeting with mentors,

working in the laboratory, completing Solar 101 training, and events. Moreover, he conducted end of program interviews with participants. As a researcher conducting ethnographic field work, this gave him intimate knowledge of the context, including the structure of the program, the various experiences and learning outcomes of the participants, and a general sense of how the program is designed to foster the next generation of solar energy engineering researchers.

In the second capacity, the researcher guided REUs through a writing project as a facilitator (Evans & Jordan, 2019). Fifteen REUs wrote for audiences outside of academia about what they were learning as novice engineering researchers. The project was framed as writing as a public intellectual, a person who shares their knowledge with as wide an audience as possible (Nash, 2004). REUs were asked to write in the genre of their choosing about what they were learning about solar cell technology and engineering research. Over the course of seven weeks, learners created a variety of texts and shared them primarily online (YouTube videos, edits to wiki articles, op-ed articles, etc.), the content being primarily about how photovoltaic cells are manufactured, the underlying scientific principles behind solar technology, and related environmental issues, but written with the express purpose of informing audiences who were not experts in the field. The study's findings pertinent to this study indicate that REUs enacted the role of an expert in written form by using disciplinary language, including hedging, and positioning themselves as knowledgeable on the topic while expressing themselves as scientists in these ways communicating with non-experts.

While the findings for Evans & Jordan (2019) showed that such a writing project for REUs showed promise in promoting science communication at the undergraduate

level, it revealed a number of shortcomings. First, writing as an expert in this way can be characterized as following the dissemination/deficit model, which is typically used to spread science information to a large number of audiences (Trench & Bucchi, 2014; Wynn, 1991). Texts and communication approaches that are primarily focused on disseminating knowledge have been criticized as reproducing these inequalities which are in part perpetuated by forms of communication that are one-directional flows of information from the scientific community to publics. Moreover, as the literature review of this study demonstrates, there is a lack of research taking place to explore how undergraduates can learn to do public engagement and foster dialogue, a kind of science communication that future scientists will be expected to be able to do.

Another important lesson learned from the 2017 Solar Energy Center writing project was that even though REUs were asked to publish their text online or share it in some capacity with non-scientist audiences, by and large there was little response from the latter. The videos posted on YouTube had few views or comments outside of other students in the cohort. An essay posted on Reddit only received one comment months later after the Solar Energy Center program had concluded. The flow of the writing project was primarily focused on the production of a text, but not on its distribution. What efforts could the students have taken to get more attention to their texts if the project was framed in terms of generating dialogue with publics or that an important way to communicate is through interaction, a back and forth between themselves and publics, rather than simply placing the text in a space?

Another limitation of the 2017 Solar Energy Center writing project was how there was such a wide variety of genres the REUs used that it was difficult to guide them

through the creative process as a cohort. What guidance a group making a YouTube video was different than what an individual REU writing an op-ed piece for the newspaper needed. Moreover, the REUs showed a lack of expertise in writing in these genres as well, meaning they needed more scaffolding and support from the facilitator than was given or could realistically be given considering the constraints of time and resources. Lastly, methodologically the researcher did not collect data on how students approached creating their text(s), focusing primarily on collecting the final product and analyzing it through multimodal analysis (Jewitt & Oyama, 2001; Kress, & Van Leeuwen, 1996). This approach left out the moments during the creative process that the REUs potentially took on the role of expert and other roles and identities associated with the practice of communicating with publics.

However, the researcher did observe during critique sessions that REUs interacted with YS (Young Scholars) in a way that could potentially be applied to another iteration on the study. REUs shared their rough drafts with YS, inviting feedback and suggestions. In this situation, the REUs at times had to explain science concepts, which resembles what experts do when speaking to non-experts face to face (Gülich, 2003). Also, the REUs did not always appear to act as learners or non-experts while they gave feedback to the REU, sometimes being critical of the piece. To the researcher this social situation presented a promising format in which a scientist shares their creative product to get feedback and essentially uses it as a platform to engage the public to talk about science.

As a result, the researcher's participation in the Solar Energy Center's 2017 REU program and studies served as a pilot study for this dissertation. None of the data from the 2017 program was carried forward into this dissertation. However, the researcher

considered the lessons learned, as just explained above, to embark on a promising new direction for research into the Solar Energy Center's 2018 program. Key differences included narrowing the genre down from many forms of writing to just the single genre of analog or tabletop games. The researcher also chose to guide participants through the various steps of game design together to concentrate resources more effectively. The REUs would not need prior experience designing games since the steps would be scaffolded for them. Moreover, this also made it feasible for one researcher to collect data on the design process of many participants since they would all be in the same place together for many parts of the process. Moreover, the researcher chose to shift the task of the project away from public intellectualism and to public engagement through dialogue. Potentially, that would offer the REUs with an opportunity to take part in science communication that could be dialogue with the public rather than only dissemination. This was put into practice by making REUs share their games with the public in a face to face setting. Hopefully, this would give REUs a chance to take part in dialogue in a hands on, real world way whereby they could take on the roles and social identities associated with public engagement that the social situation offered.

Lastly, the researcher could leverage his familiarity with the context by focusing on only the public engagement project rather than attempting to study the entire REU experience while still fulfilling his role as facilitator.

Research Design

In general, this study used discourse analysis through cohesion to interpret the verbal interactions of undergraduate STEM participants taking part in a game design project to learn public engagement with science. As such this is a qualitative study that is

exploratory in that it attempts to “investigate a phenomenon little understood” (Creswell, 2007, p. 107). It assumes that learning is an ongoing meaning making process mediated through language as well as other modes of expression and signs (Gee, 2003; 2014a). Moreover, this is a social process in that learners learn to become through interacting with others as well as shape the context of the interaction through these enactments. Learning occurs when a person is doing, being, thinking, and relating to others while they are a part of the work of a discipline or Discourse. As such, this study seeks to determine what roles and social identities the students enact while learning to design for and enact science communication through public engagement events.

Specifically, the study concerns itself with STEM undergraduates enacting roles and social identities while designing solar energy games (Research Question 1) and while conducting player reflections at public engagement events (Research Question 2). The study also concerns itself with the enactments of the public during the public engagement events (Research Question 2). In addition, the game design features which support the enactments of Research Question 2 will also be examined. The project will include students designing a game with which to engage the public with PV solar energy concepts and issues. Students will then share the game with members of the public as part of a public engagement event that is face to face. As will be explained below, data will be collected *in situ* where the verbal interactions of participants will be recorded during the game design process and while participants are conducting the public engagement event. These encounters will demonstrate what roles and social identities the participants enact throughout the entire project so as to show learning in its situated sense in that the students are taking part in the practices associated with science communication.

Moreover, the verbal interactions during the public engagement event will indicate what game design features contribute to these enactments, if any.

Participants and Context

In this study, 12 Research Engineering Undergraduates (6 male, 6 female) participated in the public engagement project in which one facilitator led learners through the game design process and the public engagement events (see Table 3.1). One additional facilitator, female, also helped collect data and supported the public engagement events. During the public engagement event, 39 members of the public took part in player reflections with REUs (see Table 3.2).

Table 3.1

Demographic and Undergraduate Majors for REU Participants

Name	Gender	Race	Undergraduate Major
Vic	F	Black/AA	Chemical engineering
Howie	M	White	Physics
Xavier	M	Hispanic	Mechanical Engineering
Cherry	F	White	Electrical Engineering
Yana	F	white	Physics
Jordan	M	Hispanic	Physics
Newton	M	white	Electrical Engineering
Larry	M	Black/AA	Mechanical Engineering
Carter	M	Black/AA	Electrical Engineering
Beth	F	Black/AA, White Hispanic	Electrical Engineering
Anna	F	Middle Eastern	Physics
Krista	F	American Indian/Alaskan Native	Engineering

One additional facilitator, female, also helped collect data and supported the public engagement events. During the public engagement event, 39 members of the public took part in player reflections with REUs (see Table 3.2).

Table 3.2

*Research Engineering Undergraduates Participants**

REU	Game Title	# of Players who did Player Reflection	Public Event
Vic	Solar Trivia	10	First Arts Festival
Howie	Solar Mancala	6	Frist Friday
Cherry & Yanna	It's a Trap!	6	Second Arts Festival
Carter	Tilt Maze	8	Second Arts Festival
Newton, Jordan, & Xander	Solarpoly	9	Second Arts Festival
Anna, Krista, Beth	Cell-O-brate Solar	N/A	Science Center
Larry	Solar Trivia	0	N/A
		39 total	

Note. Howie and Vic, were two REUs who became focal participants for the analysis of the game design process. Howie was a junior studying physics at a university and Vic was also a junior in the process of transferring to environmental engineering from another field of engineering.

Participant Selection

STEM undergraduates who attended in Solar Energy Center's summer 2019 program took part in the public engagement project. At the beginning of the program, these students were invited to participate in the study by handing out informed consent forms and either opting in or declining to participate in the study. For those who chose to participate, they were given a participant number to anonymize data associated with

them. The researcher was not informed until after the project whether a student declined to participate in the study for his project. At the end of the project, participants were asked if they would be willing to give an interview, though these interviews were not used in data analysis. They repeated much of the discussion of the group reflection which was the last meetings for the project. Moreover, this data was constructed by a different social situation than the meetings and public engagement event, and so deemed not appropriate to mix data for analysis and not worth the effort to conduct another analysis for. Lastly, adults who played the games at the public engagement events were recruited to take part in the study after they finished playing the game. The facilitator read the consent form to them and gained their verbal consent (see Appendix A)

Context of Study

This study is set within an 9-week summer program within the Solar Energy Center, a pseudonym given to a nationwide program funded by the National Science Foundation to rapidly advance photovoltaic research, technology, and workforce (Solar Energy Center Year 8 Annual Report). Part of Solar Energy Center's mission is to inspire, train, and challenge the next generation to advance photovoltaic technology. To reach this mission, Solar Energy Center administers summer programs in which 7 to 12th graders (Young Scholars) and undergraduates (Research Engineering Undergraduate) engage in the practices of PV solar cell manufacturing and laboratory research and the communication practices of scholarship. They are matched with graduate researchers who work as mentors for research projects which they later present to industry experts and researchers. These projects are meant to cultivate a PV engineering community in which students, mentors, and scientists are treated as learners and teachers of varying

levels, though capable of making contributions of their own. The summer program included in this study is administered primarily at an engineering center at a large public university in the Southwest and a nearby laboratory where REUs use a small-scale solar cell manufacturing line.

Each summer participant in the program is part of a cohort and the first phase of their program experience is to undergo training in Solar 101, a two-week bootcamp designed to teach REUs the fundamentals of PV solar cell technology and climatize them to working in the lab and making PV solar cells. Then REUs are matched to their mentors, often assigned as pairs to one graduate student already conducting PV solar cell research at Solar Energy Center, and begin a research project under the guidance of the mentor. The 9-week program includes field trips to local solar cell farms and companies. Guest speakers who are experts in renewable energy, public policy, and research provide additional perspectives. Intensive is an apt adjective to describe the training that REUs undergo and their research projects which they must report on at the end of the summer.

Another important part of Solar Energy Center's mission, which relates directly to the public engagement project explored in this study, is its goal to foster communication beyond the academic PV solar energy field to "publics of all ages and knowledge levels, including industry and research partners, within and across teams, regardless of age or experience – all in the name of building the collective knowledge and practice of the PV community" (Solar Energy Center Report, p. 94). Moreover, the students attending Solar Energy Center work in the engineering researcher environment, taking part in research and lab activities.

Researcher Positionality

In general, a researcher's background and views contribute to the study as a product that is constructed within a context (Mertens, 2010). So it is necessary to explain what games mean to the researcher and his background that led to this study. First, he would call himself a board gamer who plays games avidly and designs them as a hobby and when possible for public engagement events. The researcher studied public engagement, game design, and science communication as a PhD student at the same university where the study took place. With collaborators, he designed games to use as platforms for engaging the public in environmental issues. He also has over five-years' experience teaching undergraduates. As described in the previous section, he developed the curriculum and facilitated the 2017 writing project for public intellectualism that REUs took part in (Evans & Jordan, 2019). REUs wrote for public audiences using a broad range of mediums (YouTube videos, op-ed piece, children's book, etc.). Combining his background and teaching experience, he developed the curriculum for the public engagement project at Solar Energy Center for summer 2018, where students would design games to engage the public with solar energy. In this capacity, he led meetings with REUs, instructing participants in science communication concepts and leading them through the game design process. He also facilitated the public engagement event.

The researcher for this study played two roles in conducting this study. He developed the curriculum and the facilitator for the public engagement project. He also was the researcher who collected and analyzed data. The first role placed limits in his capacity in the second, which influenced key research design decisions as will be

explained here. In taking this role as facilitator of the project, this meant that he could not take an observer position as a researcher. An ethnographic approach in which he was a participant-observer, with the REUs was not possible either as his role was to guide the meetings. The researcher needed to instruct, coordinate, and at times motivate the REUs during the project, making it not possible to have a strictly researcher-participant relationship. As such, the researcher recognizes that there is a power difference and privilege as a facilitator that he should not leverage as a researcher (Merten, 2010).

With these issues in mind, the researcher chose to collect data in a manner that did not intrude or add a burden on the participants, but rather collected data by audio recording meetings, events, and interactions that would have happened regardless of the research aspect of the project. As a result, he did not rely on interview data because his position as facilitator could have influenced the participants' responses and made them less forthcoming. The researcher's positionality also influenced how he approached data analysis. While discourse analysis in a qualitative study is an interpretive approach, cohesion in language is fairly rigid lens that identifies, categorizes, and interprets language quite often with limited options in interpreting how language is functioning. Of course, data analysis is a kind of claim that must be explained and supported. However, having participated in the context and "been there" to sort of speak, the researcher also has the advantage of recording impressions and situations that can be referred back to help recall who and what is being referred to in a verbal interaction, which may not be obvious from a transcript.

Public Engagement Project Curriculum

Participants in this study took part in a series of facilitator-led instructional meetings, consultations, a public engagement event, and a group reflection at the end to recap over the project (see Table 3.2). Unless otherwise noted, the following meetings and consultations occurred at the Solar Energy Center.

Table 3.3

Outline of Public Engagement Project

Date	Activity	Duration (hours.minutes)	Description
May 31	introduction to project	2	Lecture and activities: science communication models, genres used in science communication, special aspects of dialogue model. Activity: exploring what messages and genres REUs would like to try for this project
June 13	brainstorming	1.30	Lecture: game design process. Activity: brainstormed as many game concepts as possible. Activity: modified existing public engagement games to be used for solar energy
June 15	prototyping	1.30	Activity: individually and in groups REUs make paper prototype of their game concept
June 21/ 22	Young Scholar critique	1	Activity: individual REUs meet with Young Scholars share game concept to get feedback. YSs share their project about community engagement for feedback from REUs
June 21/22	consultations	1 to .15	Consultation: REUs met one on one with facilitator for feedback, suggestions, and troubleshoot problems
June 25	playtest	1	Activity: YSs played REUs prototype version of their games and gave feedback
July 2	play through	1	Activity: YSs and Research Engineering Teachers roleplayed

			as members of the public meeting REUs, playing their game, and doing playing reflection
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Table 3.3 (continued)

Outline of Public Engagement Project

Date	Activity	Duration (hours.minutes)	Description
July 6	first public engagement event	4	Public Engagement Event: at arts festival Vic and Howie shared their games and conducted player reflections
July 10	group reflection for first public engagement event	1	Activity: Vic and Howie reflected over their public engagement project experience with facilitator
July 13	Science Center	3	Crafts Activity: Anna, Krista, Beth led children through crafts activity making paper solar cells
July 13	group reflection for Science Center	1	Anna, Krista, Beth reflected over their public engagement project experience with facilitator
July 13	second public engagement Event	4	Public Engagement Event: at arts festival Cherry, Yana, Xavier, Newton, Jordan, and Carter shared their games and conducted player reflections
July 16 th and 19 th	group reflections for second public engagement event	1	Activity: Cherry, Yana, Xavier, Newton, Jordan, and Carter reflected over their public engagement project experience with facilitator

Introduction to Project. In the first meeting the facilitator lectured about science communication concepts such as the dissemination and dialogue models of communication. He stressed the differences between the two and how public engagement needs to focus more so on dialogue with the public because of their responsibility to support an informed citizenry, professional obligations, and the value of self-expression.

In one activity REUs work in pairs to find examples of science communication online in the form of news articles about science, events, games, etc., and then share with the whole group which models of science communication they embody. Another activity included REUs filling out a worksheet to explore what genres they might want to use for public engagement, what messages they want to express, which audiences they wanted to reach, and what platforms they would use to reach these audiences (see Appendix B).

Brainstorming. In the second meeting, the facilitator lectured on the concept of using a game to engage the public in a face to face conversation to foster dialogue. He covered the game design process, including brainstorming, prototyping, play testing, and iterating on design. The facilitator led REUs through two activities, a brainstorming activity and a modifying activity. In the former, REUs worked in groups to write out game concepts by writing descriptions, game rules, and diagrams of as many game concepts as they could think of in a creative sprint. During the modifying activity, REUs worked in pairs to take one of three existing public engagement games and modify it to be used for solar energy.

Prototyping. This meeting consisted of REUs working individually or in groups of their own choosing to pick one game concept for solar energy and make a paper prototype version of it. REUs also wrote out the directions and rules of how to play.

Young Scholar Critique. The REUs met with the Young Scholars to share their prototype version of their public engagement game. The YSs were doing a community engagement project with solar energy. In the activity, an REU met with two Young Scholars at a time and each presented their respective project to get feedback and suggestions.

Consultations. REUs made appointments and met with the facilitator one on one to discuss the progress of their game and get support in the next steps of the design process. See Chapter 4 for specific feedback given to Howie and Vic, the two focal participants in the design process.

Playtest. REUs brought their prototype versions of their games to a common meeting area in the solar engineering center. YSs played the games and gave feedback to the REU who designed the game. Playtesters rotated from game to game in this fashion.

Play Through. To prepare REUs for the public engagement event, a play through activity was devised where YSs and Research Engineering Teachers took on the role of members of the public and played the REUs' games. In this roleplay, the REUs described their game, led the players through a game, then conducted a player reflection.

Beforehand, REUs were tasked with coming up with two to three questions to ask members of the public to use during the player reflection. The facilitator directed them to think of questions that would be meaningful to them, get information they wanted to know from members of the public, and what would help members of the public understand solar energy and their research.

Public Engagement Events and Science Center. There were two arts festivals occurring locally and REUs chose which one they wanted to use for their public engagement event. Each REU had to attend one. For a detailed description of the events see the section Description of Games and Public Engagement Events. Note, one group of REUs who did *Cel-O-Brate Solar* chose to do their event at a science center since theirs was designed for children.

Group Reflections. After an REU or group of REUs held their public engagement event, the facilitator met with them to reflect on their experience. In a meeting room at a library near the Solar Energy Center, they discussed and compared their experiences. The facilitator guided the reflection by asking REUs what game they made for their project, what they hoped their player received from the experience, memorable experiences from the public engagement event, and how they would describe the concept of public engagement.

Discourse Analysis through Cohesion

This study uses cohesion to conduct the discourse analysis, as in the interpretation of participant discourse in enacting roles, identities, and relationships. This section describes how Halliday and Hasan describes cohesion and why it is chosen as the analytical framework in the current study.

Cohesion is how a conversation, or talk as represented in a transcript or text, fits together or is structured (Gee, 2014a; Halliday & Hasan, 1976). According to Halliday and Hasan (1976), cohesion links and forms relations between meanings within a text and to the social situation and broader world. Cohesion is a "semantic relation... realized through the lexicogrammatical system" (p.6) which means it can be done through either vocabulary or grammar, it can be within or between sentences. Cohesion is about linking a sentence to what has come before it and are a part of the text. Also, cohesion can be realized through intonation, that the words stressed between intonation units can have a relationship. It is accomplished through *markers* (reference, substitution, ellipsis, conjunction, and lexical cohesion) or devices within a text that connect a series of ideas or sentences into a text, it makes it a semantic unit and responsible, in part, for expressing

the ideas of a speaker or writer. While linking meanings they create continuity from idea to idea as a text progresses forward. It relates what is being said to what has been already said (and sometimes what will be said) as well as makes reference to the social situation, the environment in which the text is created and even social groups and abstractions. In this way, a text as Halliday and Hasan means it is not a grammatical structure. What makes a text is when one or more sentences come together to form a meaningful whole or a “semantic unit” and “The unity that it has is a unity of a meaning in context, a texture that expresses the fact that it relates as a whole to the environment in which it is placed” (p. 293).

Even if they are not named directly, a referant can be mentioned or envoked, brought into the conversation with a simple pronoun, and yet the listener is able to fill in the blanks and make the connection with just what is given. Halliday and Hasan (1976) explain it this way:

It is the continuity provided by cohesion that enables the reader or listener to supply all the missing pieces, all the components of the picture which are not present in the text but are necessary to its interpretation. (p. 299)

The implication for analysis is that by analyzing how a text uses cohesion and what is being referred to, either within the text or the social situation, one can make claims to what is happening in a conversation, Discourses being present and interacting, not just interpreting what a speaker means in a given turn of speech.

Summary of Cohesive Devices

In a brief summary of the five types of cohesive devices (reference, substitution, ellipsis, conjunction, and lexical cohesion), to show how data in Chapter 4 will be

analyzed through this particular kind of linguistic feature. The first is *reference* which is a device where the information has already occurred in the text or from the social situation. Reference devices can refer to objects, class of objects, a process, along with people and things. For example, in "Toby loves his job. He ran wild with the cake dispenser," the "He" refers back to Toby establishing who is doing what and it can also refer back to a previous incident. Reference is about specificity and often carries a lot of defining properties. Continuing with the previous example, the pronoun "he" carries the information of gender. This would be a personal form, which includes pronouns and possessives. Halliday and Hasan (1976) make the point that "we" is often "implying a particular group of individuals with which the speaker wishes to identify himself" (p. 53) pointing to a bid to be taken as a certain kind of person or belong to a Discourse. Another kind of reference is demonstratives and comparatives. The former is often words like "the" "this" "that" the establish that there is only one of what is being referred to or rather specifying which thing or person. *Demonstratives* reference location in time and space, establishing proximity through words like "here" and "this" as well as "there". *Comparatives* convey a relationship of similarity or difference between what has come before.

The next two types of cohesive devices are similar to each other, *substitution* and *ellipsis*, the former replaces one item by another and while ellipsis leaves out that item. By virtue of their function, substitution and ellipsis create cohesion only within the text and so are not exophoric. For example, substitution can be done through words like "one" and "do" as in "He threw out the old ones" and "What is he doing?" These words replace what would be a noun in the first example and a verb in the second. Ellipsis on the other

hand leaves "something left unsaid" but is implied (Halliday & Hasan, 1976, p. 142). This type of cohesion often appears in conversation when someone is replying to another person but leaves out much of the structural information that was included in the question. "Do you want fish or chicken for dinner?" - "Neither." Here, the second speaker is leaving out "I" and the predicate "want" which are both implied, and actually using a substitute, "neither" to refer to the two choices in the negative. Much is unsaid, but the meaning is clear and the single word creates cohesion with the former sentence and so gives the text its wholeness or "texture" as Halliday and Hasan would say. Halliday and Hasan (1976) go into detail about the role that ellipsis plays in question and answer interactions in a conversation. In the process they categorize different types of *responses*, or answers, that can occur. First, they can be direct response where the speaker gives the information asked for. Or speakers can reply indirectly where they comment on the question, disclaim the question by denying its relevance, or give a supplementary response where the speaker gives information but may not answer the question. The speaker can also assent-contradict, consent or refuse a command, or give a yes-no response or a WH question in response. A yes-no question is special in the sense it is a "polar question" and the response follows the affirmative or negative meaning of the question (p. 208).

Conjunction is a special cohesive device as it establishes relations between meanings that have come before, how different parts of the text hang together and relate. A conjunction can also express how the speaker is interpreting their experience of the world as well as how their attitude and how they relate to the other speakers and the role they see for themselves in the conversation. In addition, conjunctions can form relations

between the text itself and the social situation. The four types of conjunctions can briefly be described as additive (and, also), adversative (yet, though), causal (so, then), and temporal (then, next). Some words can perform both temporal and causal functions as in the case of “then”. Conjunctions can also convey nuance to their meanings and relations, such as to emphasize.

The last type of cohesive device is *lexical cohesion*, which is essentially the use of vocabulary that refers to previous words that runs the range from the general to the repetition of words with the same meaning. For example, in the sentence, "Rick always suggests we go shoot **guns**. I hate those **things**" the word “things” is a general noun that refers back to guns. However, as in the case with lexical cohesion, this use of the general noun imparts the attitude and other interpersonal meanings. In this example, the speaker could have used “it” which would have a neutral connotation or “weapon” or some other near synonym to refer to “guns” but by using “things” he is expressing disdain for that which he is referring to. The lexical cohesion spread across the text can be reiteration of the word to synonyms and near synonyms superordinate (refers to a class of words to which the more specific belongs, e.g. "pine tree... tree) to using general nouns. Moreover, lexical cohesion can occur through words that collocate, or are associated with each other because of their use in culture. For example, “gun” could be connected with “trigger”, “bullet”, etc. Like the other forms of lexical cohesion, collocation can link parts of the text to each other and the environment in which the text is being created. A lexical chain is where several instances of the same lexical cohesive words are used in succession, whether through the noun itself, references to it, or by substitution. Moreover,

a series of verbs can perform the same function and so give coherence through their similar meaning or through collocation.

In short, cohesion can be a window for interpreting who a speaker is making a bid to be taken as in a conversation, what role they are assuming, in addition to what identities/ roles they are positioning the other speakers to be. Gee (2014c) also recommends using cohesion as an analytical lens and refers to Halliday and Hasan's (1976) work as the basis for his use of it. In Gee's approach, he calls interpreting cohesive devices the deixis tool, which is similar to the above description for reference cohesion markers. That being said, Gee offers this guidance in analyzing such references:

For any communication, ask how deictics are being used to tie what is said to context and to make assumptions about what listeners already know or can figure out. Consider uses of the definite article in the same way. Also ask what deictic-like properties any regular words are taking on in context, that is, what aspects of their specific meanings need to be filled in from context. (p. 10)

Gee is pointing out how cohesive markers, such as pronouns and definite articles, can link language to the context and how nouns can take on situated meaning because of how they are used in the situation. Gee also describes the fill-in tool where the analyst seeks to determine what is being left unsaid or is already understood from the context so it goes unsaid. This could be similar to ellipsis in the way that heads and groups are left out of utterances in a literal sense.

Gee (2014c) recommends considering what is left unsaid or does not need to be said because it is clear from the context, it is the work of the listener in order to understand the speaker, so in way it is like thinking through what does the listener need

to know in order for him to understand what a speaker says. Gee makes this point explicit in the simple equation of "WHAT SPEAKER SAYS + CONTEXT = WHAT SPEAKER MEANS" in order to interpret intentionality and what a speaker is attempting to accomplish through words (2014c, p. 12). Gee recommends applying this approach to interpretation in general and not just what parts of speech are missing, as in the case of ellipsis. But in a sense, this applies to much of cohesion as the cohesive markers point to things, places, moments in time, and people without having to directly state it. In addition, Gee notes that speakers are not just trying to give information to the listener, but also attempting to accomplish a goal discursively. While there could be any number of discursive goals that the current study's participants attempt, this study is only concerned with those goals related to enacting social identity and roles while designing and sharing public engagement games. These enactments are indications of the learners taking up the practice of public engagement. Lastly, Gee draws attention to repetition and word use for content words (nouns, verbs, adjectives, and sometimes adverbs). However, this study chooses to limit analysis to repetition, near synonyms, and associated words through Halliday and Hasan's (1976) idea of lexical cohesion and lexical chains, as described above. Essentially, this means that only words that repeat or cohere will be analyzed as opposed to *every* noun, verb, adjective, etc. This will limit the scope of analysis and make the work of interpretation more manageable.

In order to gather data in which students, the public, and other participants are operating as naturalistically in the setting as possible, this study relies on audio recording verbal interactions. As Erickson notes, sociolinguistic analysis should focus on "the conduct of the practice itself" and show "the actual tactics by which the presumed

strategies are accomplished, in their moment-by-moment doing" (p. 139). It is necessary to collect and analyze data that because participants take action, take advantage of choices that are presented (Bourdieu, 1977), so to only have a picture, to sort of speak, of the beginning and the end, is to miss how the participants maneuver and could have maneuvered through a social situation. In this way, a naturalistic approach to research means following the unfolding of a project as much as it is possible.

Description of Games and Public Engagement Events

Description of Public Engagement Events

A description of the two sites used for the Solar Carnival are in order. Although the aim of this study is not to define the character of the arts festivals as an activity in which the Solar Carnival was held, some data gives some hints as to the overall context in which the two Solar Energy Center public engagement events took place. First Arts Festival is for locals and tourists to enjoy arts, crafts, food, and mingling. Researcher notes describe First Arts Festival having a slow build up as the sun went down and crowds began flowing between the booths. The weather service issued a heat advisory that day, a reason for facilitators to consider cancelling the public engagement event because it was so hot. The public engagement event for Second Arts Festival in Mesa was hot, but noticeably not as hot as the previous event. These events took place in Arizona, nicknamed the "valley of the sun" and is in many ways associated with the sun and sunlight. For example, Phoenix's National Basketball Association's name is the Phoenix Suns. The following description of the public engagement event's booth setup and format are the same for both events.

Figure 3.1

REU playing Solar Mancala with a member of the public.



Both events were called *Solar Carnival* and took place at arts festivals where members of the public were shopping, wandering, looking for fun and interesting things to do. The public engagement event had a booth with a banner announcing, “Solar Carnival” and the name of the university and Solar Energy Center. REUs and facilitators wore polo shirts with the Solar Energy Center logo. At the front of the booth toy solar crickets hopped, powered by a lamp. Often people noticed the solar crickets hopping and scratching. With a dozen of such solar crickets hopping, it often drew the attention of passersby. The REUs arranged their game on tables and another table had promotional pamphlets for the Solar Energy Center outreach programs. For example, Vic had a foldout table beside with the trivia game poster on display. She usually stayed behind the table while the facilitators called out to passersby, “Play a game, win a solar cricket.” If a person stopped, facilitators invited them to play a game with the REUs and then win a

solar cricket. After the game, the facilitator invited the player to participate in the public engagement reflection with the REU. If they agreed, the facilitator recorded the verbal interaction between the REU and the player(s) with a digital recorder.

Participant Description and Background

In this study 12 REUs in the Solar Energy Center 2018 summer program participated in the public engagement project (see Figure 3.1). These undergraduates were chosen because they study engineering and science-related majors at universities at the undergraduate level. Their participation could speak to science communication education at the undergraduate level. At the public engagement event at First Arts Festival, Vic and Howie conducted player reflections with 16 members of the public, also called players. At the public engagement event at Second Arts Festival, Cherry and Yanna, Carter, and Newton, Jordan, and Xander shared their games and conducted player reflections with 23 members of the public. Anna, Krista, and Beth shared their solar cell activity at the Arizona Science Center where approximately 50 children participated. However, this study is focused on adult participants and science students engaging the public, so data was not collected. One REU, chose not to participate in any public engagement event and declined to participate in the project after designing his game.

Games Developed by REUs

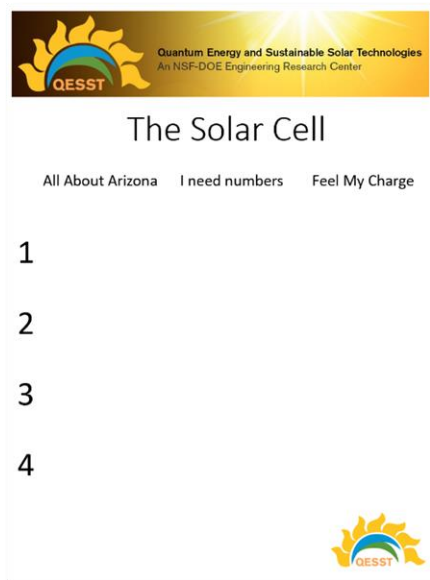
In the following sections, a brief description is given for each game the REUs designed.

Solar Trivia. At the First Arts Festival public engagement event, Vic used the game Solar Trivia (see Figure 3.2) which is about solar energy in which player's choose questions and if they get the answers right, they win a solar cricket. It consists of a large

poster board (36'' x 48'') with categories across the top and point values along the left side. Originally another REU, Larry, designed the game, however, declined to participate in the event. The game had a series of questions with increasing difficulty level and point value, but Vic thought of a simplified version and four questions of her own. If the player answered them correctly, then they win. Her questions included about how high does Arizona rank in solar production compared to other states, the amount of electricity a given solar panel array would produce, and similar questions. As she conducted the trivia, she often gave hints and clues to players to help them guess the correct answer. She also gave hints and bent the rules to let players have second and third guesses.

Figure 3.2

The Game Vic Used at the Public Engagement Event: Solar Trivia



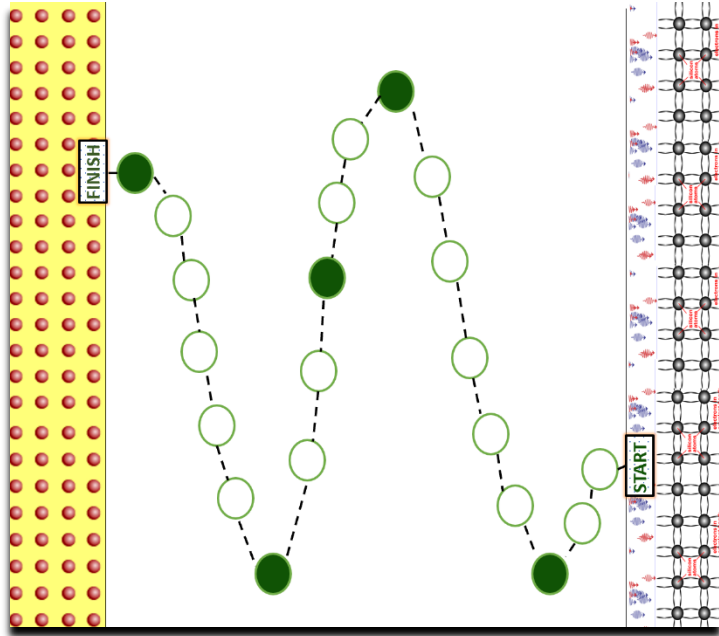
Solar Mancala. Designed by Howie, *Solar Mancala* is based on the original game of Mancala which began in ancient Egypt and is suspected to be about grain storage. The game board has two rows of six cups or divets to place beads and each player has one large cup at the end of the row to act as their storage. The players still

move beads from cup to cup to reach their storage area. The player who puts the greatest number of beads into their storage wins. In Howie's modified version (see Figure 3.1), the cups have special game mechanics when a player places their last bead into it. These are designated as three types of recombination – Auger, radiation, and trap. In this way, the game presents these types and at times represents the scientific concepts metaphorically. For example, the cups marked “R” for radiation will cause all of the beads in that cup to be removed from the game, like the electrons radiating out.

It's a Trap! REUs Cherry and Yanna designed a game about recombination called *It's a Trap!* The concept is that an electron travels across the board over many spots which represents crossing the band gap. Recombination is where electrons can get paired up with holes and results in the lack of electricity being produced in a PV solar cell. Color cards drawn by players are different wavelengths of light, or colors, and they move the player's electron across the board. When a player makes it to the other side first, they successfully make electricity.

Figure 3.3

Cherry's Public Engagement Game: It's a Trap!



Note. This final version of *It's a Trap* is based on the hand-drawn design by Cherry and Yanna, but different than the one they used at the public engagement event of this study.

Solar Monopoly. REUs Newton, Jordan, & Xander designed a modified version of Monopoly, i.e. *SolarPoly*, to represent the solar energy industry (see Figure 3.4). Their goal is to show that some states and cities have a climate and available sunlight more conducive to solar energy production than others. Their game includes trivia questions on solar energy as well.

Figure 3.4

Jordan, Newton, and Xavier's Game: *SolarPoly*



Tilt Maze. Carter designed a tilt maze with four sections where the player navigates a steel ball through the maze to reach the finish. Conceptually, he wanted to communicate that with solar panels, the more panels there are the more difficult it becomes to transfer electricity efficiently.

Game Content Evaluation

In order to evaluate the scientific accuracy of the above games’ content, this study asked PhD students at the Solar Energy Center to evaluate the games (see Appendix C). Evaluators were asked to judge from examining the game what science concept it conveys and to rate its accuracy from 1 to 4 or “Cannot be determined.” In general the 8 evaluators’ responses align with the game’s intended content and on average rated between 3.8 to 4. The one exception was *Tilt Maze* which scored a 3.2 and some evaluators remarked that it was difficult to determine what the content was because it lacked visual design such as color and graphics to indicate what the game represents. This study suspects this is due to the game still being a rough prototype and not a finished prototype.

Data Collection and Analytic Process

Data Collection

This study followed REUs doing a public engagement project which consisted of a facilitator leading STEM undergraduates through the game design process and a public engagement event. Most meetings and consultations for the design process were held in conference rooms. Data collection for the facilitated design process took place from the beginning of the project on May 31st and lasting until July 19th, beginning with the Introduction to the Project meeting and concluding with the last group reflection, respectively (see Table 3.2 for outline of design process). This was a total of nine meetings lasting approximately one to two hours each. Individual consultations lasted approximately 15 minutes to 40 minutes each. This produced approximately 960 minutes of audio, 420 minutes of which was analyzed for focal participants. The two public engagement events lasted four hours each, where REUs conducted a total of 39 player reflections. Each player reflection lasted approximately 2 to 3 minutes. In total 98 approximately 98 minutes of audio was collected. The science center event lasted three hours and no player reflections were conducted because the potential participants were children and the interactions fell outside of the scope of this study's research questions which was limited to adults.

This study uses discourse analysis through cohesion as its analytical lens, which relies on interpreting individual words, such as indefinite articles and conjunctions, that participants use to communicate verbally. This necessitated capturing what was said during the meetings, consultations, and public engagement events with as much fidelity as possible. Moreover, spoken language is one of the primary ways that meaning is made

during a social interaction (Gee, 2014a) and it is how participants were expected to enact roles and social identities during the design process as well as during public engagement events. As a result, data collection primarily consisted of digital audio recorders placed in the setting to capture verbal interactions during each of the meetings and the player reflections that REUs conducted with members of the public at the public engagement event. In the case of meetings and consultations, digital audio recorders were placed in the setting to capture the lectures and verbal instructions of the facilitator leading each meeting. Digital recorders were also placed at tables to capture REU verbal responses to the facilitator as well as for when REUs worked in small groups and pairs during activities. The audio recorders were re-positioned as participants moved to different parts of the space. By capturing the verbal interactions of the facilitator and REUs, their language could be analyzed to answer the research questions. In addition, following Kilburn's (2014) approach of triangulating video cameras to capture visual communication in learning settings, two action-digital video cameras were placed around the room. This data was used to further augment and clarify who was speaking and what they referred to in the environment, such as books, pictures, other persons, etc. to aid verbal analysis. The video cameras were setup and not moved during data collection. During public engagement events, two facilitators floated between REUs using hand-held digital audio recorders and began recording once the REU initiated the player reflection with members of the public. Pictures were also taken when opportunities presented themselves. The researcher for this study kept a research journal to record thoughts, impressions, and descriptions of noteworthy moments, which he completed at the end of every meeting, consultation, and public engagement event.

As Gee and Green (1998) note, ethnographic data collection methods work well with sociolinguistic analysis because the researcher is embedded in the context, working closely with participants as either an observer or participant observer. While this study does not use ethnographic methods, the author was a researcher in an ethnographic study of the same program the year before where, as a researcher, he was an observer (Bowers, Jordan, Fischer, Holman, & Evans, 2019) and facilitator (Evans & Jordan, 2019). This is described in the Prior Research/ Pilot Study and also Researcher Positionality sections. This intimate familiarity with the context and experience with the types of learners that took part in the program allowed the researcher to collect data from the context only relevant to the public engagement project while still having a sense of how it fit into the overall program. Moreover, the program's structure and key scientists, researchers, and administrators remained the same between 2017 and 2018, meaning that there were no significant differences between the program as studied in 2017 to that when this study took place. As a result, the researcher's data collection process focused on collecting verbal interactions occurring within the public engagement project that could be analyzed through cohesion.

Data Analysis

Once the audio data had been collected, the audio files were organized in files according to the name of the meeting, consultation, or public engagement event. The player reflections were categorized by the REU who conducted the player reflection and the players were assigned numbers, i.e. "Player 3". Then these audio files were transcribed keeping in mind that the transcription format is in part a kind of interpretation in that spoken words, gesture, and relevant details of the environment are represented in a

text (Ochs, 1998). The type of representation appropriate for this study's use of cohesion would be a verbatim rendition of the speaker's words to catch the smallest words, such as indefinite articles (a/an), as faithfully as possible. While in Gee's approach to discourse analysis, a line is made up of one intonation contour and such lines can be ordered into stanzas to show how the text is structured and the language fits together (2014a). In addition, these stanzas are labeled according to how the line/stanza functions in the overall structure, depending on the genre, such as the exposition and inciting event of a narrative. That approach is particularly useful for long stretches of speech, especially in interviews where a speaker is expressing themselves during in-depth interviews that can last over an hour. This study did not take that approach with structure, nor would it have been appropriate in many cases with player reflections because they were short interactions, two to three minutes long. The talk turns are relatively short and generally indicate more of a back and forth between the REU and player instead of a one-sided interview where the interviewee is expected to speak on a topic until they have exhausted it. The player reflections were conducted as conversations the name implies guided by undergraduates attempting to do public engagement which does not have the same interactional goal or positionality as an interview, though as Chapter 4 indicates, the REU certainly set the agenda for the conversation and at times elicited information from players.

As a result of these important differences in context and the nature of the texts they produced, this study does not rely on lines based on intonation contours and stanzas. Rather, this study interprets structure in terms of cohesion by way of references, conjunctions, substitutions/ellipsis, and lexical cohesion, meaning that the text fits

together through lexicogrammatic relations (Halliday & Hasan, 1976). By and large, these aspects of the language are not dependent on how the speaker’s intonation or emphasis to be represented in a text and interpreted during analysis. Likewise, cohesion, in the Halliday and Hasan sense, does not rely on a participant to express themselves through genres, like narrative and argumentation, for the text’s shape to be interpreted. As a result, the end of a line in this study’s transcripts is an arbitrary occurrence based on the limited amount of space set by the margins.

Moreover, any pertinent observations in the researcher’s journal or included in the video recordings in terms of gesture, who is speaking to whom, and what objects, persons, or places are being somehow indicated other than through speech, can be included in the representation. As such, the transcripts in this study follow the below conventions:

Table 3.3

Transcription Conventions

Symbol	Use
--	interrupted speech
(????)	inaudible / unintelligible speech
[]	action, gesture, or notation of object, person, place, or thing
. , ?	standard punctuation

The first data to be analyzed was from the public engagement event where all transcripts were analyzed according to discourse analysis through cohesion. As noted in Chapter 1 and 4, the data was analyzed in this order because it was the culmination of the project and a crucial test, to sort of speak, of whether such a project and this level of students could position themselves as experts and enact roles and social identities for

public engagement. The first step was an open reading of each player reflection to determine what linguistic features stood out and if any general patterns emerged. On printed hardcopies of the transcripts, these noteworthy stretches of text were highlighted and noted. This was done to become familiar with the general shape of the player reflections, their typical beginnings, middle, and, endings. Using the analytic software NVivo version 12, the next step was to upload the transcripts as Word documents and code each utterance according to the speaker (e.g. Facilitator, Howie, Player 4, etc.). This was done to be able to retrieve more easily who and which type of participant used which question types and other cohesive markers.

The analysis with cohesion started with labeling every occurrence of reference, substitution/ elision, conjunction, lexical cohesion, and question type. This included labeling by each of their subtype, as in labeling an instance of the conjunction “but” as a contrastive conjunction. By its nature, cohesion links parts of a sentence together and also sentences together through lexicogrammatic (vocabulary and grammar) relationships (Halliday & Hasan, 1976). Halliday and Hasan note that these linkages refer to past meanings (or future) meanings in the text or to the environment in which the text is made, which can be the immediate or distant social situation. In terms of analysis, this required that each cohesive device be further interpreted to determine what is being linked and what that relationship means and then taking it the next step, what is the speaker doing with words. For example, a reference “we” was understood to be first person plural based on its lexical meaning. However, clues as to whom is being referred had to be interpreted through clues in the text, other instances of the same personal reference, who was speaking, is it an answer to a question? In this way, each cohesive device was interpreted

to determine what is being linked together and further interpretation of intention could be derived. Of special note, is that conjunctions were interpreted last because they express relationships between entire word groups, which often contained cohesive devices, that needed to be interpreted first in order to see how the larger structures that conjunctions formed could be understood. These interpretations were made as annotations in Nvivo. Then these annotations were written as analytical descriptions that identified what roles and social identities were being enacted either by a single kind of cohesive device or cohesive devices working in concert with each other.

Another analytical approach used was to consider what a speaker could have said, but did not (Gee, 2014c). This was a way of checking the interpretation against what other opportunities a speaker could have taken at a role or social identity level down to a specific cohesive device. It was also a way of comparing how REUs positioned players differently and players accepting a positioning or refuting certain assumptions of the REUs.

With the analytical descriptions, arguments were devised and then compared to other player reflections to test if the former still is able to describe what is happening accurately and to note important differences. Doing this comparative process indicated what could be considered a typical instantiation of a role or social identity as well as important and unique ones. In doing so, key findings were developed. Moreover, these key findings from the public engagement events led the analytical process to focus on two participants, Vic and Howie, for reasons that will be explained fully in Chapter 4 to explicate the roles and social identities the project offers these REUs during the

facilitated design process. The same analytic process of labeling the transcript for cohesive devices by subtype, interpreting what is being linked or related through the device and annotating this, as well as the proceeding analytic descriptions and comparing as described above.

The findings based on this process just described will be explicated in the following chapter.

CHAPTER 4

FINDINGS

This chapter focuses on explicating the key findings of the data analyses conducted in this study as they relate to the research questions and the literature review previously described. As discussed, this study is concerned with exploring what social identities and roles the participants enact discursively over the course of a public engagement game project. Through the guidance of a facilitator, REUs (research engineering undergraduate) designed a public engagement game and then shared it at a public engagement event. This chapter begins with findings from the latter first, focusing on the enactments REUs, members of the public, and to a lesser degree the facilitator, took part in during the public engagement event because it is the culminating step of the project. For this reason, Part 1 of the findings focuses on what social identities and roles the REUs and their players enact discursively when they discuss their player experience after playing the game. Part 2 turns this study's focus to the facilitated design process and the social identities and roles REUs enact discursively. The design process includes the meetings and consultations that lead up to the public engagement event as well as the group reflection at the end of the project.

In both parts, these findings are based on data from audio recorded conversations in the settings making up a series of encounters. Discourse analysis of these encounters was conducted through the lens of cohesion, which interprets the use of lexical cohesion, reference, ellipsis/substitution, and conjunctions of discourse (Gee, 2014c; Halliday & Hasan, 1976) to interpret what speakers mean and are attempting to accomplish discursively. This includes the cohesive qualities of question asking and answering or

responding (Halliday & Hasan, 1976) Social identity is defined as demonstrating thinking, doing, being, and using the tools of a particular kind of person which is recognizable construct, in the case of this analysis, accomplished through language (Gee, 2003; 2014a). Role taking is similar to social identity, but does not include associating with a social group. Interpreting social identities and roles is important for educational purposes in that this study seeks to determine what opportunities such a project offers participants to do public engagement in real world situations during a facilitated project in which they develop and share a public engagement game with the public. Also in question, are these students enacting the roles and social identities in ways that promote dialogue between experts and non-experts in ways that are mutually beneficial and in which both sides can contribute to the interaction is also an important criterion to examine their enactments (Baram-Tsabari & Lewenstein, 2017; Trench & Bucci, 2014).

Part 1: Roles, Relationships, and Identities Enacted during Public Engagement Events

Part 1 focuses on key findings from data collected at the two public engagement events that REUs took part in. Analyzing data from this later stage of the project (see Table 3.3 for full outline) was done because this study seeks to explore the actual enactments of STEM undergraduates in real situations with members of the public. This would determine what opportunities such a project provided such learners to do, be, and think as scientists taking part in public engagement. In turn, these findings would speak directly to Research Question 2 and speak to what aspects of public engagement and dialogue STEM undergraduates are ready to enact at that point in their development as future scientists.

What follows is an in-depth discourse analysis of the player reflections that REUs conducted at the public engagement events where they spoke with 39 players of their games. As such, this chapter will present a summary of key findings for Part 1, followed by a brief description of these key findings, including a section on the use of personal references, then cover a detailed explanation of the analysis to illustrate these claims.

Summary of Key Findings for Part 1

To begin a summary of Part 1 key findings, during the public engagement events, REUs most frequently enacted the social identity of science game designer and the role of educator. The sociotechnical role was performed less often and mostly by one REU. In general, the REUs and players enacted the overarching roles of interviewer and interviewee, respectively as the former asked questions and the latter answered/responded until there were no more questions.

The second key finding was that both REU's and players make direct bids to be taken as certain kinds of persons through personal references, particularly first person singular (I) and plural (we). The third key finding is that REUs used their game's design features to help enact the science game designer social identity and science educator role. For example, when the game was about science concepts *and* the REU assumed a science educator role, then the REU used their game to help teach the player and the players frequently assumed the learner role. Moreover, when the game was about Arizona's solar energy and the REU asked open-ended questions about the player's experience, then players often assumed a local Arizonan social identity as well as other roles and social identities. As a result, the game's design and the REU's choice of approach for player reflections influenced what roles and social identities they and the players assumed.

These key findings will be briefly described in the following sections before presenting the full analysis that led to and that support them.

Brief Description of Key Findings for Part 1

During the public engagement events, the REUs enact the science game designer social identity and science educator role most commonly. When REUs enact the former, the players are positioned in the corresponding role of playtester and take up this role. Likewise, when an REU assumes the role of science educator, this positions the player as a learner. However, sometimes players reject this role by refuting the assumption that the game teaches solar energy. One REU enacts a sociotechnical role in which she seeks to establish the player's relationship to science and/or solar energy. This role has been singled out because it leaves the player's role and social identity open to how the latter relates to science and/or solar, meaning they can speak as a person curious about solar energy, critical of the solar energy field, a consumer, a professional, or local Arizonan.

The science educator role is based on interactions that can be characterized as reviewing and sometimes correcting what the player *should* have learned by playing the game. This claim is demonstrated by the nature of the cohesion between REU questions and the player answers/responses, demonstrative references REUs use to refer to their game and science concepts (game content), and an ellipsis/ lexical cohesion sequence. To begin with, cohesion between REU questions (**wh** questions and polarizing questions) and player answers/ responses significantly influence the enactment of roles and social identities. Often, the questions are the points at which the REU first asserts a role/social identity and positions the player in a corresponding role (see Table 4.1). For example, Howie often assumes a science educator role and positions the player as a learner by

asking “So what did you learn...?” after playing his game. The “what” question type asks for the other speaker to supply content or information, in this case science concepts that the game presumably supports the learning of. The player can answer directly, thus accepting the role of a learner. Moreover, Howie’s questions can include demonstrative references to specific features of the game (“The A, R, T” in line 2035) and also science concepts themselves, sometimes simultaneously as the game represents solar energy concepts.

Table: 4.1

Occurrences of Lexical Chains by Questions and Statements

Question/ Statement #	Line numbers	Question or statement	Lexical Chains				
			play	learn	solar	game	
1.1	2001-2006	Howie: What I always like asking first is would you play again?	play (3) that it (2)	learn			
1.2	2007-2015	Howie: So what do you think you learned like if you were to tell this game as a story, what happened?	playing	learned learning memorize remembering sticks your mind that	solar it (2) technically		this game it (2) a good ol fashioned childhood game colors this that
1.3	2016-2024	F1: Do you think like you were winning in the beginning? Or you know how did your arc go?	winning losing playing this (3) that practiced				this (2) there four (2) it this part mine

*Note. Instances of lexical chains with an asterisk * indicate that the word could belong to more than one lexical chain. For example, the in 1.6 solar lexical chain could also refer to the game itself and belong to the game lexical chain.*

Table: 4.1 (continued)

Occurrences of Lexical Chains by Questions and Statements

Question/ Statement #	Line numbers	Question or statement	Lexical Chains			
			play	learn	solar	game
1.4	2025-2029	Howie: So compared to a regular game of Mancala do you think this was harder or easier?	counting that it (2)	think		a regular game of Mancala it (2) this harder (2) easier Mancala This one that mindless game
1.5	2030-2034	F1: Which part did you have to think about?	which (part)	think mixed up? remember		The A R the Ts (2) which (2) red that (3) the one took away stuff random things

*Note. Instances of lexical chains with an asterisk * indicate that the word could belong to more than one lexical chain. For example, the in 1.6 solar lexical chain could also refer to the game itself and belong to the game lexical chain.*

Table: 4.1 (continued)

Occurrences of Lexical Chains by Questions and Statements

Question/ Statement #	Line numbers	Question or statement	Lexical Chains			
			play	learn	solar	game
1.6	2035-2049	Howie: Do you remember what A R and T stand for?		remember (3) Got it think stand for?	A (4) / (an) R T* that (3) the one Auyur radio laser trap (2) it	the half jumpity thing The R* The T* trapped away* They leave the board That* (2)
1.7	2050-2057	F1: For enduring this game with Howie here's your solar cricket.	Enduring playing	studied learn geek out	here your solar cricket this* mechanical (science) engineering (science) this it it*	this game

*Note. Instances of lexical chains with an asterisk * indicate that the word could belong to more than one lexical chain. For example, the in 1.6 solar lexical chain could also refer to the game itself and belong to the game lexical chain.*

In addition, the ellipsis and lexical cohesion sequence is done cooperatively between the REU and player, indicating they are enacting the science educator and learner roles respectively. They elide, or omit, clausal groups and replace and repeat the correct science information. For example, in the extract below, Player 3 answers Howie's question by stating what she "remembers" from the game. Then Howie repeats the part that is right, "A" while making a new clausal group with it to make the correction "A was Auyur":

2036 **P3**: I remember A one did sound like it started with an A [laughing]
2037 That's the one I remember.
2038 **Howie**: So yeah A was Auyur
2039 **P3**: Auyur yeah
2040 **Howie**: Yeah and that's when the half jumpity thing.
2041 **P3**: Yeah

Notice that Player 3 repeats back "Auyur" which is the answer Howie is looking for, but she elides the rest of the clausal group focusing closely on "Auyur." This repetition is lexical cohesion occurring between speakers, like an echoing between teacher and student, the former correcting while the latter is repeating to give the correct answer. Moreover, Howie elaborates on what Auyur is by using the demonstrative reference "that" (2040) to refer to Auyur and then lexical cohesion using the general noun "the thing" with modifier "half jumpity." This modifier is a description of how the game mechanic works in his game, beads being moved or jumping around. This also demonstrates how an REU uses their game to help enact the science educator role by referencing a design feature. Altogether, these uses of questions, demonstrative references, ellipsis, and lexical cohesion indicate Howie is checking for learning and

reviewing solar energy concepts with the player, and so is taking the role of a science educator.

As noted above, REUs act as a science game designer (social identity) and science educator (role) multiple times in any given player reflection. The start, stop, and continuation or changing of a social identity/role occurs concurrently with lexical chains starting and stopping and continuing based on what enactment is being attempted. In other words, lexical chains are an indication of and help produce shifts in roles/ social identity. Continuing with Howie's player reflection with Player 3, Table 4.1 shows the *learn lexical chain* appearing during Questions 1.1 to 1.2 when Howie takes on the science educator role, but stops in Question 1.3 when Howie shifts to enacting the science game designer role. The *learn lexical chain* becomes prevalent again when Howie asks what the player remembers about science concepts in Question 1.6 which is where he resumes the science educator role. Also, it is at this point that the *solar lexical chain*, which contains references and nouns associated with solar energy concepts. Both lexical chains appearing concurrently is understandable because this is where Howie tests and reviews solar energy with the player as just described in the paragraph above. In this way, lexical chains show how the text fits together around particular topics as the REU and player assert and shift how they are being in the conversation in terms of assuming social identity and roles.

Participants Make Direct Bids through Personal References

The second key finding for this study is that both REU's and players make direct bids to be taken as certain kinds of persons through personal references, particularly first person singular (I) and plural (we). For REUs, this most often occurs through the plural

“we” and the possessive form “our” when they associate themselves with their research laboratory, the Solar Energy Center program, and even the scientific community at large. This is interpreted as a bid to be taken as the social identity of the scientist as it associates themselves with science. Moreover, when it comes to players using personal references and other demonstrative references to enact a social identity, players often assert their belonging to the local Arizona community using “we” and demonstrative references to “the sun” and circumstance reference “here.” At times, which social group the player refers to is not clear when using “we” because there is not additional references and other contextual clues. In these cases, players likely are referring to Arizona, their country, and/or possibly the world. In addition, the facilitators also position the REUs as experts and/or scientists of solar energy through personal references such as “he” and adversative conjunctions that work to differentiate the facilitator from the REU in terms of the latter being an expert and/or a scientist and the former not an expert.

The last key finding for Part 1 of the Findings is that the REU’s game design can coincide with their particular approach to conducting the player reflection to result in influencing which roles and social identities players can enact during the player reflection. More specifically, when the game is about solar energy concepts that is considered specialized knowledge, such as recombination, and the REU acts as a science game designer (social identity) and science educator (role), the players often only enact the playtester and learner roles respectively. However, if the game is about an aspect of solar energy that is a part of a local Arizonan’s knowledge system and the REU assumes a designer/educator, then the player speaks to that topic as it relates to their social identity as a local Arizonan. In other words, if the game is about something that touches on who

the player identifies themselves as, then that social identity can potentially be enacted and they respond from their particular way as that kind of person. This claim is based on a comparison between REUs who take the former approach with their game and player reflection, such as Howie and Cherry, versus Vic who takes the latter.

Participant Use of References

This section gives special attention for how REUs and players use personal references as well as demonstrative references during player reflections. The subsections are divided by which kind of participant (REU or player) and the type of reference (e.g. first person singular “I”) is being highlighted. References serve as important ways that the participants use language in terms of role taking, making bids of social identity, and shaping their relationship to other speakers as well as the local community and larger contexts. Moreover, they are used in such a way that this type of cohesion can be interpreted on its own by and large though with some exceptions. However, most of the cohesive properties must be analyzed together as they work in concert in making the text fit together and so cannot be so easily isolated as references. As a result, the below section on references will be followed by the remainder of the chapter in which all of the types of cohesion will be analyzed together.

REU use of First person plural “We” and “Our”. For identifying as a scientist, Cherry uses the first person plural personal references “we” to associate herself with those who are doing research. She also uses the possessive form “our” with nouns such as “research,” so that she connects herself collectively to what researchers do and the scientific community. One point is that she uses the avowal conjunction “actually” to set

her research apart from other areas of research in regards to energy and PV solar energy research.

2737 **Cherry:** So **we** are actually working on the efficiency of these solar cells for
2738 right now. Well that's what **our** research is based upon.

Carter uses “we” with Player 27 in a similar way as he describes what researchers want to be happening in a PV solar cell, what the engineering challenge is for himself and the researchers he works with.

11 **Carter:** Right, the silvers conducting but like if I really go into it, it's more that
12 it traps light within the solar panel. And **we'll** try to keep it there as long as
13 possible to gain as much energy from it. So like it'll go through the front of it
14 and kind of bounce around in it until (????)

REU use of First person singular “I”. Carter uses “I” with Player 27 to speak as an expert on solar energy line 11 above. The conditional conjunction “if” sets up the situation as being him explaining a science concept in depth and the result is his explanation. Howie uses “I” to refer to himself as a science game designer:

2001 **Howie:** Quick question. What **I** always like asking first is would you play
2002 again?

2003 **P3:** I'd play again yeah. I do like that.

2004 **Howie:** **I** always find it important because it's one thing to learn by doing
2005 it. It's another to want to play again.

REU use of “you”. REUs use the second person singular and plural frequently, particularly in the questions they direct at participants, which is often to speak to them as players of the game.

2115 **Howie:** Ok so one question I always like to ask first is would you play it
2116 again?

2117 **P5:** Yes

2118 **P6:** Yes of course

In this way, the personal reference such as “you” can be a way of associating a player with a particular role. Another common role that REUs position players is as a learner:

2161 **Howie**: So does that help **you** understand a bit more?

2162 **P5**: Yeah it's interesting

2163 **Howie**: Yeah and **you** can think about all of this energy moving around the

2164 board as electricity flowing through a circuit

Naturally, it takes more than just the reference “you” in the excerpt for the REU to position the player as a learner, however, it performs an important function in this regard because of how it puts the player on the spot, gives them responsibility and accountability at the individual level and speak from that point.

Here Vic uses the second person plural “you guys” to ask both players the same question and it is not to position them as players but seeking to establish what relationship they have with science:

2493 **Vic**: So you guys have science backgrounds at all?

2494 **P13**: No

2495 **P14**: No

2496 **Vic**: Why that? Science isn't that bad

2497 **P13**: No nothing like that

Moreover, the “you” refers to the player of course, but it can associate players with certain social identities and be a way of speaking to the player as a kind of person they are making a bid to be taken as. For example, Player 14 states “I’m very interested in solar as far as... getting a house.” He is speaking aspirationally as a person who wants to buy a house and having solar panels on it, meaning he is speaking as a potential homeowner and essentially as a consumer (social identity). Vic then confirms this bid using “you” to explain how solar benefits him *as* a consumer (lines 2509-2510):

2504 **P14**: It's interesting and actually I'm I'm very interested in as far as solar

2505 thinking about you know getting a house and solar panels and you know

2506 So it's it's it's-

2507 **Vic**: Right it's definitely something to look into because--

2508 **P14**: Especially with the world right now

2509 **Vic**: Yeah and for the long run especially if **you're** looking for cost that

2510 definitely will benefit **you** definitely

Players use of first-person plural “we”. Player 5 uses “we” to refer to himself and Player 6 as a team and competitors against Howie. Player 6 uses it to refer to themselves in their experience as playtesters (role). However, Player 5 uses the first person singular as he gives a contrary evaluation of the game.

Many of Vic’s players use “we” to refer to themselves belonging to a larger social group which is defined by the circumstance reference “here” and demonstrative reference and noun such as “the sun” or quantifier modifiers “a lot of sun” and “so much sun.” These two other references indicate that the “we” refers to the local community and since it points to the location of where the player is and Arizona is associated closely with the sun and sunlight, the study concludes it is a reference to being an Arizonan (social identity). At times the player will specifically identify “Arizona” along with these references:

2440 **P10**: I didn't think that **Arizona** actually used a lot of solar panels **here**

2441 **Vic**: Really?

2442 **P10**: Yes so that's why I said top five but yeah

2443 **Vic**: And why did you think that?

2444 **P10**: Because I don't see many. I do see a lot, but I don't see as many as

2445 **we** should since you know **we're Arizona. We get a lot of sun**

Players use of first person singular “I”. Most often players use “I” while speaking as a player role, which is understandable because most of the REUs assume a science game designer social identity and seek to elicit the player’s feedback using “you” in their questions, thus directing players to speak from their perspective, hence use “I”:

2025 **Howie**: I may have practiced a little. So compared to a regular game of
2026 mancala do you think this was harder or easier?

2027 **P3**: I think it's harder because just like regular mancala is just you
2028 counting and that's it. This one makes you think a little bit more about it
2029 which I like. It's a better twist than that mindless game

At times, players use first person singular, or “I,” to identify themselves by way of their profession. Player 20 does this by stating, “I am a jeweler so we do a lot of problem solving,” where she refers both to herself as a jeweler and also with “we” to her profession. The causal conjunction describes this profession in an *a therefore b* logical conclusion in that because she is a jeweler, therefore she uses problem solving. The quantifier “a lot of” and the head “problem solving” is relevant to the topic of engineering and technology and so she is expressing how she fits into the engineering and science field, how she relates to it *as* a jeweler (social identity).

Player use of second person “you”. Players can also use “you” as a general exophoric reference to refer to any person who is in the same situation that is being talked about. Like REUs, here a player uses this version of “you” to refer to any person playing the game and is a way of talking about the rules from the perspective of the playtester role:

2119 **P5**: We would win. (laughter) Because now I understand **you** can't just
2120 grab random piles.

Player use of other personal references. Players at times use “we” in a non-specified, broad way that could refer to a social identity tied to the local community or the nation or world. However, there is a lack of additional contextual clues, such as those that might be proved by references to circumstance, that would help define what social identity is being enacted. For example, below Player 20 states “we need to rely on solar

power more” (line 52), the “we” might refer to local Arizonans or all Americans or perhaps even the world. However, there are not enough additional clues to interpret which social identity she is enacting. Yet, there are numerous possessive personal references, personal references, and other cohesive devices in the extract below to make the claim that Player 20 is enacting the social identity of daughter for herself and then references to her own daughter (she), implying her identity as a mother:

50 **P20: My dad** worked in the automotive industry for **his whole career**. He
51 worked for Ford **he** was **an engineer**. Energy is a big deal and **she** knows that.
52 **She** knows that **we** need to rely on solar power more.

Here the player refers through personal pronoun possessive form “My dad” to her father and “she” to her daughter. The player is associating herself and her whole family to engineering and valuing technology and solar energy. She does not refer to herself personally, but she is the logical bridge between generations for these values passing down. This is shown through the demonstrative reference “a big deal” to refer to energy and it is a declarative statement, like a truth or factual statement that is connected to her daughter by way of the additive conjunction “and.” In lexical cohesion terms, the player repeats “she knows that” to emphasize this point of what her daughter is aware of, what is being passed down from mother to daughter. In this way, this player is establishing her relationship to science by way of her father’s profession (social identity) and her social identity as a mother passing down knowledge to the next generation.

Enactments of Roles and Social Identities at Public Engagement Events

This section of the Findings uses all of the cohesive devices to analyze player reflections that are typical of what they demonstrate in terms of enactments or unique in important ways. The subsections are divided by what key social identities and roles are

being enacted either by an REU or a player. The analysis is meant to describe through cohesion what kinds enactments are being attempted and if it is being accomplished.

Science Game Designer Social Identity and Science Educator Role. Howie's player reflection with Player 3 illustrates the typical enactments of the REUs and the player(s). At the arts festival, Howie shares his board game *Solar Mancala* with Player 3 who is a female in her late teens to early twenties and a university student. Howie and Player 3 stand by the game while the facilitator stands beside Howie with the audio recorder.

Howie begins this player reflection with a polarizing question "...would you play again," a question that seeks a "yes" or "no" answer from Player 3. On the face of it, an affirmative implies that the player thinks Howie's game is good or she has a positive attitude toward it. A negative implies the opposite, that she does not like the game if she would not want to play it again. This type of question and use of the personal reference "you" puts the player on the spot to give an evaluation of the game based on her perspective. The yes/no is then information provided by a person with direct experience with the game and so puts the player into a position of giving player feedback, meaning Howie is inviting her to take on a playtester role. When considering that Howie designed the game and he is asking this question, it suggests he is eliciting this player feedback which a designer would want to know or care about. As a result, this is a key way that he and the other REUs enact the science game designer social identity.

Other cohesive devices in lines 2001 to 2006, support and elaborate on this interpretation of what Howie and Player 3 are doing discursively. To begin with, Howie's

question starts a lexical chain for play in which he states “play again” first, she repeats it, and then he repeats it again as shown in Question 1.1:

2001 **Howie**: Quick question. What I always like asking first is would you play 2002 again?

2003 **P3**: I'd play again yeah. I do like that.

2004 **Howie**: I always find it important because it's one thing to learn by doing 2005 it. It's another to want to play again.

2006 **P3**: Yeah

The *play lexical chain* suggests the prominence of playing the game for this question.

Both use the personal reference “I” to refer to themselves, meaning that they are speaking from their perspective. In this way Player 3 is giving her perspective on playing the game, which is what can be considered player feedback in terms of a game design process. Howie also uses the first person to speak from his perspective which is different from what Player 3 is speaking to even though they both played the game together.

Howie’s use of the temporal conjunction “first” in line 2001 conveys an importance to this question he is asking, meaning he values it above other questions. He communicates just as much and more in line 2004 with the causal conjunction “because” which establishes the *a therefore b* relationship is between a) the importance of “it,” which is an extended reference and textual reference and b) to the notion of the importance of a player wanting to play the same game again along with two notions that he compares to each other. The first is that a game teaches something and the second is that a game is designed in such a way that players want to play more than once. Howie indicates the latter is more important and so is the result of the causal conjunction, meaning that he values that design aspect of his game. As such, Howie is giving a rationale for his question and expressing an aesthetic choice he makes for game design. Both eliciting

player feedback and making a statement about aesthetics are expressions of Howie's enactment of the science game designer social identity. Moreover, Player 3's confirmation to his question "yeah" demonstrates that she is accepting the role of playtester as Howie attempts to elicit player feedback. The second and lesser aesthetic, the educational aspect of the game, is still worth noting because it is the first instance of another lexical chain, the *learning lexical chain* that will be examined in greater detail below.

This role taking of Player 3 as a playtester and Howie as a science game designer continues with Question 1.4 (See Table 4.1). Here Howie asks in lines 2025 to 2026, "So compared to a regular game of mancala do you think this was harder or easier?" which again uses the personal reference "you" directing the Player 3 to speak from her perspective. The alternative conjunction "or" establishes that the player is to choose between "harder" or "easier," a choice between two comparatives that compare his version of *Mancala* and traditional *Mancala*. The player answers in part "harder," repeating the choice offered in the question. Right away, she is giving an evaluative statement of Howie's game, which she does through the generalized exophoric reference "you" which refers to anyone playing the game, meaning she is not just recounting her experience or an opinion but giving an evaluation of the game:

2025 **Howie:** I may have practiced a little. So compared to a regular game of
2026 mancala do you think this was harder or easier?

2027 **P3:** I think it's harder because just like regular Mancala is just you
2028 counting and that's it. This one makes you think a little bit more about it
2029 which I like. It's a better twist than that mindless game.

Part of Player 3's answer is making an argument, in this case an evaluation of Howie's game, and then supporting it with evidence. Her argument, that Solar Mancala is "harder"

is supported through the causal conjunction “because” which mean that her following clause(s) are the causes or reasons for the fact. She states in reference to Howie’s game “This one makes you think a little bit more about it,” which has two important cohesive devices at work. Her use of “you” is of course not a reference to Howie, but is a generalized exophoric reference of anyone who plays the game. In this way, she is giving feedback that would be true not just for herself but for all players. This means she is not just sharing her experience, but her judgement of how the game in terms of what kind of experience it offers players. She does this again in line 2029, stating in reference to the game, “It’s a better twist than that mindless game.” Here the comparative “better... than” compares the two games on a quality, the “twist” or novel surprise between the two, expressing that *Solar Mancala* is better in this regard.

Moreover, Player 3 uses the demonstrative reference “that” to refer to traditional Mancala, a reference that conveys a distancing to begin with and also has the modifier “mindless” which conveys even more of how the player interprets the game in a negative way. On the other hand, she states that, “this one makes you think,” in reference to Howie’s game. Again, she uses the general exophoric reference “you” to refer to anyone who plays the game, so she is giving an evaluation of the game that is to apply to anyone playing. She uses the demonstrative reference “this” which implies a closeness as opposed to the distal “that” she uses for traditional Mancala. And she uses “think” to describe what the player does while playing. The verb is in opposition to “mindless” traditional *Mancala*. All of these cohesive devices in the way she describes *Solar Mancala* versus traditional *Mancala* clearly convey her giving a positive opinion and supported evaluation of the former.

Taken together, she has enacted the role of playtester demonstrating her acceptance of this positioning and the relationship that it forms between herself (playtester) and Howie (science game designer). Their relationship can be described as the member of the public supplying information that is other than what he can offer himself in regards to evaluating the game. Moreover, her opinion has value in this way and she has the authority to speak her mind within the confines of the questions. In addition, it would be expected that she is speaking honestly otherwise the information she gives has less value or does not give an accurate evaluation, defeating the purpose of the conversation.

In summary, numerous cohesive devices are used by Howie and Player 3 during Question 1.1 and 1.4 to form a science game designer and playtester relationship. Howie's use of the personal reference "you" in the questions asks her to answer from her perspective, a hallmark of player feedback in game design. Player 3 not only speaks from her perspective using the first person singular personal reference "I" while answering, she also uses the general exophoric personal reference "you" to make statements that apply to anyone playing the game, suggesting she is evaluating the game. She uses comparative reference to distinguish and value Howie's version over the original version of *Mancala* which it is based on. In terms of lexical cohesion, Player 3 repeats back words and clauses of the question while supplying the information the question pointed to, which indicates she answers directly and is participating as positioned in the interaction. Moreover, causal conjunctions are used in supporting their argument. In Howie's case, he expresses the importance and value on players wanting to play a game more than once, indicating his ethos *as* a science game designer. In Player 3's case, she supports her

evaluation of Howie's game through the causal conjunction. Asking such questions is a way of gathering feedback about a design, to understand how a player experiences his design and not just getting a positive or negative appraisal of the game. In fact, Howie's questions seek to answer if his design meets his design goals of being replayable and somehow distinct from traditional *Mancala* in a way that he values, which is its overarching purpose of teaching science. In this sense, the science game designer social identity is in service of disseminating knowledge and the player participates in this by way of playtesting to help create a better educational tool.

Science Educator Role. Another role that Howie attempts to enact during his player reflections is the science educator role. This is evident from Questions 1.2 and 1.6 in the player reflection with Player 3. Like the science game designer enactments, questions serve as an important discursive tool for the REU to attempt to do something with words which requires the responder to either accept or reject how they are being positioned. In other words, the player has the choice of playing along.

In Question 1.2, Howie asks what the player "learned" along with the personal reference "you" making the question about her personally. To ask the player to supply such information can be seen as a kind of test in two ways. First, it potentially is a teacherly question in which a person taking an educator role seeks to check for learning after instruction (in this case playing the game) has occurred. This points to the assumption Howie builds into the question that is that his game teaches something. He could have asked a polarizing question on this topic, such as "Does this game teach?" Instead, he chose to ask, "what" the game teaches putting her in the position of supplying that information and in the role of a learner. So the question suggests less of a focus on

eliciting feedback about the game, but what the player should possess as a result of playing the game.

Player 3's response in line 2009 and 2010 in the first person singular personal reference "I" corresponding to the "you" in Howie's question, and she repeats the verb learn, indicating she answers his question directly. Within her talk turn she also uses "memorize" "remembering" and "sticks" which is a continuation of the *learning lexical chain*, indicating two important things (see Table 4.1). Considering she is directly answering the question and continues on the topic of learning, she accepts the assumption that the game teaches and that she has learned something. That something will be explored in a moment, but the other important point is that the verbs of this chain indicate that learning is in the form of memorization. What is it that the player is supposed to have memorized makes a closer examination of her answer worth while. Her answer starts the lexical chain for *solar* as it is stated and then pointed again through the reference "it" (line 2011) but there is a distinction between learning how to play the game and learning the game's representation of solar:

2009 **P3**: I would pretty much describe it as playing a good ol fashioned
2010 childhood game but then learning about solar at the same time and then
2011 being able to like sit there and try to memorize it. You have colors and like
2012 you have good ways of like remembering oh this goes in that (???)
2013 **F1**: Right.
2014 **P3**: ...even if it's not technically right. It like it sticks in your mind and
2015 that might (???). So I like that.

In lines 2011 to 2012, the game lexical chain is continued through "color" and references to the game's beads, through "this," and the cups, through "that," and the verb "goes" to describe the action of playing the game. Keeping in mind she uses "remembering" which is part of the *learning lexical chain*, she expresses the notion that what she has learned by

playing the game is the game itself, as in the game's rules. This interpretation is supported in the next question, this one as a follow up by the facilitator:

2030 **F1**: Which part did you have to think about?

2031 **P3**: The A R and the Ts. I would get mixed up on which was which but

2032 I would try to remember like oh the T was red and that was the one he

2033 always like took away and stuff like that so like random things like that.

2034 **F1**: Great.

In explaining what she has to “think about,” Player 3’s references are to the game itself and not what the game is intended to represent. For example, “The A” and the “R” and “the Ts” are demonstrative references to the letters painted on the game board. In fact, she states “the T was red,” which are two instances of the *game lexical chain*, meaning she is talking about the game but not what the T is supposed to represent in terms of solar energy. She would try “remembering,” which is another instance of the *learning lexical chain*, the letters on the game board as well as game rules “took away” to describe the action of removing beads from the board. In short, Player 3’s answers to Question 1.2 and 1.5 indicate that she is learning how to play even though the overt question concerning learning is information about solar energy. In light of how the *learning* and *game lexical chains* overlap in these answers, it further suggests that the player has learned the game.

And she expresses the notion that the game teaches solar in spite of its inaccuracy through “even with,” an adversative conjunction with emphasis, that the game is “not technically right,” the adverb here being another instance of the *solar lexical chain*, pointing to the field of knowledge. What is interesting the implication of the game not being “technically right.” It implies that the game represents solar and this representation has a limitation in its veracity and also that Howie explained, likely during their game, the science concepts otherwise she would not know that the game’s design does not

completely represent what it is attempting to represent. Even so, the causal conjunction that Player 3 uses in line 2015 is in relation to the game being able to make the solar energy knowledge “stick” in the player’s mind and her positive appraisal of that aspect. Hence, she is giving more player feedback, meaning she is continuing the playtester role in that she is commenting on the game’s ability to teach. Her use of the adversative conjunction “even with” could be taken as negative feedback with which to make improvements on the game.

In Question 1.6, Howie’s attempt to take on the role of science educator is its most overt and concentrated. Howie asks, “Do you remember what A, R, and T stand for?” which is a polarizing question that presumes that playing the game and perhaps Howie’s explanation of the game would have taught Player 3 what these three letters stand for:

2035 **Howie:** Do you remember what A R and T stand for?

2036 **P3:** I remember A one did sound like it started with an A (laughing)

2037 That's the one I remember.

2038 **Howie:** So yeah A was auyur

2039 **P3:** Auyur yeah

2040 **Howie:** Yeah and that's when the half jumpity thing.

2041 **P3:** Yeah

2042 **Howie:** The R was radio and

2043 **P3:** Yeah

2044 **Howie:** That's how laser work.

2045 **P3:** Ok

2046 **Howie:** And then the T was trap.

2047 **P3:** Trap. Got it.

2048 **Howie:** And think of it as trapped away. They leave the board.

2049 **P3:** That's so cool. I love that. Thank you.

Interestingly, Player 3’s answer is indirect. She does not answer with a “yes” or “no.” She states what she is able to “remember” which is just how one of the solar energy words sounds like, but not the full word itself or what the R or T could represent, which is a way

of avoiding answering “no” to the question. Moreover, her answer includes “A one” which seems to be an incompletely uttered “the A one” which, regardless if she meant to include a demonstrative reference, still has what can be considered a reference to what appears on the game board or to what is previously spoken during game play or possibly is an endophoric reference to Howie’s question. Regardless, this again suggests that she cannot recall, and so would have learned, what about solar Howie wants the player to have learned.

Howie’s response and the back and forth that ensues in lines 2038 to 2048 uses lexical cohesion and ellipsis in a way that indicates Howie is teaching and Player 3 accepts her role as learner. In lines 2038 and 2039, Howie states “A was auyer” to which Player 3 repeats only “Auyer.” The repetition alone shows how she is following him, repeating what he says while omitting the “A” and the verb “was,” which shows she is supplying the important information, the word she is supposed to have given in her answer. This mirroring is very much a teacher – student relationship where the latter repeats back that which is supposed to be learned or known. This repetition and ellipsis combination occurs again in 2046 and 2047 for the letter “T” and solar concept of “trap.” Moreover, after each of these mirrorings, Howie refers back to his game. In the first, he uses in line 2040 the demonstrative reference “the” and modifiers “half jumpity” with the general noun “thing” to refer to how the beads move in the game when the player lands on the trap cup. Then he speaks in a similar way in line 2048, he uses the third person plural personal reference “They” to refer to the game’s beads and “the board” for the game’s board as well as “leave” which is a description of the game’s rule of removing beads that end up in the cup.

The last instance of referring to the board is worth noting for how the science term “trap” and the game mechanic “leave the board” have a metaphorical aspect in that the game design does not simply have a letter on the board to represent a science concept. Rather, how the game functions is representative to some degree in how electrons behave in a solar cell, which Howie draws special attention to through stating “trapped away” and “leave the board” which are near synonyms for the same action of taking or removing the beads from the game and for how electrons act in a PV solar cell. Compare this to “The R was radio,” which has no such relationship to how the game works or any design or symbol on the game.

Though it is clear that “trapped away” refers to the game, it is difficult to definitively interpret “trapped away” as strictly a part of the *solar lexical chain* or the *game lexical chain*. This also goes for “The R was radio” in line 2042—the demonstrative reference could be exophoric and point to the letter painted on the game board or it could possibly be endophoric referring to “A R and T” within Question 1.6 which are themselves science concepts. This indicates how Howie’s game is a metaphor for solar concepts. As he at times refers to the game and at other times to the solar concept and then again at times the two are indistinguishable from each other. This is important for two reasons. First, this occurs during Howie’s review with Player 3 where he essentially uses his game as a tool to teach because of its metaphorical properties. This is possible, this is a viable approach to educating the player because when recalling how Player 3 answered that she learned about how to play the game in Question 1.2 and that she at times was confused about the rules and had to think about them, meaning that what she learned is how to play the game. She learned what happens when beads land in

certain cups and to a lesser degree the letters and to an even lesser degree what they represented in solar energy terms.

The claim that players are learning the game as opposed to the science concepts is further supported in Question 1.5 where the facilitator refers back to Player 3's statement that Solar Mancala made her think more than original Mancala:

2030 **F1**: Which part did you have to think about?

2031 **P3**: The A R and the Ts. I would get mixed up on which was which but

2032 I would try to remember like oh the T was red and that was the one he

2033 always like took away and stuff like that so like random things like that.

2034 **F1**: Great.

In lines 2031, Player 3 uses the demonstrative reference “the” to refer to the game itself as in the ones painted on the game board and their accompanying rules. For example, “the T and that was the one he always like took away” uses demonstrative references “the” and “that” and “the one” to refer to the trap cups on the board. The verbs “took away” and the general noun “stuff” and “things” are also instances of the game lexical chain. Keeping in mind that Player 3 struggles to “remember” these game rules and this is the verb associated with learning, these cohesive devices indicate that she learned the game or at least spent considerable effort learning the game suggesting that her attention and learning is not on what they represent in solar energy terms.

So this indicates that the player has learned one half of the metaphor, the game half or the thing that does the representing. During Howie's discursive action of reviewing the solar energy terms, he reviews the second half of the metaphor, the science part, and as much is possible, uses that game half to teach the science half as he references the game. As a result, the game itself has a role of its own in the interaction as Howie uses it as a tool, a kind of visual aid and demonstration of what he wants the

player to ultimately learn. To use his game in such a way, is another indication of Howie assuming the role of science educator, positioning the player as a learner, which her repetition of solar and game words of the lexical chain demonstrate she accepts as a learner (role).

Another example of how Howie uses his game as a teaching tool is the cohesive devices in Question 1.6 itself. The abbreviation “A, R, and T” lack demonstrative references, such as “the” which would point back to the game board, as in “Do you remember what *the* A stands for?” Without a cohesive device to point to the game, that leaves the three letters to be taken as the initials for the solar energy concepts (Auyer, radio, and trap respectively) that they abbreviate, as in solar energy concepts that belong to the *solar lexical chain*. Then again, “stand for” is associated with the notion of representation, and the game’s design has these three letters painted on corresponding cups on the board. The verb “stand for” points to a referent, or thing that is being referred to, which would be the game and an instance of the *game lexical chain*. Then again, “stand for” can also be taken as what do the letters represent in science terms. So that leaves a murky interpretation of whether “A, R and T” and “stand for” are instances of the *game* or *solar lexical chain*. Another way of considering it is that these letters are learned, are the content or things to be memorized and what it means in game terms is one thing and what it means in solar terms is another. For example, in the game “T” means to remove the beads from the board. In solar, it means when an electron leaves the flow in the solar cell. But the overall objective is for the player to learn what it means in solar terms. The right answer is not what game mechanic the A is associated with, but

what does it point to in solar energy terms even if the former is used as a tool to teach the latter.

Competitor Role

Howie is the only REU who played his game against his players consistently. This particular aspect of his approach often is referenced during his player reflections. With Player 3 as an example, this player uses third person singular personal references “he” and “him” to refer to Howie and the first person “I” and “mine” to refer to herself during the game:

2016 **F1**: Do you think like you were winning in the beginning? Or you know

2017 how did your arc go?

2018 **P3**: I thought I was losing in the beginning because I was playing him

2019 (laughing) But then I was like oh I remember this and then like you kind of

2020 like think like Oh there's four. If I do four more, I'll get it in this part of

2021 mine. I started thinking like oh maybe I might have this but he was like no

2022 I've been doing this for a while.

2023 **F1**: Yeah that's come up a lot today

2024 **P3**: (laughing) You think you-

2025 **Howie**: I may have practiced a little

These exophoric personal references recall the game play where Player 3 and Howie are players playing against each other. Verbs of “winning,” “losing,” and “playing” are instances of the *playing lexical chain* as well indicating that the game is the content of their conversation and the associations with which the conversation coheres. She shares her internal thoughts at that moment by shifting to the generalized exophoric personal reference “you” and using the conditional causal conjunction “if” to express her strategizing. The contrastive conjunction “but” then expresses how her sense of possibility is countered by Howie’s experience playing the game. From the personal references and her use of conjunctions, Player 3 casts Howie in the role of player and

suggests their relationship to be between competitors, an unequal one at that. The facilitator's reference to Howie's expertise at *Mancala* seconds that positioning and Howie speaks in the first person to refer to his level of experience, indicating he accepts the role and relationship.

So far, when a speaker enacts a role it is either through Howie asking a question or making a statement or Player 3 answering a question from Howie or the facilitator. In other words, the player does not ask questions of her own and she takes up roles in reaction or in response to what Howie offers her as he attempts to educate her and elicit player feedback. In fact for the competitor role and relationship, the facilitator's choice of "winning" as a way of referring to playing in a competitive way nudges the player to characterize her answer in those terms. At the end of the encounter, an incidental remark by the facilitator about "enduring" the game with Howie breaks this pattern. The verb "enduring" is another instance of the *play lexical chain* however the facilitator's particular word choice to describe playing with Howie as a hardship or something strenuous to overcome, provokes a response from Player 3 that is not limited to the playtester, learner, and competitor roles previously taken up, though she enacts them again:

2050 **F1**: For enduring this game with Howie here's your solar cricket.

2051 **P3**: Oh nice. I like this. I studied engineering so I like trying to geek out and
2052 learn something new

2053 **F1**: At [university]?

2054 **P3**: No I go to South Carolina so the other side

2055 **F1**: Thanks for playing.

(Other speaker asks Player 3 question)

2056 **P3**: Mechanical. So this is totally not (me?) but I love it so thank you. It's
2057 so cool.

Player 3 makes direct statements of social identity through the first person singular personal pronoun “I” in stating her major. In line 2051, she repeats the verb “like” and uses it in the first person indicating that perhaps these point to her social identity of being a “geek.” Her use of the causal conjunction “so” in line 2051 establishes a cause effect relationship between what she studies and her liking to “geek out” and “learn,” which are two forms of learning if the former is considered where learning can also take place by engaging in a participatory culture. She uses the contrastive conjunction “but” to draw contrast between solar energy not being her field yet still having a strong affinity for it, which could be taken as more player feedback. Why she makes these strong positive statements towards learning and playing the game is likely a way of defending the game in opposition to the suggestion it is somehow a negative thing to endure. In doing so, she asserts her social identity as having a background in science and personal affinity for some elements of the experience.

Interestingly enough, Player 3 does not make such statements during the questions while she is being a playtester or learner, though it could be argued her discursive actions are done *because* they relate to her social identity as a geek and science student. So it can be said that for an REU to position the player as a playtester or learner, the player does not see their social identities or other roles as available based on how the REU has shaped the conversation.

An analysis of the six players who Howie conducted player reflections with indicate this pattern of questions/statements provide particular roles for players to assume on a consistent basis. Another exception to the pattern, other than the one examined above with the competitor role, occurs when another facilitator asks Player 5 and 6, “So

do either of you have a science background?” The role taking and the relationship that his question entails will be examined below in greater detail with Vic’s player reflections as it is part of her approach to the player reflections and serves as an important departure in what roles and social identities are available for members of the public who take part in games and player reflections such as this.

Overarching Interviewer – Interviewee Roles

So far, analysis of Howie’s player reflection with Player 3 covers how he conducts the conversation from question to question. They show how Howie to a great degree and the facilitator to some degree are responsible for positioning themselves and other speakers in the encounter through question asking. The player reflection begins with Howie asking his first question (line 2000) and it ends after his review of what A-R-T mean, which is his response to her not being able to answer his question (line 2035). That is the last question. Asking six questions of the player is a repetition, a lexical cohesion, in itself which in many ways is that which the text hangs on and gives the encounter its structure. The fact that the source of this cohesion is due to Howie, and to a lesser extent the facilitator, asking the questions, indicates who is responsible for shaping the context of the player reflection, steering the conversation to particular topics (as shown through the shifting lexical chains), which is even more telling since the questions and answers serve so powerfully in positioning. The important exception being when Player 3 takes the initiative to defend her association with the game (lines 2050 – 2057).

This preponderance of question asking suggests that Howie is also assuming a kind of guide role or interviewer role when considering that he is often seeking information, gathering data on questions he has. He is expected to ask the questions and

the player is expected to answer them and the encounter concludes when the former has no more questions, which is essentially how the player reflection unfolds. Moreover, if Howie is taking a kind of interviewer role, that invites the player to be an interviewee, a source of information and in some ways a subject in an experiment considering it is being conducted by an undergraduate engineering researcher. Player 3's direct and indirect answers indicate her participation. So it can be said that Howie, Player3 and potentially all of the REUs and players in the public engagement events are taking on the overarching roles of interviewer and interviewee, respectively. Even while Howie is enacting the science educator role as described above, he is still discursively performing the role of interviewer in a general sense as he asks questions. Note that in findings for Vic's player reflections, she at times asks questions as an interviewer would and does not assume an additional more specified role until after the player responds (see Interviewer (Limited) – Interviewee Roles).

In summary, an analysis of cohesion in Howie's player reflection indicates he primarily attempts to take on the role of science game designer and science educator. In the above encounter, Player 3 accepted this positioning, participating in the conversation as a playtester and learner respectively. Also, the player is able to continue the playtester role at various points in the encounter even if Howie's question positions her to be a learner (Question 1.2). In both roles, the player is answering questions, supplying information that is sought in the question word whether a **WH** question or a polarizing question (yes/no). And Howie is seeking information in one case that is useful to him as a designer as in the feedback is what a designer wants to inform his design process. Naturally, Howie already knows the answer to what the A-R-T mean. It is not for his

benefit in the same way that player feedback tells him something he does not know. This demonstrates that he is checking for learning as a teacher does and is able to be taken as capable of doing so if he conveys the sense that he is an expert himself, but that he has the knowledge himself and attempting to pass it on. Likewise, the science game designer social identity presumes that Howie has expertise in the subject if he is making a game about it, particularly about something that is not common knowledge, nor what even another engineering college student knows.

In short, both the science game designer social identity and science educator role are based on and presume being a kind of expert on solar energy. Now, in this player reflection, Howie does not make claims of social identity, such as “I am a scientist,” though it should be kept in mind that at the outset of the encounter before data is collected that he introduced himself as a member of the university’s solar energy program. His polo shirt with its organization’s logo on it and his presence at the Solar Carnival booth certainly all contributed to him making a bid to be taken as a solar energy expert. The point being that his enactments imply that being a science game designer and taking the role of an educator are not wildly different ways of being. Rather, they relate to and are predicated on expertise of the same knowledge or field. Or better yet, they both point to his association with the discipline of science.

Most of the REUs attempt the science educator role and science game designer social identity during their player reflections, though they do not ask identical questions nor do they ask them necessarily the exact same way or in the same order.

Player 3’s player reflection is representative of the social identities and roles that Howie and his players attempt to enact during his five other player reflections. In all of

them, he uses the same questions though worded at times differently but in the same general order. In five of the six cases when he checks for learning, the player(s) indicate they do not know the science content and each time he reviews with the player what A-R-T mean in science terms and at times gives examples from everyday life, such as mentioning that radio is how lasers work, as illustrated in his review with Player 3. However, one notable difference is that the other players do not repeat back the science word Howie states and usually only give a “yeah” which elides the statement while confirming their understanding. As a result, it can be said that the Player 3 reflection is typical and indicative for how Howie approaches engaging the public with solar energy. And it is also exemplary in the way that Player 3 readily accepts the positionings on offer. What role taking and relationships occur when a player contests an assumption of the game is worth examining.

From player reflection to player reflection, Howie consistently enacts the science game designer social identity and science educator role while his players predominantly enact the playtester, learner, and competitor roles. However, Howie and the players are not restricted to enacting one role at a time or are limited to the role in which they are being positioned into. Howie’s player reflection with Player 5 and 6 is noteworthy in this regard. Howie asks his question, “would you play it again?” which elicits player feedback and positions the player into a playtester role. Player 5 takes on this role through his answer, “yes,” but he also expresses the competitor role on his own:

2115 **Howie:** Ok so one question I always like to ask first is would you play it
2116 again?

2117 **P5:** Yes

2118 **P6:** Yes of course

2119 **P5:** We would win. (laughter) Because now I understand you can't just

2120 grab random piles.

In line 2119, the lexical chain for play is continued through “win” and “grab” where the word choice indicates the win/lost attitude of a competitor. Also, the personal reference “we” includes himself and Player 6 and does not include Howie, suggesting they are on opposing sides, further conveying the oppositional nature of their relationship. Moreover, the causal conjunction “because” establishes a cause and effect relationship between winning and knowing the rules of the game so that the cause of their success is due to having learned how to play. The continuative conjunction “now” implies that this situation is at present and was not the case earlier. Player 5’s use of these two conjunctions point to how a change has occurred as a result of playing, and it can be assumed that by playing, he feels that he has learned and is capable of defeating Howie. This is further supported by his use of personal references “I” and “you” where he indicates this change is for himself personally and the manner of playing the game, “grabbing random piles” is not how anyone should play since the “you” is a general exophoric reference pointing to anyone playing. In short, Player 5’s answer to Howie’s question indicates multiple role taking where he is not just giving player feedback, but is still very much being a competitor and positions himself as a learner, in this case of the game rules.

In Howie’s next question he asks about the players’ experience which is consistent with his positioning of them as playtesters. However, Howie asks the players to express their experience in terms of “a story.” What is interesting is that Player 6 uses “my overtly sexual friend” to refer to Player 5, using the possessive personal reference in a way that shows their relationship and a social identity:

2121 **Howie**: Are you sure because I can go first next time. So if you two
2122 could make this game into a story or like a your experience how would you
2123 explain it?

2124 **F2**: What's the story here playing this game?

2125 **P6**: Love it. Well I met my overtly sexual friend at at (????) and we
2126 went on a midnight prowl for some amazing experiences and discovered the
2127 solar carnival and yeah and we were actually enthralled with this is
2128 definitely the longest we spent at any booth tonight so

Player 6 answers in the form of a narrative linked together through a series of additive conjunctions “and” and overall gives a positive impression of the game through instances of lexical chain “friend” “a midnight prowl” “some amazing experiences” associated with “the solar carnival” “booth” as what they discovered. Also, the conjunction “actually” conveys that what he experiences is other than what he expected, a comment on the reality of the situation.

Then contrast this positive evaluation of the game to Player 5’s answer which is negative:

2129 **P5**: And it was very confusing. More confusing than regular Mancala. And
2130 I still don't know exactly how it applies to solar.

Player 5’s use of the additive conjunction “and” is a curious way to interject and give an answer that is in contrast to his friend’s. In using this cohesive device, he adds to the answer his friend gives, but not in a way that is confrontational or presents conflict with his friend. It also conveys that the game can be a good experience, but still having a serious issue. Player 5 repeats “confusing” and uses the personal reference “I” to speak from his perspective in him “not knowing” how the game represents solar energy. This is another instance of the “know” lexical chain and is in contrast to him knowing how to play the game as a result of playing. In a sense, he is continuing to position himself as a

learner by asserting that he did not learn about solar by contesting the assumption that the game “applies to” or connects with solar.

That being said, Player 5’s answer is still player feedback. He has presented a perceived problem in the game’s design. A game designer is interested in these sticking points and where a player does not understand the message of the game. This puts Howie on the spot to react somehow to the problem. Howie chooses to ask a polarizing question in which he asks for permission to explain the connection between his game and solar:

2131 **Howie:** Ok. So want me to recap what how it applies to solar again?

2132 **F2:** Don't ask. Just do it.

2133 **P5 or P6:** Just do it

2134 **Howie:** So in so solar cells like silicon

Howie’s question uses personal reference “me” to refer to himself and his game “it” so within his question is to offer his personal perspective in answering the question. This suggests positioning himself along the lines of being an educator in that he is offering to “recap” which is essentially review the science content. His question also is a repetition of Player 5’s clausal group, “how it applies to solar” so he is attempting to address it directly. The verb “applies” is part of *the connection lexical chain* in which his game represents or relates to solar. So Howie’s response to the refutation that his game represents solar energy concepts is to take on a science educator role. The conjunction at the end of line 2131 “again” conveys that at a previous point in time he already did the explaining and this would be a repetition of that same action. And the causal conjunction “So” at the beginning of line 2134 indicates that his explanation of silicon at this point in time is the result of that lack of learning. This further suggests that Howie implies the fault is not in the game’s design but perhaps in how the game was explained when they

were playing or in a short fall in the player's role as learner and so basically this presumes a failing somewhere in the science educator—learner dynamic.

Howie enacts the science educator role from 2131 to 2145 then briefly speaks as a game designer in 2146 before returning to attempting to teach the players about solar until 2161. He uses the game as a teaching tool as illustrated with Player 3. Notable differences occur in the level of detail he gives in this player reflection about silicon cells and what and how he teaches:

2136 **Howie:** So silicon is a crystal and crystals have defects like when you're
2137 thinking about diamonds by carat

2138 **P5:** Yeah

2139 **Howie:** is actually how pure it is. So when there's an impurity in a solar
2140 cell that's a way it might not function like it should

2141 **P5:** yeah

2142 **Howie:** and

2143 **P6:** reduce energy

2144 **Howie:** reduce energy

2145 **P6:** gotcha

In this stretch of interaction, the solar lexical chain includes "solar cells" "silicon" "crystal" "crystals" "diamond" "carat" which is noteworthy in how two superordinate words associated with solar energy, "silicon" and "crystal" followed by properties of them and then a type of the superordinate with "diamonds" and a property of that type with "carat." This displays a tightly packed lexical cohesion of words that are for the most part in common discourse and not a specialized language of the solar field. The additive conjunction "and" between "silicon is a crystal" and "crystals have defects" also gives the sense of a simple step by step progression of information, especially since "crystal" is used in two clauses right next to each other. Howie continues this way of describing solar with "pure" and "impurity" which are associated and like near synonyms

to “carat,” as he essentially states one idea multiple ways. Then he arrives at his conclusion with the causal conjunction “So” in line 2139 in which the result of these properties of crystals is the reason for solar cells to “not function like it should.” Overall, this approach of explaining solar cells is simple and incremental, and noticeably not focused on science terms such as “Auyer” or “trap” as he uses with Player 3. Moreover, this is a concerted bid to be taken as a science educator, which Player 6’s response of “gotcha,” as an expression indicating an understanding, in line 2145 suggests an acceptance of that bid.

One last point to make concerning this stretch is how Player 6 interjects during Howie’s talk turn and the latter repeats it. In line 2143 Player 6 states “reduce energy” while omitting what would make up a full clausal group and yet it fits grammatically with Howie’s additive conjunction “and” and his “it might not function as it should.” This instance of collaborative completion suggests that Player 6 has some grasp of solar energy information. Howie’s repetition of that clause “reduce energy” works to confirm that Player 6 is correct. It can also suggest that the player is helping Howie with his explanation. Either way, Howie’s repetition of it is a kind of stamp of approval that the information is correct and it is allowable as part of his explanation. This also contributes to Howie’s role taking as a science educator that he is attempting to communicate as much accurate information about solar as possible.

Another way for players to enact the playtester role is to offer design suggestions rather than evaluations and experiences. Towards the end of Howie’s player reflection with Player 5 and 6, he is enacting the science educator role by checking for learning in line 2161 and then using the board game itself as a visual for science concepts he teaches

in lines 2163 to 2166. Then Player 5 asserts his role as playtester in line 2167 in a new way:

- 2161 **Howie**: So does that help you understand a bit more?
2162 **P5**: Yeah it's interesting
2163 **Howie**: Yeah and you can think about all of this energy moving around the
2164 board as electricity flowing through a circuit
2165 **P5**: yeah
2166 **Howie**: to run something like a solar
2167 **P6**: (???) maybe analog circuit
2168 **P5**: Oh
2169 **Howie**: That would have been that's a good idea. I really should have
2170 (laughing)
2171 **P5**: Next time
2172 **Howie**: yeah
2173 **F2**: for your next design
2174 **P5**: (???) prototype
2175 **Howie**: So does that help you understand a bit more?
2176 **P5**: Yeah absolutely I had no idea.

Demonstrative references “all of this energy” and “a circuit” and “a solar” give cohesion around solar concepts. However, Player 5 adds “analog circuit” to this lexical chain. It is a specific type of circuit as opposed to the superordinate that Howie uses. He elides “to run something like a,” adding on to Howie’s thought and replacing that reference with this suggested one. Moreover, it is a suggestion for the board game’s visual design to have the game represent a particular kind of circuit. Both the lexical cohesion and ellipsis convey how Player 5 is collaborating, riffing off of Howie’s metaphor of his game as a circuit. Howie references this suggestion as “a good idea,” conveying his appreciation of the player’s suggestion. In line 2169 Howie uses the personal reference “I” to refer to himself. He does not complete the clausal group, however, the utterances by Player 5 and the facilitator begin a lexical chain focused on the game design process. The two references “next time” and “your next design” refer to a future point in Howie’s work

with his game. The facilitator even uses the personal reference in possessive form “your” to emphasize his close association to it and what a science game designer is expected to do. One last point about this shift to Howie as a science game designer is the personal references put the focus on him personally. He assumes responsibility for seeing these design possibilities and to make changes that would improve the game’s representation of science. This is noteworthy in that he does not attempt to defend his decision, rather he expresses willingness to adopt it.

Identifying as a Scientist

Howie is not the only REU to have a player contest the assumption that the game teaches science or is related to solar energy. When Cherry encounters this issue, she too assumes a science educator role to the negative feedback. One important difference is how she positions herself as a part of the scientific community and her game, “It’s a Trap!” as a representation of an issue her research is working to resolve. So while assuming the science educator role, she also positions herself as a scientist in the social identity sense:

2689 **Cherry:** Now we are researching defects which are happened to be kind of
2690 recombination traps that you guys were playing

2691 **P31:** Mm hm. [sound of agreeing]

Cherry uses “we” to refer to the scientific community to which she belongs. Moreover, she uses another reference, “that,” in line 2690 to refer to the scientific concept of recombination in connection to her game. In her subsequent statements, she continues to use the “we” personal pronoun as a statement of social identity in lines 2692, 2695, and 2697 as she describes what research she is involved with in improving solar cells:

2692 **Cherry:** That we want to eliminate these. It will up the efficiency of a
2693 solar cell

2694 **P31:** Ok.

2695 **Cherry:** And so what we are trying to take away from this game is trying to
2696 bring to light that there are problems with solar cells like as in these
2697 recombinations, but we, as our researchers in solar cell, we're trying to
2698 reduce these, and we're trying to make the paths easier for electrons to flow
2699 because as you saw an electron making it to the conduction band is complete
2700 chance cause these (...)

Above, Cherry uses a number of verbs as part of a *research lexical chain*, which includes “eliminate,” “up,” “reduce,” and “make,” which is her way of expressing the goals and nature of her work as an engineering researcher. In explaining the ways of thinking and objectives of her social identity, she also attempts to educate the players, informing of them of current research. Moreover, she includes the “we” as part of an effort to communicate the issue of recombination through lexical verbs “take away” and “bring” as in “bring to light” relate how she envisions her work as a researcher doing public engagement with science through game design. So while she associates herself with the scientific community, she also attempts to characterize her social identity as a scientist engaging the public through the additional social identity of game designer. In doing so, her enactments amount to an interrelated mesh of social identities that are also related to her role as science educator, presenting herself as a researcher who engages the public. Player 31 expresses an acceptance of Cherry’s bid to be taken as this kind of person as shown below:

2724 **P31:** Yeah but that's a neat way to visualize it though. Understand a little
2725 bit about why the inefficiency (????) why that was. I mean I knew that that
2726 was issue, but

2727 **Cherry:** Say like solar panels, if they were more efficient, we would have
2728 converted over already. We wouldn't need fossil fuels and all of that, but
2729 there's still more efficient than what a solar panel would do.

2730 **P31:** Right.

Above Player 31's response expresses commentary on both Cherry's game and the information the latter is sharing. First, the demonstrative reference "a neat way" conveys a positive attitude toward "it" which refers to Cherry's game. The player also uses verbs "Understand" and "knew" as part of a *know lexical chain* in relation to "the inefficiency" which refers cataphorically back to the current limitations of solar cells. Her use of the contrastive conjunction "but" draws a difference between what she knew before about the limitations and what she now knows based on what she has seen that night, which possibly could be the scientific concepts underlying the issue, though this is speculation since it's the topic of the game and Cherry's explanations.

In lines 2727 to 2730, Cherry's use of "we" shifts from just the scientific community to society at large, implying possibly her social identity as an American or perhaps she means humanity as a whole. She does this within a conditional statement in which the situation is having "more efficient" solar cells, which is a particular comparative in the aspect of solar cells which she is working with. The result of this condition is society not needing "fossil fuels and all of that," the additive conjunction combining a polluting and limited energy source with other energy similar energy sources. In other words, Cherry promotes solar energy as a solution to national and even global energy needs.

To this rather rosy portrayal of solar energy, Player 32 raises a problem in the solar energy field, that of the "storage problem." His use of the temporal conjunction "still" implies that this is an as of yet unresolved issue, and comes across as a counter to Cherry's argument of solar's promise to improve or help America and/or the world:

2732 **P32**: There's still a storage problem.

2733 **Cherry:** There is a storage problem. We're actually studying the battery,
2734 battery storage and stuff like that. It would be actually be cool if we figure
2735 that out.

2736 **P32:** Very cool.

2737 **Cherry:** So we are actually working on the efficiency of these solar cells for
2738 right now. Well that's what our research is based upon.

2739 **P31:** Alright. Oh cool. That was really interesting!

Player 32's response appears to be a push back against Cherry's argument of solar being a solution to energy needs. Perhaps this can be taken as criticism of the solar energy field, a recognition of what it currently lacks and its limitations in solving the world's energy problems. Cherry's repetition of "storage problem" is a way of acknowledging the fact. She shifts back to using "we" as a member of the research community along with using "studying" and "figure that out" and "working" that are more instances of the *research lexical chain*. She concludes in lines 2737 to 2738 through the causal conjunction "So" in which she uses a number of lexical devices to separate herself from the research into batteries. She uses the avowal conjunction "actually" to make a correction or express that the situation is not how it is presumed when she uses "we" and "our research" and refers back to the efficiency issue. In this way she is clarifying and hedging her involvement in the scientific community to this issue, and by implication, not the battery storage issue, though her use of "we" implied that she too is involved in it.

In summary, Cherry makes a bid to be taken as a solar energy scientist while explaining how her game expresses scientific concepts. She also positions herself as a researcher engaging the public through her game design, thus expressing her science game design social identity and science educator role as extensions of her scientist social identity. In promoting solar energy as a solution on a large scale, a player contests her characterization of solar energy by pointing out its current limitations. In response,

Cherry shifts back to speaking as a scientist belonging to her niche in the field rather than the whole solar energy field. Out of the REU's she is a typical example of how an REU asserts her social identity as a solar energy scientist.

Sociotechnical Role

While analysis of cohesion in player reflections indicates that most REUs enact the social identity of science game designer and role of science educator, a less common role emerges particularly with Vic. As the analysis below will demonstrate, Vic's conversations with players focus on establishing the latter's relationship with solar energy and science in general. For example, in Player 7's player reflection below, Vic uses the second person personal reference "you" to direct the player to speak from his perspective. The first of two questions is a content question using this personal reference in the possessive form, "your interest" further making the question about the player himself. Her second question, which is in the same talk turn as the first, is a polarizing question about the player having or not having "a science background." Firstly, this question does not presuppose that the player has any association with science and it stands in contrast to the first in the sense it sets up a difference in social identity between having an interest in science and being a part of the scientific community or having some kind of professional association or education with it. This association is conveyed through the demonstrative reference "a science background." Using a polarizing question with it asks the player to identify themselves in relation to science in its broadest terms. Moreover, it implies that Vic herself is associated with science and in a sense asking such a question seeks to define the player in this insider/outsider or close/distal relationship to what she is a part of.

With the cohesive nature of question asking and responses, the player is being put on the spot to explain their interest in solar, define themselves in relation to science, and possibly both. In his response, Player 7 does the latter:

2301 **Vic:** So what exactly peaked your interest in solar energy? Like do you
2302 have a science background or... ?
2303 **P7:** You know its funny I think when I was in high school I had to do a
2304 research paper and for some reason I picked solar energy. That's why I was
2305 like that was unfortunately 1981
2306 **Vic:** Early 80s
2307 **P7:** So like when you said in the 20s I remember that I remember some
2308 of the hypotheticals that they were talking about back then and I feel like it
2309 really hasn't advanced some of those things haven't advanced as far as they
2310 should. That's why I was asking
2311 **Vic:** Right
2312 **P7:** I think it just has to do with I've almost lived in Arizona my whole life.
2313 It just seems like such a no brainer. I've always been fascinated by the solar
2314 technology
(...)
2323 **P7:** So when your power came back on I saw this sign (referring to Solar
2324 Carnival) when I first started loading oh that could be interesting. And again
2325 I think when I saw that it was from [university] I've had this burning
question I
2326 meant to ask that guy in Scotland like why hasn't the efficiency increased in
2327 40 years?
2328 **Vic:** Right
2329 **P7:** I was like I'll come over and ask them I graduated from [university] so
2330 **F1:** Awesome
2331 **Vic:** Ok
2332 **P7:** I really appreciate that [university] has this kind of program I wish they
had a
2333 bigger program

Within this excerpt, lexical cohesion occurs through a *years lexical chain*, *solar lexical chain*, and *ask lexical chain*. In the *years lexical chain*, Player 7 states “1981,” “back then” “my whole life” and “40 years” as well as Vic’s near synonym for the first instance with “Early 80s” in line 2306. Here the player is making a point of reference in time that is distant from the present. The *solar lexical chain* is more complicated as it includes

verbal cohesion as well as references. It begins with Vic's first question and goes into the direction of scientific inquiry and the field of solar energy with "a research paper," "solar energy" "in the 20s," "some of the hypotheticals," and "the efficiency." These focus on the research of solar energy, what researchers are working on in that past point of reference. Two more key components of the *solar lexical chain* is the verb "advanced" and its opposite, "not advanced" in the way it expresses a lack of progress in that research. The demonstrative reference "a no brainer" is quite expressive in its negative evaluation of this lack of progress as well, characterizing the necessity or the issue of solar energy as obvious and even simple in that one does not even need to think about it to see that it needs to be done or is possible. In this way, the player is criticizing the solar energy field for its lack of progress in creating more efficient solar cells in the last 40 years. As such, the player is assuming the role of critic of solar energy research.

Personal references are also important in this chain because the player states "you" to refer to Vic in connection with giving information about the level of efficiency ("in the 20s") that PV solar cells are currently capable of producing and also "they" to refer to researchers developing theories in the past point of time referenced by *the years lexical chain*. So, Player 7 is positioning Vic with the scientific community involved in research perhaps as a university student involved in research, though this is not clear. However, the third person plural personal reference "they" does not include her, likely because he is referring to scientists in that past point in time. And so the player's criticism does not seem to be leveled at Vic personally. He does at one point offer more criticism when he states: "I really appreciate that [university] has this kind of program. I wish they had a bigger program" (lines 2332 to 2333). The comparative "a bigger

program” conveys a comparison between the current size of the university’s solar energy program and what he thinks it should be. So this player is enacting the role of critic that avoids conflict with Vic by way of his choice of reference and offers support for the university’s organization she is involved with.

The lexical chain for *asking* also ties into how Player 7 and Vic relate. The verb “ask” starts at 2310 is connected with the demonstrative reference “this burning question” in 2325 to 2326 as part of a lexical chain expressing Player 7’s sense of curiosity. He does not just have a question. The modifier “burning” within the demonstrative reference implies urgency and deep interest. The verbal repetition of “ask” refers to two points in time—when the player had an opportunity to ask an expert (“that guy in Scotland”) about progress in solar energy research but did not take it and then also when he played Solar Trivia with Vic and did ask her. To begin with, this further positions Vic as belonging to solar energy research. And considering the several points in time that the player refers back to—high school research paper, guy in Scotland, always been fascinated with solar technology—conveys his relationship to solar energy, which is ongoing and personal, and includes an interest in its scientific development. With Player 7 taking Vic to be a part of that community, this means he is interacting with that community and learning from it and using this opportunity to answer questions important to him. A final point of relating where Player 7 makes a direct statement of social identity through the first person personal reference “I” in stating that he also graduated from the university sponsoring the Solar Carnival and which Vic is a part of.

In short, Vic’s questions direct the player to define themselves in relation to science and express their relationship to solar energy. Player 7 accepts this prompting and

positions himself in terms of having an ongoing and personal interest in solar energy, takes the role of critic and supporter of the solar energy research community, and uses the encounter as a way to reflect on how talking with Vic about the current state of research in solar, means to him as a person interested in solar. Vic takes the role of sociotechnical person in this capacity, inviting and putting the player on the spot to express where solar and science connect to their social identity.

There are other possible instances of the *solar lexical chain* in line 2312. Player 7 states, “I think it just has to do with I've almost lived in Arizona my whole life,” where the personal reference “it” can refer to his “feeling” that solar research has not made enough advances which caused him to ask about the current state of PV solar cell efficiency during the game. Within this clausal group is another direct statement of social identity, “I’ve almost lived in Arizona my whole life,” the first person referring to himself personally as well as the possessive reference “my whole life.” The modifier “whole” conveys a sense of his extensive time being in Arizona and that his life is connected to the location as a result. This implies a sense of belonging and identifying with the location. The next two clausal groups that follow this statement include instances of the *solar lexical chain* with “it” and “a no brainer” and “the solar technology” as described above. To have so many instances of the *solar lexical chain* before and after the statement of Arizona social identity suggests that the latter is relevant to the topic of solar energy for Player 7, that there is some undefined connection for him between being Arizonan and solar energy. It is possible that he means to express that solar energy is important to the sense of being Arizonan. Though Player 7 does not use cohesive devices, such as conjunctions, that could further express this relationship, other players who make

similar statements of social identity associating themselves with Arizona do express its connection to solar to a greater degree as will be shown below.

Science Educator Role – A Meeting of Knowledge Systems

In Vic's other player reflections, she often asks questions about the player's experience and what they were thinking during playing the game. With Player 10, Vic begins the encounter with this approach and the player's answer expresses a negative evaluation of Vic's game, *Solar Trivia*. In one sense, the question is Vic taking the science game designer social identity as Howie does in examples above. In lines 2411 and 2413, Player 10 refers to Vic's game through the personal reference "it" and attributes to clausal groups to it that are related through the adversative conjunction "but". The first clausal group states that the game "made [him] feel [he] didn't know Arizona" and the second is that the game "was good". What is important is that Player 10 uses "but" as a contrastive conjunction between these two statements. With the second expressing a positive evaluation of the game, "it was good" indicates that the first statement is the opposite, or *not* good. As he uses the first-person personal reference "I" in his answer, he is directly answering Vic's question as to the content of the game experience, and so for this player, it is not good to "not know Arizona." Moreover, the player also begins a *know lexical chain* in his answer, which the player uses in the negative "didn't know," an action associated with learning something new:

2409 **F1**: Okay So maybe like what was it like playing the game?

2410 **Vic**: Okay So what was your experience like playing the game?

2411 **P10**: It made me feel like I didn't know I didn't know Arizona I guess

2412 **Vic**: Ah

2413 **P10**: as much as I could, but it was good

Her question references the situation of playing the game through a textual reference “it” and her game *Solar Trivia* through “the game” and the wh question directing the player to speak to the content of that textual reference. She does not presuppose that learning has taken place, yet the player states “know” for the first time, which is a key lexical chain associated with learning. However, to understand the science educator and learner roles in this player reflection, first analysis must consider what the player means by “I didn’t know Arizona,” because learning here is not strictly in terms of memorizing science-based facts, but rather a confrontation between two ways of understanding the world, two knowledge systems—the scientific community’s knowledge and the local community, or Arizonan’s. But first, analysis will show how the latter social identity is enacted as it relates to solar energy and knowledge.

Vic continues to assume the sociotechnical role asking Player 10, “why did you come over here” to the Solar Carnival and “what attracted you?” which are similar to the questions she asks Player 7 about his interest in solar. Then her follow up question “And then I guess all the categories when they ask questions” uses the demonstrative reference “all the categories” to refer specifically to questions in her trivia game that he just played. Through the additive conjunction “and,” he connects the solar cell on display at the booth to his person interest in solar energy, which points back to Vic’s question of asking him to define his relationship to solar energy:

2420 **P10:** Yeah, I saw the solar cell and always interested in all this solar,
2421 how we use our solar energy here

His being “interested” is a verb that carries over to the next clausal group in which he uses two key references. First, he uses the first person plural “we” to refer to himself and

a larger group and also the demonstrative reference “here” to refer to a near location or area. With these together, he is associating himself with the people and place in which the conversation is taking place. Moreover, he uses the possessive form of the first person plural in describing “our solar energy,” which conveys the sense of that larger group having and using solar energy infrastructure on a community scale. This is interpreted so broadly because the player could have stated “my solar” or “my house” or “my parents’ house” to refer to his interest in the use of solar. However, he chose to reference a less specific though proximal sense of belonging which is consistent with a larger area in which they stand and to a social group that is larger than his family.

This interpretation is supported further and essentially stated directly when Player 10 answers in lines 2440 to 2445. Player 10 states “Arizona” and refers to the location with “here,” which clarifies that the larger group is in fact the entire state to which he belongs:

2440 **P10:** I didn't think that Arizona actually used a lot of solar panels here
2441 **Vic:** Really?
2442 **P10:** Yes so that's why I said top five but yeah
2443 **Vic:** And why did you think that?
2444 **P10:** Because I don't see many. I do see a lot, but I don't see as many as
2445 we should since you know we're Arizona. We get a lot of sun
2446 **Vic:** Right

In line 2445, Player 10 directly states his belonging to the Arizonan social identity through the first person plural personal reference “we” in “we are Arizona.” So he is no longer speaking only in terms of his personal relationship to solar energy as an individual, but rather as one member of an entire state-wide community. Their relationship to solar is expressed in demonstrative references “a lot of solar panels” and “a lot of sun,” both of which include modifiers that express an abundance (or lack

thereof) of what they associate with this local social identity, at least from his perspective. This modifier “a lot of” expresses the lived experience of this player and conveys what can be called local knowledge in the sense that Arizonans believe the state “didn’t actually used a lot of solar panels here” and yet they “get a lot of sun.” Conjunctions also communicate a great deal in this excerpt. The conjunction “actually” is a commentary that what is true is unexpected or other than what might be assumed. In this case, the Arizonan assumed that the state did not produce so much solar energy. Then he uses the causal conjunction “so” as a conclusion to indicate that this assumption of his is the reason why he guessed incorrectly during the trivia game. Vic’s follow up question asks the player the reason to which Player 10 answers with the causal conjunction “because” and the personal reference “I” to speak from his perspective that he does not “see many,” the modifier substituting for “many solar panels.” In other words, Player 10 based his answer in the game on knowledge he accumulated by being an Arizonan and living in the state.

Two more conjunctions in lines 2444 to 2445 work together to express a more-is-better attitude of the Arizonan. In line 2444 Player 10 states that from his perspective, as he uses the first-person personal reference “I,” that he “does see a lot,” the latter modifier is a substitution for “a lot of solar panels.” Then this statement is contrasted against “I don’t see as many as we should” through the adversative “but” which conveys the sense that he concedes Arizona has a lot of solar panels, however, they are not enough. He uses the causal conjunction “since” to convey that this assertion is based on the conclusion that “we’re Arizona. We get a lot of sun.” So in other words, Player 10 expresses an attitude that sunlight is such an abundant resource for the local community that it is not

being taken advantage of to its potential. This sense of dissatisfaction echoes the criticism that Player 7 expresses in the lack of progress in research in PV solar cell efficiency. The important difference is that where Vic does not argue against Player 7's criticism, however, Player 10 expresses the "feeling" that he is factually wrong, that Arizona does not produce "a lot" of solar energy.

This points to a conflict between knowledge systems—Player 10's local knowledge and Vic's scientific knowledge that are connected to their respective social identities. The former is based on a member of a local community's observations and impressions while the latter on research in the solar energy field and industry. This conflict between knowledge systems appears at the beginning of the player reflection when Player 10 states for him to "feel like [he] didn't know Arizona... as much as [he] could," which earlier analysis indicates this is a negative experience for him. Moreover, the *think lexical chain* has verbs of thinking and knowing which are used to express the present state of that knowledge. For him to state "didn't think" is an indication that his prior belief has been challenged if not overturned. He states "see" three times, another example of lexical cohesion, which emphasizes that his knowledge is based on his observation of everyday life. In short, Player 10 is enacting a social identity, or more accurately aspects of a Discourse, through stating the reasoning, belief, and attitude of that perspective. Another point is that he expresses a negative feeling toward the game experience due to this conflict and he accepted the science-based fact over his own local knowledge.

At this meeting of conflicting perspectives Vic could assert her scientist social identity and relate science-based facts. However, she chooses to relate to this player through her own local identity, which is not an Arizonan one:

2453 **Vic:** And it's funny that you say that you don't think there's a lot because

2454 I'm from Philadelphia and I think it's the exact opposite. There is a lot

2455 **P10:** Oh really?

2456 **Vic:** So you're like oh it's not as much as it could be but I'm like

2457 **P10:** (laughing)

2458 **Vic:** So it's an interesting perspective definitely

Throughout this excerpt, Vic addresses the player directly with the second person personal reference “you” as she repeats back his assertions about the amount of solar energy Arizona produces. Then she uses the causal conjunction “because” to explain why she finds his assertion so curious and that is due to her own social identity of being a person from Philadelphia. From her local perspective, “there is a lot” which begins with a personal reference to the situation or place of Arizona and the substitution “a lot” to stand in for “a lot of solar panels.” Her demonstrative reference “the exact opposite” and its modifier precisely conveys her attitude in this regard. Moreover, she essentially reiterates this point in line 2456 in which she compares his perspective again with “you” and hers with “I” through the contrastive conjunction but to show how they are in opposition. As a final touch, Vic refers back to Player 10’s Arizonan perspective through the demonstrative reference “an interesting perspective.” In this case, the modifier “interesting” conveys her attitude that it arouses curiosity but is not necessarily accurate or in line with hers.

In short, in attempting to establish the player’s relationship to solar energy, the player enacts an Arizonan social identity through expressing how a person who grew up

in that environment perceives solar energy, values it, sees the sun as an underutilized power source, and the state's solar power capacity as lower than what is possible. He also expresses how the game challenged his knowledge on the topic and even his sense of being Arizonan because his assumptions were challenged by the scientific community's knowledge system of the state's solar power capacity as embodied in the game's trivia questions. Moreover, Vic asserts her own local identity as a point of reference and comparison to his Arizonan belief and attitude regarding solar energy.

One of Vic's players happens to be of both social identities, scientist and Arizonan. When answering the question about his science background, Player 9 states in line 2362 that he is a PhD student studying chemistry at the same university as the Solar Energy Center. The facilitator asks the player about when the latter was answering the trivia question. The player uses "know" four times, which forms a lexical chain the same as Player 10 through verbal cohesion, and also uses the first person plural "we" to refer to the local knowledge of an Arizonan:

2384 **F1**: So when you were playing the game what went through your mind as
2385 you were playing the game?

(...)

2389 **P9**: Like I don't know (saying with laughter) how many solar cell
2390 production companies there are in Arizona, but I know we have a lot of
2391 sun and I know that California is the number one producer

2392 **Vic**: Yep

2393 **P9**: So if we weren't in the top five I was like yeah we're probably we're
2394 probably number 2. I know we have the big solar panel park

Conjunctions in this excerpt show how Player 9 reasoned his way to the correct answer.

The contrastive conjunction "but" in line 2390 emphasizes what he knows about solar based on his local knowledge. Then the additive conjunction "and" connects this to additional information he knows about the solar, followed by his use of the causal

conjunction “So” to express his conclusion through a conditional conjunction “if” to arrive at his answer. Interestingly, he uses the personal pronoun “we” in labeling Arizona and what they have. However, he uses the first person “I” when speaking about industry knowledge “the number one producer” and Arizonan “the big solar panel park.” The key difference is that he does not use “we” in stating what California is or has, further demonstrating his association with Arizona while California as an other. In summary, Player 9 “knows” more about solar energy than just what his Arizonan Discourse would lead him to believe. He demonstrated through his reasoning that he has additional knowledge which may or may not be due to his belonging to the scientific community as a PhD student. In a sense, his use of reasoning could be a demonstration of scientific thought in this regard, of coming to a logical conclusion based on available facts.

Unlike with Player 10, Player 9 does not use the *know lexical chain* in the negative sense, as in stating what he did not know. The former does not use the word “learn” to describe his change from not knowing to knowing, however it can be argued that it is a kind of learning. Two players that do use “learn” to describe their player experience is Player 13 and Player 14, male and female respectively, African Americans in their 50’s to 60s. They are from Chicago. Below, Vic asks her question about their “thought process” and “what was going through [their] head during the game?” which is an enactment of the interviewer role. In their response, both players use the demonstrative reference “a learning experience” to describe it and how Vic completes their clausal groups when they try to recall what they learned, taking on the role of science educator. In other words, Vic shifts to the science educator role *after* the players

assume the role of learners or at least characterize their experience during the game as learners:

- 2480 **Vic:** Oh okay. And then your thought process with the game the
2481 different categories why you chose them like what was going through
2482 your head during the game?
2483 **P14:** Ah there was a learning experience
2484 **P13:** Yeah.
2485 **P14:** It was a learning experience I learned something new
2486 **P13:** Yeah, I did too I never would have thought California was--
2487 **Vic:** Number 1?
2488 **P13:** Yeah
2489 **P14:** No I never would have thought New Jersey--
2490 **Vic:** (laughing) Would be top 5? I know
2491 **P13:** So I learned something on that one
2492 **P14:** Yeah

Notice how in lines 2487 and 2490 Vic elides the subject and/or the verb in her response to both players as the latter state what they “thought.” She does collaborative completions, giving the information that comes from the Solar Trivia questions. In this way, Vic assumes a science educator role reviewing with the players the information covered in *Solar Trivia*. Moreover, “thought” and “a learning experience” form another instance of the *know lexical chain*, this time the learning aspect being made the most explicit. Player 13 makes this clear through his use of the causal conjunction “So” in line 2491 to refer to what mental process he went through during the game.

In summary, in earlier examples of Vic’s player reflections, Player 9 and Player 10’s answers to this question are analyzed in terms of how the player relates to solar and enacts the Arizonan social identity. Another way of considering their responses is to consider how they are also instances of Vic assuming a science educator role at the same time. If the *know lexical chain* in Player 9 and 10’s player reflections are forms of learning in that to know and didn’t know are verbs associated with having and coming to

have information, or in the latter case, learning. Even though Player 9 uses “know” in the lexical chain stating what he already knew prior to playing the game, he derives at new knowledge through reasoning and having his guess confirmed correct during the game, which means he also learned something new. And the player reflection with him reviews that process. Vic’s simple statement of “Yep” in line 2392 is a confirmation that he is correct, which is akin to an educator putting her seal of approval on a fact. Also, Vic’s questioning of why Player 10 thought the way he does about Arizona not having that many solar panels is a kind of review and her relating to him as a person from Philadelphia is an attempt to help him change his perspective, which is also another form of learning.

Interviewer (limited) – Interviewee Roles

As explained in the section on the Overarching Interviewer – Interviewee Roles, REUs are more or less always enacting an interviewer role as they ask questions of the players and position the players as interviewees. Vic’s probing into the player experience by referring to specific parts of the game and the player’s thinking process is different from the overarching interviewer role in that she is not simultaneously enacting other roles or social identities concurrently, such as the science game designer or educator. She asks questions in such a way that she is only assuming an interviewer role, hence the enactment is interviewer in a limited way. For example, in this interviewer (limited) capacity, she asks more open-ended questions that do not assume learning even while that appears to be what happens for many players during the *Solar Trivia* game. This is demonstrated in the above example with Players 13 and 14.

What is key, however, is that Vic directs these interviewer questions to specific game design features. She refers back to the player's experience of the game, specific questions, and specific moments of when they played the game. This points to how the game design feature works in tandem with this approach by an REU. The game questions task players with recalling knowledge they have before the game and can inform through confirming or refuting that knowledge. So even though Vic's player reflection question does not point to learning or automatically assume the positioning of being a science educator, *Solar Trivia's* design, especially since its choice of subject matter coincides with local knowledge on solar energy, results in these instances of Vic taking on a science educator role. The game itself is a test of knowledge, often turning into a test of what a local person values and knows about their everyday world. So it is the combination of player reflection question and the game's design that leads to this opportunity for Vic to assume the part of an expert who explains solar energy to non-experts. Moreover, it is likely that Vic's players do not express any learning of the game itself because the trivia game is such a common and simple game genre that no additional learning is required to play.

More Player Roles/Identities as a Result of the REU's Sociotechnical Role

So far this analysis has demonstrated that Vic's players assume the role of critic of the solar energy field (Player 7) and Player 9 makes a statement of social identity as a PhD student in chemistry. These two examples show how players can have an obvious connection to solar. However, what this section explores is that even when Vic's players do not have such an obvious connection to science or solar, players manage to find one. For example, Vic's player reflection with Player 13 and 14 show how the latter do not

have a direct connection to science, however, they still take on a role and form a relationship to Vic's self-positioning of being associated with science:

- 2493 **Vic:** So you guys have science backgrounds at all?
2494 **P13:** No
2495 **P14:** No
2496 **Vic:** Why that? Science isn't that bad
2497 **P13:** No nothing like that
2498 **P14:** No actually it's not. You know (????)
2499 **P13:** When I was in school (????)
2500 **P14:** Shit, that was 50 years ago
2501 **P13:** It was 40 years ago for real
2502 **P14:** For real for real
2503 **Vic:** But
2504 **P14:** It's interesting and actually I'm I'm very interested in as far as solar uh
2505 thinking about you know getting a house and solar panels and you know
2506 So it's it's it's-
2507 **Vic:** Right it's definitely something to look into because--
2508 **P14:** Especially with the world right now
2509 **Vic:** Yeah and for the long run especially if you're looking for cost that
2510 definitely will benefit you definitely

In line 2496, Vic asks the follow up question as to why the players have no connection to science. She also makes a statement of fact, stating "Science isn't that bad," which is what the players answer "No," to, omitting this clausal group as they refute it. Two times Player 14 uses the avowal conjunction "actually" in the following talk turns, which is a way of stating that the reality of the situation is other than what is expected. In this case, what is unexpected is that the player is "very interested in ... solar... getting a house and solar panels." So the player is expressing that even though they have no connection to science, they still want to own a house with solar panels. A house is not simply a place to live but is also a long term investment and a typical aspiration of many Americans. So "a house" is part of a lexical chain with words such as "solar panels," "the long run," "cost," and "benefit," that are associated with homeownership and being a consumer as a social

identity. Vic uses two key causal conjunctions in her response. First she uses the causal conjunction “because” in line 2507 which means she is expressing a reason, she is going to explain the why of what Player 14 has just stated. Moreover, Vic’s use of the conditional conjunction “if” in line 2509 expresses the notion that “looking for cost” is the result while “that,” a reference to solar panels on the house is the condition to bring about that result. In other words, Vic is stating that having a house with solar panels saves money over a long period of time, or over “the long run.” Her use of the two causal conjunctions “because” and “if” demonstrate how she gives an expert’s perspective on the player’s statement about wanting to have a house with solar panels. In this way, Vic is promoting solar and stating the positives of this form of technology as a kind of expert advising a person who is taking the role of a consumer. In short, even though Player 14 had no social identity or role associated with science per se, he makes a bid to be taken as a kind of consumer and so relates to solar energy through the possibility of owning a home with solar panels.

Player 13’s statement “Especially with the world right now” in line 2508 includes an ellipsis of the clausal group “it’s definitely something to look into” from Vic’s statement, which essentially means solar panels are worth exploring. There are two interesting cohesive devices at work and not easy to pin down exactly what she means. The temporal conjunction “right now” points to the immediate present. The demonstrative reference “the world” refers to presumably everything and everyone on Earth but taken with the sense of the present moment, could refer to the many things that make up a sense of her reality, which could include the environment, economy, moral fiber, government, world conflict, etc, though it is not defined. However, it is implied that

the present state of reality is not positive because she has raised the topic as something to be responded to, dealt with somehow. Connecting this interpretation to the ellipsis, Player 13 is stating that it is worthwhile to explore having solar panels on a house in light of the negative present state of their reality. What role she might have been prepared to assume in this player reflection is not clear and falls into the realm of speculation. Perhaps she relates to Vic as a person concerned about the environment. Another REU, Carter, encounters players who do express a need for solar in response to a perceived negativity in the broader context and assume a more defined role/ social identity in the interaction, which will be explored in the next section.

Another example of a player assuming a social identity and role when they do not have a science background is Player 8, a white male in his 40s. In response to Vic's question, "Do you have a science background," he gives an indirect answer with supplementary information, sidestepping a direct "No" answer. He uses the first person personal reference "I" in his answer to refer to himself as well as a demonstrative reference with comparative modifier, "a more of an artistic background," to state that his social identity is closer to art than to science:

2543 **P8:** I have a more of an artistic background
2544 **Vic:** Ok
2545 **P8:** seventeen years in nursing but I have an Associates in Commercial Art.
2546 I'm working on my Bachelor's in Interior Design
2547 **Vic:** Ok
2548 **P8:** and green design is very important
2549 **Vic:** Correct
2550 **P8:** in the aspect of me designing a building you know how economic is
2551 solar in regards to other avenues of you know renewable energy

Player 8's answer also uses a demonstrative reference to refer to his art background and a first-person possessive to the design degree he is working towards. The contrastive

conjunction “but” works to forefront this aspect of his professional background. The additive conjunction adds the clausal group “green design is very important” to this as well. Here is the start of a *design lexical chain* beginning with “green design” and continuing with “designing,” “a building,” “solar,” “other avenues,” and “renewable energy.” Here solar energy is put into association with his design work and so the player expresses how it is relevant or fits within his professional background. His use of the personal reference “you” as in “you know” in lines 2550 and 2551 is a way of referring to common knowledge or what anyone familiar with the topic would know, or at the least asking Vic to relate to what he is saying.

In this way, Player 8 is finding common ground between his social identity as an interior designer and Vic who represents the solar field in some form. Vic responds by making a statement about the topic of design, continuing the *design lexical chain* and using words, such as “LEED,” associated with its environmental aspect, particularly her characterization of this kind of design as being popular, or having “a really big push for it,” two demonstrative references which are instances of this lexical chain:

2569 **Vic:** So a lot of people (????) I know out here I've noticed there is LEED
2570 certified. Not too often will you find that East Coast but here there's a really
2571 big push for it
2572 **P8:** Really it kind of started back there but it's really a lot more popular here
2573 because everything is so new out here
2574 **Vic:** Correct
2575 **P8:** You know you're bringing in all the new technologies that are current in
2576 the day. So if you meet a certain kind of building requirement or a certain
2577 percentage of building requirement and there's a big criteria for the list you
2578 know you have to do
2579 **Vic:** Yeah
(...)
2586 **P8:** and then you meet all of this criteria you become a LEED certified
2587 building so

Vic's statement about environmental design in lines 2570 and 2571 are worth examining because of how the player responds to it. She uses a demonstrative reference "that" to refer to LEED, or environmentally friendly, designed buildings. In fact the demonstrative reference "a big push" includes the modifier "big" to interpret the magnitude of this effort to build LEED buildings in Arizona. She has also contrasted this against LEED buildings in the East Coast through the contrastive conjunction "but." This is an assertion tied to "you" in this case a generalized exophoric reference to anyone presumably who looks into the matter. Player 8's response in line 2585 begins with "Really" as an avowal conjunction, like how *actually* can be used to make a statement about a situation being different than what is presumed. In this case, Vic is presuming this lack of environmental design on the East Coast. Player 8's clausal groups after this conjunction is his statement of how things really are, or the actual situation. He states "it" which is a reference to environmental design and uses "back there" to refer to the East Coast. With the whole clausal group and conjunction taken into consideration, "Really it started there," is a kind of correction or at least presentation of information that is not already present in what Vic asserts about environmental design. Then he uses the causal conjunction "because" in line 2573 to give the reason why there is "a big push" for environmental design in Arizona, pointing back to her observation. So by Player 8 using conjunctions to supplement, and possibly correct, and explain why something is the way it is, he is asserting his social identity and relating as an expert in his own right in the interaction.

In the subsequent lines, Player 8 makes many demonstrative references to environmental design in connection with the "you" as a generalized reference as before, which is a way for him to relate the demands of his job, and in a sense, the values and

necessities of the Discourse he is enacting. For example, in line 2575 he states, “you're bringing in all the new technologies,” which uses the second person personal reference “you.” Naturally, he is not referring to Vic but rather anyone who is in his shoes needing to do environmental design. The demonstrative reference “all the new technologies,” has the modifier “all” that expresses the magnitude of the “new” or latest “technologies,” which work together to imply the enormity and newness of this work. In a sense, he is attempting to convey the massiveness of the change his kind of work is bringing. Another example of the demonstrative and generalized reference combo occurs in line 2576 where he states, “So if you meet a certain kind of building requirement,” where the “you” again refers to a person doing environmental design and “a certain kind of building” includes “certain kind” as a modifier that expresses the specificity and exactness of the Discourse’s standards. Interestingly enough, this statement uses a conditional conjunction “So if” which relates a series of demonstrative references and instances of the design lexical chain as the condition for a result that is not expressed until lines 2586 and 2587 which is “and then you meet all of this criteria you become a LEED/ building.” Overall, Player 8’s use of the generalized exophoric reference, demonstrative references as part of the *design lexical chain*, and conjunctions to assert his social identity as a designer and relate to Vic as colleagues, one expert to another, and possibly even educate Vic, particularly as to how her Discourse relates to his.

Facilitators Shaping Roles and Social Identities

In the player reflections analyzed thus far, the REUs almost always take the lead in conducting the player reflections. REUs usually ask the first question and ask the most questions and do so in a consistent manner, giving consistency from one encounter to the next, essentially putting their stamp on the encounter. At times facilitators ask questions and interject. While this study is concerned primarily with the roles, relationships, and identities that REUs and players enact, facilitators are a part of that dynamic as speakers in a conversation are capable of positioning others and so take part in constructing and shaping the roles, relationships, and social identities of both players and REUs.

At times facilitators participate in player reflections in ways similar to the REUs. A typical way that facilitators participate in a player reflection is to ask players questions that are closely related to the questions REUs ask. When Howie is with Player 3, the facilitator asks the player about her experience in terms of a narrative:

16 **F1**: Do you think like you were winning in the beginning? Or you know how
17 did your arc go?

18 **P3**: I thought I was losing in the beginning because I was playing him
19 (laughing) But then I was like Oh I remember this and then like you kind of
20 like think like Oh there's four if I do four more I'll get it in this part of mine. I
21 started thinking like, "Oh maybe I might have this," but he was like, "No I've
22 been doing this for a while."

23 **F1**: Yeah that's come up a lot today.

So in addition to eliciting player feedback in ways that have already been explained earlier, it can be said that the facilitator is on the side of the REU, cooperating with the latter with a common goal. The distinction between the facilitator and the REU in this case is that the former is not also the game designer and the player's response do not have the same implications. For example, when Cherry's game is given a negative evaluation,

the facilitator does not come to the game's defense or attempt to explain the science to make the connection between game and science clear for the player. Nor does the facilitator attempt either when Howie's game is given a similar negative evaluation as shown above. The games are the REUs' clearly, but also the facilitators' silence is also indicative of their attempt to stand in the background. For example, in the beginning of Howie's encounter with Players 5 and 6, the facilitator hands the baton to the REU to sort of speak, referring to Howie and the players collectively as "boys":

- 1 **F2:** Do you want to say that again?
- 2 **P5:** I love science.
- 3 **P6:** I love science.
- 4 **F2:** I love it. Alright boys take it away.
- 5 **Howie:** Ok so one question I always like to ask first is would you play it
- 6 again?
- 7 **P5:** Yes
- 8 **P6:** Yes of course
- 9 **P5:** We would win.
- 10 (laughter)
- 11 **P5:** Because now I understand you can't just grab random piles.
- 12 **Howie:** Are you sure because I can go first next time. So if you two could
- 13 make this game into a story or like a your experience how would you explain
- 14 it?
- 15 **F2:** What's the story here playing this game?

Notice how the facilitator re-enters the conversation in line 15 not to ask a question of her own, but to repeat Howie's question. She rephrases Howie's first request, "if you two could make this game into a story" and his second request, which is a rephrasing with the object in the grammatically incorrect first position, "your experience how would you explain it," into the shorter and more grammatically correct question, "What's the story here playing this game?" In terms of cohesion, the facilitator omits both the conditional conjunction "if" and the alternative conjunction "or" in her modified version of Howie's question. She also omits a number of references, particularly personal references like

“you” and “your.” She also changes the question type to “what” and she omits “you” as the persons being asked to answer is implied. In this example, the facilitator is repairing another speaker’s statement, simplifying it and combining two requests into a single one.

In this sense, the facilitator sees her role as supporting the REU in terms of clarifying the latter’s speech, making it more understandable for the players. However, as previous excerpts above show, the facilitators in most cases do not come to the rescue of players or REUs when either is in a face threatening situation. An important exception is in Howie’s encounter with Players 5 and 6 where the REU expresses disappointment that he did not design his game with the analog circuit metaphor in mind. In this case, in line 64 when the facilitator states, “for your next design” she is echoing Player 5’s statement that reduces the face threat on Howie. Moreover, the facilitator implies through the reference “next design” that Howie’s social identity includes being a solar expert who is communicating through games and will continue to do so. As will be demonstrated in more detail below, the facilitator often positions REUs and players as being experts and capable of being other relevant and desirable social identities related to solar.

At other times, the facilitator(s) ask player reflection questions that are of a different sort than what the REU is asking. For example, after Howie has finished eliciting player feedback, explaining the game-science connection with Players 5 and 6, the facilitator asks the players about their connection to science:

68 **F2:** So do either of you have a science background?

69 **P6:** I studied engineering for a little bit so I actually worked with crystalline
70 structures down in Tucson

71 **F2:** oh yeah?

72 **P6:** but not this in depth trying to make (????)

73 **P5:** I just like it

74 **P6:** he just likes it (laughing) (????)

The facilitator is taking the sociotechnical role, identical to Vic's instantiation of the role. Player 6 makes a statement of social identity through the personal reference "I" and uses the avowal conjunction "actually" to imply that his having "worked with crystalline structures" is other than what might be assumed. He also uses the adversative "but" in line 72 to contrast his association with science from Howie's, which implies the latter has a closer relationship to science than himself.

This brief analysis of the extract is significant in light of the player reflection with Player 5 and Player 6 as well as for most of the REUs. In this encounter, these players do not make bids of social identity during the stretches in which the REU or the facilitator are assuming a science educator role or science game design social identity. This does not happen until the facilitator asks a question of a sociotechnical nature. In fact, Howie's players rarely make statements expressing social identity or enacting roles and they do occur only when a facilitator does an enactment other than science educator/ science game designer. Recall Player 3's reaction to the facilitator's statement that to play *Solar Mancala* with Howie is an ordeal (line 2050). Not until that point in time does the player make an assertion of social identity. The exception being when she expresses liking to play *Mancala*, which could point to a furtherance of her "geek" social identity.

Overall, the facilitator's roles and doings are fluid as she at times is responsible for setting up the player reflection, but also helping the REU at times while also conducting the player reflection *as* an REU. However, the facilitator does not form the exact same kinds of relationships with the players because she is not the game designer and she is not taking the lead in the player reflections, conceding that to the REU at the

outset of the player reflection. She concerns herself with making sure that the encounter goes well in the sense of the REU being able to accomplish their apparent discursive goals in terms of enacting roles and social identities while at times managing and repairing that process. Such role taking implies a supervisory relationship between the facilitator and REU that is responsible for shaping the overall encounter, the minor adjustments that happen and the sense that there are guard rails in place during the encounter it would seem primarily for the REU's sake.

From this analysis, clearly the facilitator's role is to make the player reflection go as smoothly as possible and the REU accepts this relationship. However, not all REUs complied automatically to requests made by facilitators during these player reflections. Carter is reluctant to conduct player reflections for his game. He declines to conduct the player reflection with Player 24, so he is present but does not speak during the player reflection. First, by declining to conduct his own player reflection, Carter is resisting against the demand placed on him by the facilitator and so is testing the supervisory relationship that facilitators and REUs have. While there is no data to support the claim that Carter is observing and focused on what the facilitator is saying during the first encounter, his encounters with Players 24, 25, 26, 27, and 20 and 21 can be interpreted as a whole. So while the following analysis in this section details how facilitators shape the building of roles and social identities in the player reflections, Carter's participation in the Solar Carnival can also be seen as one in which an REU is at times pushed into these roles/ social identities and other times he acts on his own initiative by the end of a progression.

In the encounter with Player 25, the facilitator starts the player reflection and asks two questions. After some back and forth with Player 25, the facilitator asks Carter what questions he has:

3213 **F1:** What questions do you have, Carter? He designed it, so I putting him on
3214 the spot.

3215 **Carter:** Yeah, right I'm not quite sure. Maybe if you could give me
3216 another (????)

3217 **F1:** Gotcha. And so did it give you, did it raise any questions for you about
3218 solar energy or solar technology?

The facilitator is asking Carter not *if* he would like to participate in the player reflection as in he is offering an opportunity for Carter to direct the player reflection. Rather, the question assumes Carter has questions and the issue is what they are, not if he has any. Moreover, in terms of cohesive markers, the second person pronoun “He” and possessive form “him” in line 3213 refers to Carter even though in the previous clause he was speaking directly to Carter. This indicates a switch to speaking to the player *about* Carter and what the facilitator is doing is that he is describing Carter, establishing Carter’s relationship to the topic of the game as a designer, which conveys the idea that Carter is significant and relevant to the situation. To directly state that he is “putting [Carter] on the spot” is also a kind of intertextual narration in which he is making explicit what is happening on a social, discursive level. Perhaps this is a way of deflating the degree of face threat by calling it out in the open. The coordinating conjunction “so” conveys the idea that because Carter created the game which they are talking about, therefore, the facilitator needs to have Carter’s involvement or it is the right thing to do in that the game is his or he has a closer relationship to the game and so he need be involved in talking

about the game. In short, the facilitator is inviting Carter to participate in the player reflection, handing the wheel over to him as he gives a reason for this involvement.

Carter's response in lines 3215 to 3216 is to decline the invitation to participate. In fact, he may not even see the player reflection as his player reflection even though it is about his game. In terms of cohesive markers, Carter states a conditional reference "if" in which he makes his participation in the player reflection dependent on something else. It appears he is requesting or bargaining for more time before he asks questions. At the point he is not flat out refusing to participate in the player reflection as he did previously as he shows a small degree of willingness to take part. Interestingly, in line 3217 the facilitator accepts this refusal with "gotcha" which can convey either he understands and/or he agrees. Moreover, he states next "And so" which is a coordinating conjunction that conveys a continuation of what was said before, creating a bridge over his invitation and Carter's refusal to participate and more questions about the game. However, later in line 3222 the facilitator states "Carter was saying a minute ago..." followed by claims about how the game is about resistance between panels and power increasing. In doing so, he is referencing Carter's words in the third person even though the latter is present in the conversation. This attempts to accomplish two things discursively. Firstly, referencing Carter's words is to give his own words more authority as in he is referencing an expert source on the topic. In turn, this further positions Carter as knowledgeable and an expert based on his having designed the game. Third, referring to Carter in the third person while he is present also keeps Carter involved in the conversation by having him speak without actually having to say anything, keeping Carter present and a part of the

player reflection. In this way, the facilitator is involving Carter in the player reflection in spite of the latter's refusal to participate.

In Carter's next player reflection, he participates without such prompting from the facilitator. The facilitator asks the first player reflection question then Carter asks the second without prompting from the facilitator:

3301 **F1**: When you were playing the game, what happened?

3302 **P26**: My mind was focused on trying to avoid the wrong way.

3303 **F1**: Oh, okay.

3304 **P26**: Yeah.

3305 **F1**: That makes sense.

3306 **Carter**: Did your idea about solar panels change over the game?

3307 **P26**: Now that you said it, it did, yes.

3308 **F1**: Really? In what way?

3309 **P26**: In the way that you increase the voltage, you were saying, on each
3310 panel.

What is interesting is that in line 3309 the first "you" is a personal pronoun referencing the ambiguous "you" as in anyone playing the game will be doing this action and it happens the same each time, as in a universal effect when someone does that thing. And "each panel" refers to parts of Carter's tilt maze. Interestingly, the second "you" in line 3309 is to either the facilitator or Carter when they explained the concept of voltage. This indicates the learning occurs not from playing the game but from the explanation about the game, and the game then demonstrates the metaphor after the relationship has already been established for the player. The role of the facilitator and/or Carter's explanation in helping the player see what the game is supposed to be teaching occurs in encounters with other players. For example this occurs when Player 25 states, "Well, I didn't get the game until you explained it." What is clear is that the player took "your idea" and "change" to be a reference to a learning process. In this way, the player explains what

they learned over the course of the encounter. In this sense Carter is checking for learning discursively like other REUs enacting the science educator role. Then the facilitator asks the next question. In this way, the facilitator still is asking the majority of the questions in the player reflection, however, Carter has taken the initiative to participate for his first time.

In the next player reflection with Player 27, Carter starts the encounter asking if the player's "thoughts... change" on solar panels and the player makes a similar referential interpretation to a change in knowledge:

3401 **Carter:** Okay, so did you all understand the point of the game?

3402 **P27:** Yes, I understood the point that with each solar cell you gain energy.

3403 **Carter:** And then did you (.) I guess your just thoughts on solar panels

3404 change between the beginning and end of it or

3405 **P27:** No.

3406 **F1:** Well that's interesting. Why?

3407 **P27:** Because I still don't feel like I understand solar panels. (laughing)

3408 **Carter:** So that's gonna take a little bit more than just (???) understand it.

The players interpret "your idea" and "your... thoughts" to be a reference to knowledge about solar panels. Player 27's response to the question indicates that this educational aspect of the game is inherent in the game in her response to "[understanding] the point of the game". However, her response also implies that the game is not successful in its objective, giving a negative evaluation of the game's educational aspect in the sense that it does not educate her on how solar panels actually work. While Player 26's response indicates that learning took place as a result of an explanation, and so not due to the game, Player 27's response directly states that the game did not teach. Carter's reaction in line 3408 is curious. Where other REUs either launch into an explanation of how their game teaches solar technology (Cherry) or offer to explain again (Howie), Carter seems

to indicate that the explanation will take great effort. The transcript is not clear. The comparative “a little bit more than just” seems to indicate that such an explanation is beyond either the game’s capability or the amount of time and/or energy required to do so. And yet his first question in line 3401, “the point of the game” and Player 27’s response of the point being to “gain energy” with “each solar cell” shows that he cares about the learning aspect. He is trying to determine if the player has learned, e.g. checking for learning which is an enactment of the science educator role. He does not try to defend his game or give another explanation. Moreover, he displays unwillingness to explain the science, hence ending in that instant the action of science educating. In short, once Carter’s attempt to educate the player runs into a problem, he gives up.

Interestingly, the player is not refusing to take up the role of learner in this situation. She is only saying that what she has experienced so far in the encounter did not teach her the target information.

Interestingly enough, it takes prompting from the facilitator and a kind of olive branch by the player to get Carter to carry forward with the science educator role:

3409 **F1**: So like in a nutshell, how does a solar panel make energy? In a nutshell?

3410 **P27**: Well he did tell me silver.

3411 **Carter**: Right, the silvers conducting but like if I really go into it, it's more
3412 that it traps light within the solar panel. And we'll try to keep it there as long
3413 as possible to gain as much energy from it. So like it'll go through the front
3414 of it and kind of bounce around in it until (???)

In line 3409 the facilitator is constraining what it is that Carter is being asked to explain the science. The coordinating conjunction “So” establishes a conclusive relationship so that what follows is the conclusion. He reiterates “nutshell” which perhaps emphasizes how Carter is not being put on the spot to give a full explanation and just the simple short

version, one that would be appropriate for the audience. This presumably puts pressure on Carter to reconceptualize what he is on the spot to do and also reconsider his unwillingness to explain the science to the player. Player 27's talk turn is also meant to be helpful in this regard. In line 3410 Player 27 refers to an earlier point in the encounter confirming that something in happened, the mentioning of "silver" indicating that it is of significance. Also, she uses the pronoun "he" to refer to Carter even though he is standing right there. This implies that the player is talking about Carter, indirectly speaking to him, which has a lessening effect in terms of directly confronting Carter. The facilitator lowers the demand of the task while the player brings up an important piece of information with which Carter can use, a starting point for his explanation. Carter reiterates "silver" and interestingly he uses the coordinating conjunction "but" to contradict the importance of "silver." He sets up the conditional situation of "if" when he states "really go into it" the "it" referring the explanation. He references himself with "I" personalizing what he is about to do, taking charge of the moment. In this way, Carter resumes explaining science and his role as science educator teaching the player.

In the next player reflection of the public engagement event, the facilitator uses two tactics to turn over the conversation to Carter. In Carter's player reflection with Player 28, the facilitator asks a polarizing question of the player in line 3518 to 3519 and then turns the conversation over to Carter in lines 3521 to 3522 while at the same time positioning him as a scientist in solar energy:

3518 **F1**: Right. So I'm curious did this raise any questions for you about solar or
3519 anything about the science behind it?

3520 **P28**: Yeah, I have a lot of questions.

3521 **F1**: Go ahead. This guy, he's actually doing research in solar technology.

3522 Not me, but Carter is.

3523 **P28:** So did the ball I'm sorry did the ball represent like...?
3524 **Carter:** Energy.
3525 **P28:** Oh ok. Cool. So the more complex it gets the more energy it produces,
3526 right?
3527 **Carter:** Right. Because each cell has the energy of the whole entire thing.
3528 **P28:** Oh, that makes so much more sense now.
3529 **F1:** So kind of like these four solar panels right? And going from there, to
3530 there, to there, or at least combining?
3531 **P28:** At the end.
3532 **Carter:** At the end.
3533 **P28:** Compounds. Cool.

The facilitator uses circumstance reference in “this guy” to refer to Carter and the personal reference “he” to refer to him in connection with “doing research in solar technology.” The avowal conjunction “actually” connects Carter to this fact about Carter. Then in lines 3521 and 3522, he uses the negative “not me” in reference to himself in relation to being a solar energy scientist. Then he uses an adversative conjunction “but” to emphasize the distinction between himself and Carter once again as he states, “but Carter is.” In doing so, the facilitator positions Carter in the social identity of scientist and presumably capable of answering the player’s questions about solar technology.

There are many indications in the above extract that Carter accepts this positioning by the facilitator in terms of him being a scientist and the player positioned as a learner. In line 3524, Carter omits the player’s clausal group and only states one word, “energy” which completes the missing word from the player’s statement. In this way, he is doing collaborative completion, which is a way of enacting the science educator role. Moreover, in line 3527 he answers the players question with a confirmation and then uses the causal conjunction “Because” to express the reason. To confirm the player’s attempt to make a correct statement about science is another way of taking on the science educator role as well as conjunctions that show him explaining science facts.

Moreover, the facilitator positions himself as a learner along side of the player. In line 3529 the facilitator interjects with a question, “So kind of like...right?” that ends with a tag question asking for confirmation. In a sense, this is a false question in that the facilitator has heard the explanation numerous times, is familiar with the science to some degree, and so he already knows the answer. This implies that he is not asking it for his own sake and since Carter obviously knows the information because he is explaining it, the facilitator is asking the question for the player’s benefit. The question is curious in that first it begins with the coordinating conjunction “So” which conveys that what follows is a result of what Carter just stated. He references the points on the game board “these four panels” and then ends his talk turn with a question with his final point of “combining?” which means he is essentially taking Carter’s science explanation and connecting it to the game board. What the facilitator is doing is asking for confirmation from someone who knows more than him, thus taking up the role of learner along side of the player.

Consider how the facilitator could have responded to Player 28’s question in lines 3525 to 3526 in which the latter wants to confirm he is understanding the science correctly. The facilitator could have said in the affirmative, telling the player that he is correct, implying that the facilitator himself knows the information already. Such a statement would position him closer to Carter in terms of knowing the information. Again, the facilitator is quite familiar with the game and the science already, so he is taking up a feint learner role. By asking the question as he does, the facilitator is showing another way in which he positions Carter as having expertise by way of his social identity as a solar technology scientist.

Facilitator Taking a Sociotechnical Role and Positioning REUs and Players

So far, much of this section has focused on how the facilitator positions an REU as a scientist (social identity) or science educator (role) or science game designer (social identity). During player reflections, facilitators also attempts to establish what social identities players have in relation to science through asking follow-up questions on information that is revealed. For example, in the excerpt below in Carter's encounter with Players 20 and 21, the latter is a 10-year-old girl who asks Carter about solar paint. After Carter explains that at present it has not been invented yet (and so speaking as a solar energy scientist knowledgeable about the latest research as explained above), the facilitator asks the girl two follow up questions. Both questions (line 3042 and 3049) ask her to elaborate on her questions or statements. However, the girl does not answer. She hides behind her mom which is indicated when her mother states her daughter is "going to run and hide" which is an exophoric reference to action taking place as she speaks. The mother refers to her daughter as "she" referring to her in the third person singular, though the girl stands right behind her:

3042 **F1**: (to Player 21) Did you say the paint? Do you paint them on?

3043 **P20**: Yes, my daughter is, she's going to run and hide. For about a year, year
3044 and a half she has been really mulling over in her mind how to she just
3045 turned ten. She wants to come up with solar paint for cars, so that they are
3046 solar powered but the paint is the solar panel.

3047 **F1**: That's awesome, even I hadn't thought about that. Oh that's a neat idea.

3048 **P20**: Yeah,

3049 **F1**: That's really cool. Where did she get that idea from?

3050 **P20**: My dad worked in the automotive industry for his whole career. He
3051 worked for Ford he was an engineer. Energy is a big deal and she knows
3052 that. She knows that we need to rely on solar power more.

Player 20 directly states that she is Player 21's mother by stating the latter is her daughter, asserting her social identity as mother and her familial relationship to her

daughter. Both Player 20 and the facilitator refer to her in the third person, “she” from line 3043 onward. She answers for her daughter, explaining her daughter’s recent thoughts and actions about this idea of solar paint. The facilitator’s question in line 3049 is interesting because it refers to the daughter, “she” in the third person, also because he is asking the source of the solar paint idea. He is highlighting the importance of it by reiterating it and referring to it numerous times. Why does it matter where the idea came from? There are two reasons for this, presumably because the idea is coming from such a young person and because it is not an idea that has been explored very much to Carter’s knowledge, in other words the player is exhibiting creativity and not asking for knowledge but supplying a new possibility to an expert.

The mother’s answer to where the idea came from uses personal references and its possessive form “My dad” and “his whole career,” whereby this player establishes a multi-generational connection to technology and engineering. So this player is communicating how within her family they value technology, and particular technologies related to “energy” as she puts it. The mother conveys what she is passing on to her daughter through the statement, “She knows...”. So the mother is establishing her family’s values in regards to solar technology and science and engineering in general. She is enacting her role as mother in the sense of speaking for her child and for the family, establishing her social identity as a tech savvy person in the process. In terms of proximity, she is placing herself near and related to science and engineering.

In later talk turns, the mother states, “I am a jeweler so we do a lot of problem solving,” making a direct statement of social identity through the personal reference “I” and the demonstrative “a jeweler,” connecting herself to also how engineers and technical

work. These are direct statements of identity as it relates to the topic of science and solar technology that are made from the facilitator pressing players to define themselves further in relation to these fields.

The facilitator then asks Carter “how [he] got into science or engineering,” a question which presumes that the latter is a part of that social identity, further positioning him in this way. Carter answers “how,” or the manner in which he came to be involved with science by referring to his own mother, using the personal reference “she” and demonstrative reference “an engineer.” His use of “herself” is a way of adding emphasis and the need to distinguish two things that are similar, that he is an engineer and so is his mother, which is also a way of positioning himself into that camp:

3100 **F1:** Carter how did you get into science or engineering. How did you get
3101 into sciences?

3102 **Carter:** That came through my Mom. She is an engineer herself. She kind
3103 of passed that along.

3104 **P20:** Just grew up with it?

3105 **Carter:** I grew up with that and my Dad would (????) but I kind of was
3106 interested for sciences. It was right there so she was able to help.

3107 **P20:** That is kind of how I ended up here too my dad being an engineer.

3108 Although it has its drawbacks, I've had the same blow dryer since I was in
3109 high school, he just keeps fixing it for me. (????)

In lines 3102 and 3103, Carter’s use of personal and demonstrative references is a parallel construction as Player 20’s description of her father and source of her connection to technology. Moreover, Carter and Player 20’s use of verbs “came through,” “passed... along,” and “grew up” that form a *grew up lexical chain* associated with being raised in such a way to learn about technology and science-related ways of working and thinking. In summary, through the facilitator’s questions about the source of an idea and the manner in which the REU came to become an engineer, the REU and player make

statements of social identity and relate to science by way of family history and parent-child relationships.

A final way that facilitators worked to position players is through the question, “Do you have a background in science?” which is the same question Vic asks in her player reflections. The facilitator asks Player 5 and 6 this question, showing how the facilitators borrowed from and learned from the approach of an REU.

Selecting Focal Participants

Overall, the most common role that REUs assumed during player reflections is the science educator and the most common social identity is science game designer. Howie does these enactments throughout his player reflections in the ways typical of REUs. His instantiations of the science educator include his attempt to check for learning and review science concepts with his players, which is common approach that REUs took with this role. For the science game designer, he sought player feedback from the players and accepts design suggestions from players. For this reason, this REU is chosen to be a representative of REUs for analysis of the facilitated design process data. A less enacted role is the sociotechnical role, which seeks to establish the player’s relationship to science and solar energy. This role is rarely enacted by REUs other than Vic who uses it during her player reflections consistently. For this reason, Vic has also been chosen as a focal participant to analyze her data from the facilitated design process.

The next section of this chapter will analyze Howie and Vic’s discursive data gathered during the facilitated design process to explore what social identities and roles they enact during these steps of the public engagement with science project.

Part 2: Enacting Social Identities and Roles during the Facilitated Design Process

During the public engagement project at Solar Energy Center, REUs participate in workshops and meetings to support them in developing a game about PV solar technology and presenting it to the public at an arts festival. For the two focal participants, this flow consists of the following encounters with the facilitator: 1) introduction to the project, 2) brainstorming, 3) prototyping, 4) Young Scholar critique, 5) consultation with Howie, 6) consultation with Vic, 7) playtest, 8) playthrough, 9) public engagement event, and 10) group reflection. This second part of the Findings chapter will concentrate on the two focal participants taking part in the other phases of the project. This will be an analysis of what social identities and roles they enact, as well as being positioned by others in the encounters, during these phases of the project. First these enactments will be described briefly as key findings. Then the chapter will explicate how these key findings are derived from analyzing the data through cohesion.

Key Findings of the Facilitated Design Process

Key findings of the analysis of the facilitated design process is that the facilitator positions himself as a teacher and the REUs as students of science communication, a positioning that is enacted throughout the project. This positions REUs overall as university science students in a social identity sense. Moreover, the facilitator positions REUs as scientists first and then progresses from positioning them as scientists who do public engagement to the additional science game designer social identity. While the focal participants accept this positioning, as will be described below, two REUs reject this social identity as well as the public engagement aspect of how scientists have been defined in the project. Towards the end of the project, the facilitator positions REU's as

scientists doing public engagement face to face using their game. Both focal participants accept these positionings, enacting them as the progression occurs, except in the case of enacting public engagement face to face, which they enact later than when first positioned. How each of the focal participants enact the roles and social identities just described is explained below.

Vic identifies herself as a rapper (social identity) and involved with music and having experience engaging the public with science. She enacts the science game design identity through this association with music through a rap battle concept for a game. During a critique session with YSs (Young Scholars), she enacts a science game designer social identity, near peer role with the YSs, and also a sociotechnical role. After discarding her game concept, she acts as a science game design by designing a new concept and prototype based on science concepts. Rather than participating in the walkthrough meeting with her game, she merges her game with another group's game. Ultimately, she participates in the public engagement event with a game (her third one) she modifies for the event. In the event she enacts a science educator role and sociotechnical role primarily. She also speaks as a person enacting the sociotechnical role during the group reflection at the end of the project.

Howie identifies himself as a person experienced doing public engagement with science and so positions himself as that kind of scientist, one who is familiar with the role of public engagement. He also has used games to engage the public with science already. He enacts the science game designer social identity, designing a concept to teach science concepts. During a critique session with high school student program participants, he acts as a science game designer and also a near peer role and expert in electronics. After

discarding his first concept on aesthetical grounds, he designs another concept, continuing to act as a science game designer. During the walkthrough meeting, he acts as a science game designer and takes on the science educator role. During the public engagement event, he enacts the science game designer social identity and science educator role. In the group reflection meeting, he continues to act as a science game designer.

Through these two descriptions of the focal participants enacting roles and social identities, a pattern emerges in their enactments associated with a scientist engaging the public. Vic and Howie both connect being a science game designer to other aspects of their social identity. In Howie's case, he is familiar with games and can be considered a gamer while Vic draws on her association with music to guide her science game designer work. When it comes to taking on the role of engaging the public face to face with their game, important differences emerge. He enacts the science game designer social identity and science educator role consistently in the meetings leading up to the public engagement event and during it and after. In one sense, this project aligns well with his gamer identity and the way he does public engagement with science in general since he performs these enactments throughout the project. Vic's enactments diverges from Howie's in that her enactments of the science game designer social identity diminishes considerably by the time the public engagement event occurs and is not a social identity she takes on by the end of the project. Moreover, during the event, she enacts the science educator role in a way different from Howie in its focus on conveying information relevant to local knowledge system rather than the specialized knowledge of scientists.

In summary, the focal participants' instantiations of social identities and roles during the engaging the public with science design process differ in important ways and these differences occur consistently indicating a fundamental difference in how they approach the role and social identities the projects offers. When engaging the public face to face, these differences are apparent and affect the roles and social identities that members of the public enact. In the case of Howie, his approach primarily enables the public to be learners of science and playtesters. In Vic's case, members of the public enact a wider range of roles and social identities that relate to science and solar energy. As noted in Part 1, these enactments by players is influenced by the game's design, which in light of the overall design process, can be seen as additional occurrences of the focal participants' approach to public engagement with science. In short, a through line runs through the latter part of the design process and particularly in the face to face public engagement with science in which their respective approaches to public engagement is demonstrated.

Lastly, the facilitator positions the research roles associated with the participants' scientist social identity above the science game designer social identity and related roles at times during the project. In particular, he gives priority to the REU's research role over their public engagement role in regards to time while still trying to place importance on the public engagement project.

These claims about focal participants enacting roles and social identities are based on an analysis of cohesion in the transcripts made from meetings that comprise the facilitated design process and will be explicated below.

Game Design Event 1: Introduction to the Public Engagement Project Meeting

During the introduction meeting, the facilitator seeks to introduce Vic, Howie, and the other REUs to core concepts in science communication.

Teacher-Student Roles. The facilitator begins the project by positioning the REUs as students of science communication and himself the teacher. First he does this through using circumstance references “there” (line 1) and “here” (line 1) to draw attention to aspects of the room that match a classroom setting and the demonstrative reference to himself “the teacher” (line 2) to identify himself as a teacher:

1 F1: Let's all sit at the table. There's a spot open there and also over here next to
2 me. There's always a spot open next to the teacher. Nobody wants to sit next to
3 the teacher. It's okay.

(...)

4 And so I'm at the Teacher's College, and I focus a lot on science communication
5 and public intellectualism. And so what I'm really interested in is how we can
6 talk about our research. How researchers, scientists can communicate their ideas
7 better to people who are outside of academia. Does that make sense? Okay. If
8 something comes up that you're not sure about, just raise your hand and I can
9 talk about it. Awesome. Neat. All right.

(...)

10 F1: And by the way, there are no grades in our project. Nothing with Solar
Energy Center

11 has to do with grades. It's all about getting hands-on experience.

In lines 1 to 3 of the above excerpt, the reference cohesion markers “here,” “there” indicate the physical location near him and the “the” of “the teacher” indicates that he is referring to himself as a teacher and that since the REUs chose not to sit next to him, the teacher, that they are by inference students. He is also referring to not just this situation but the phenomenon of teachers and students having physical distance in the classroom in general, which again characterizes them as being in a learning environment. Another implication is that he is responsible for imparting knowledge or has responsibility for

their learning of the topic of science communication and therefore it is their responsibility to learn it. Moreover, in line 9, the facilitator uses the personal reference in possessive form “your hand” to refer to what the REUs can do to get his attention. Raising one’s hand is associated with students using inobtrusive body language to get the teacher’s attention and to get permission to speak. When they are to do this is expressed through the conditional conjunction “if” in which the condition is the REU not understanding something and the result is the REU raising their hand. This simple reminder of how REUs are to behave in class positions REUs in the role of a student.

Lines 10 to 11 are further indications that their relationship is teacher-student of a special kind. “And by the way” is an additive conjunction that is an aside as he draws attention to the fact that they are not using grades. What it is that the REUs will be doing is referenced through “it” in line 11 and “our” of “our project” in line 10. He is outlining the nature of this educational experience that he is including them in.

Generally speaking, the REUs demonstrate their acceptance of the role of learner or student in this meeting and other encounters by answering the facilitators questions directly. Here is an example of Vic, a focal participant, volunteering to share what she finds during an activity:

121 **F1:** (...) So would
122 anybody like to share with us one that they found? The point of death. All
123 right, you can share.
124 **Vic:** Okay, so I found an article on NPR, which is National Public Radio.
125 Should I go through the questions?
126 **F1:** Yeah, if it's easier.

The definitive article “the” for “the point of death” after asking a question is another example of the facilitator drawing attention to the teacher-student relationship and

learning situation of the meeting. Vic volunteers and then in line 125 asks a yes/no question about how she should answer. Asking for such direction further indicates her role as student in this situation and the facilitator is setting the criteria for how she should speak and she is expressing her willingness to meet that criteria.

REUs and Facilitator as Researchers who Do Public Engagement. There are a number of ways the facilitator positions the REUs as scientists and also as scientists who do science communication as an accompanying set of roles that further define the scientist in social identity terms that is different from how scientists are traditionally perceived to be. The most common way the facilitator positions the REUs through cohesion as scientists is through using personal references and their possessive forms. In the first meeting, as shown in lines 4 to 6 below, the facilitator refers to his work at the Teachers College, associating himself with research using the first person “I.” Then in lines 5 and 6, he uses “we” and “our” to include the REUs in this type of work, thus associating them with this shared social identity as researchers.

In the excerpt below, Howie accepts this positioning as a scientist using the first person plural personal references “we,” in a similar way as the facilitator. He also identifies himself with scientists doing science communication:

- 13 **F1:** So public engagement with science, what does that sound like to you?
14 **Howie:** How we present research to the general public or--
15 **F1:** Yeah, yeah. Present research to the general public. Okay (...)

Another REU answers the question and the facilitator’s response uses the personal reference “you” to not just refer to this one REU, but Howie and Vic and any scientist doing public engagement with science:

- 19 **Larry:** Basically being able to tell them what we're doing but not in technical

20 terms so that they can understand

21 **F1:** Yeah, that's a really interesting part about communicating with the public,
22 right, is you can't necessarily sound like a textbook because they're not coming
23 from the same place you are. That's a really important part

In lines 22 to 23, the facilitator uses “you” as a general exophoric reference to refer to all scientists in this situation of needing to explain technical information to non-experts. So, such a reference includes the REUs with scientists by implication, further positioning them as scientists and scientists who communicate with the public about science. The facilitator further draws distinctions between the REUs and those outside of academia by referring to them through the demonstrative references “the public” and the personal reference “they.” Moreover, this differentiation is further expressed by the comparative “the same place” being used in the negative. In this way, the facilitator is positioning the REUs as scientists and non-experts as different from them in terms of social identity in this regard.

Howie answers the facilitator’s question about having experience with doing previous science communication projects in the past. In doing so, he accepts this positioning of being a scientist who engages the public. He does so through using “I,” a self-referencing cohesive device, to talk about his past experiences engaging the public, making a bid to be taken as a person with some expertise in taking on this role:

83 **Howie:** So the big thing about communicating with science, I've noticed, is
84 audience. For example, I've actually talked to kids about hydrogen fuel cells
85 and did a little class on that. But I noticed when I go out and talk to adults on
86 similar material, it's definitely different language.

Howie uses a number of cohesive devices in special ways to indicate he is experienced with science communication. In terms of lexical cohesion, the general noun and modifier “the big thing” expresses this. The definite article “the” expresses that it is singular and

the adjective “big” implies importance and gravity to what the general noun “thing” is standing in for. In this case, it is an anaphoric reference, referring to something before the actual thing appears in the text. This builds suspense as that information is vaguely defined at the beginning of line 84 and then not revealed until line 86 after recounting two separate situations. He sets up his point, that he finds himself speaking a “different language” depending on which age group he speaks to about science, by using the adversative conjunction “but” to contrast two separate situations he experienced as an expert doing science communication. The suspense he builds coupled with his positioning himself as one who has much experience with science communication, results in a rather strong bid to be taken, in terms of social identity as a scientist, or at least science student in the process of becoming a scientist, who does science communication already. At the same time, the adversative conjunction does serve to draw attention and present his observation as a problem that in a sense he wants the facilitator to comment on. Moreover, the issue of scientists needing to change their register depending on their audience is an important issue in science communication. So it should be noted that Howie is not simply strutting his stuff, but demonstrates knowledge of the practice in a way that the facilitator recognizes.

Another way the facilitator uses personal references to position the REUs as scientists that do public engagement is to refer to the REUs directly. He uses “you” to directly reference the REUs as scientists. For example, he uses “you guys,” a second person plural personal reference below in this way:

47 **F1:** (...) So scientists, that's all of
48 you guys, right?

The facilitator also uses “you” and the possessive form “your” to refer to the REUs’ knowledge and research in the lab to further position them as scientists by virtue of their expertise and involvement in generating knowledge:

177 **F1:** (cont.) A lot of people haven't thought
178 about it in that way, but it can be another way of sort of sharing your ideas,
179 sharing what you know and what you find out in the laboratory.

Moreover, lexical cohesion is at play as the facilitator repeats “sharing” in lines 178 and 179 as well as “your ideas” and “what you know” are near synonyms. Such lexical cohesion demonstrates how the facilitator is not only closely connecting the social identity of scientist with doing public engagement with science, but positioning the REUs as that type of person through the personal references.

During an activity to find examples of public engagement online, Vic reports back about an article she finds about an oil refinery polluting a neighborhood in Los Angeles. Vic uses personal references “they” in line 132 to refer to the media and various demonstrative references, such as “some type of legislation” in line 133 to refer to policy makers:

132 Vic: So my thinking was that they probably wrote this to bring awareness
133 and maybe have some type of legislation written up to maybe have some law
134 in compliance with the environmental health and safety going on for the
135 neighborhood.

While describing this article, Vic uses demonstrative references that make up a legislation lexical chain where many references coalesce around this idea of policy makers being the audience of the news article. For example, “some type of legislation” and “some law” and “the environmental health and safety” are tightly packed references that make up the audience to a great degree. Her use of the quantifier “some” implies that

the laws are not defined yet, still in an abstract form that becomes more defined through the demonstrative reference “environmental health and safety.” The last demonstrative reference, “the neighborhood,” has no modifiers and so is defined far less.

In response the facilitator asks Vic a polarizing question about who will be affected by the pollution to which Vic answers in the negative. She uses a causal conjunction to state her reasons for this in which she uses the personal reference “I” to refer to herself and what she knows on the topic:

140 **F1:** And so, so far there's this news article, right? I wonder (.) is it going
141 to reach everybody who might be affected by this issue? What do you think?
142 **Vic:** I don't think it would because I didn't even know about it until I googled
143 it. But maybe to someone who is trying to build a case again to be able to
144 create this piece of legislation or bring it to lawmakers and bring it to their
145 attention.

Within Vic’s reason is the temporal conjunction “until” to relate that prior to reading the article, she is not aware of this issue. This indicates that in spite of her being a kind of expert on the topic, she is not aware of it, which is further expressed by the adverb “even.” So her meaning is that those living are not going to be aware of this issue, if she herself an expert, is not aware of it. In line 143 she uses the adversative conjunction “but” to indicate an idea contrary to this statement. What could be happening in her estimation is “someone,” a substitution to refer to the media most likely and then more demonstrative references that are instances of the *legislative lexical chain*. Such instances of this lexical chain include “a case” and “this piece of legislation” as well as “their attention” which refers back to lawmakers. A final point on lexical cohesion, is how in these two extracts (lines 132 to 135) and (lines 140 to 145) also includes verbal cohesion through verbs along the lines of “wrote” (line 132) which begins with the media doing

the writing but predominantly involves policy makers writing legislation by way of “written up” (133) and “build” (line 143) and “create” (line 144). These two lexical chains, legislative and wrote, co-occur throughout the extracts. Overall, Vic’s use of demonstrative references, lexical cohesion, and conjunctions portrays this article in terms of the media and policy makers taking action.

The facilitator’s response to this portrayal shows how he attempts to shift her portrayal towards the neighborhood and scientists being the focus. He starts this shift using the adversative “but” to draw contrast to her portrayal and how he wants to present it:

154 **F1:** (cont.) An article is a great start because you're potentially
155 reaching thousands of people. But what if they don't know some of the
156 details, like in what situations or where specifically they might affected? Or
157 what can they do to sort of counteract or avoid the health risks, right? That's
158 why the two-way is so important, is because the people who it affects, they
159 can ask questions and make this information relevant to them.

The conditional conjunction “if” presents a hypothetical situation which involves the neighborhood, the latter referenced through personal references “they” and “them” in lines 155 to 159. This shifts from being readers of the article in line 155 to being those affected by the air pollution in line 156 where it remains for the rest of the excerpt. In this sense, the facilitator is positioning the locals as having a place in the situation, they are the ones who scientists should be interacting with and not just being informed but asking questions of the scientists. In other words, the facilitator is promoting a scientist-local person relationship that does not exist in Vic’s description of the example of public engagement. The facilitator encapsulates this in a dialogue model of science communication, which he links to in the above excerpt through the words “the two-way.”

This is an example of lexical cohesion in that it is a shortened version of the definition of the dialogue model, which is a conceptual model he promotes at the same time.

The facilitator's reference to the dialogue model of science communication refers back to his earlier positioning of the REUs and the public as having differing perspectives. In referring to scientists, and REUs by association, he first uses the personal reference "they" to talk about them and then he shifts to the first person "I" to speak as them. After that, he uses the same third person-first person shift in personal reference when referring to the public:

60 Or sometimes scientists kind of imagine people like an empty bottle. And they
61 think, "Okay, I'm a scientist, I've got all this wonderful knowledge, I've just
62 made this awesome discovery. I'm going to pour that discovery into people and
63 fill them up with knowledge." And there's a lot of problems with that because
64 sometimes they're like, "I'm not interested," or "That's not important to me," or
65 they may not see it as relevant to their lives. Or they don't understand how it
66 could be relevant to their lives. And so that's why the two-directional flow is a
67 much better model because there's that give and take and there's a sense of, at
68 least for the scientist's side, what's important, what's relevant, what might be
69 interesting. Okay?

The facilitator presents the other side of the science communication relationship, speaking as a non-expert. The facilitator presents the solution to this discrepancy and problem by using lexical cohesion referring to the dialogue model of science communication as "the two directional flow" and "that give and take". In effect, the facilitator is attempting to re-position non-experts in relation to scientists, potentially shifting the REUs conception of their relationship by implication.

In summary, analysis of this encounter, indicates that the facilitator attempts in many ways to position the REUs as not just scientists, but scientist who have done science communication and will be doing it in a the dialogue fashion through the project.

Howie makes a bid to be taken as a person with experience taking on these roles and knowledgeable on the topic. Vic's portrayal of public engagement positions the media and policy makers more involved in the communication process than the local community to which the facilitator attempts to recast this positioning so that scientists, and by extension Vic and Howie, relate to the local community.

Game Design Event 2: Brainstorming Meeting

During the brainstorming meeting, the facilitator meets with Vic and Howie and the rest of the REUs to begin the game design process. The central activity is to begin the REUs' brainstorming what their public engagement game will be about.

Science game designer. The facilitator continues to position them as scientists who engage the public with science as shown below in the next two excerpts. But then in the third excerpt, he positions them for the first time as science game designers, a positioning in terms of a social identity that Vic and Howie accept as they relate their other respective social identities to it.

The personal reference “you” and is used by the facilitator to refer to the REUs as experts doing public engagement. He uses this reference as he asks them to convey to the public what is interesting to them and so asking them to think about and draw on their expertise knowledge:

236 **F1:** When you're thinking about what to engage the public with, you want to
237 be thinking about something that is interesting to you. Let me give you an
238 example. Like the band gap. You guys know what a band gap is more than I
239 do. (...) All right, Howie, I forgot, what is a band gap?

The facilitator uses “you guys” to also refer to them as experts of solar energy, perhaps in the sense of them being students of the field and/or scientists. But the difference between

236 “you” and line is that in the latter it is collectively and only as experts. The former is asking them to think of themselves individually as scientists doing public engagement, to focus on their personal attitude to their expert knowledge. This puts the focus on them individually and implies that what they choose to convey to their audience can be idiosyncratic, and touch on their other social identities available to them.

In addition, the facilitator continues to draw distinction between himself and the REUs on the grounds of the latter’s disciplinary knowledge of PV solar technology. He does this by positioning Howie in the excerpt below as an expert by asking him a confirming question as to the correct explanation of a scientific term:

240 **Howie:** Band gaps is essentially the gap between energy level. Or the energy
241 across (.). The difference of energy of the highest electron states occupied to
242 the lowest level of vacant electrode states
243 **F1:** Okay. For me whenever I hear about that, that does sound interesting.
244 This idea of electrons jumping around and that's how energy is being
245 released?
246 **Howie:** Produced.
247 **F1:** Produced? Is that right? Okay.

In the last three lines of the above excerpt, the teacher – student relationship between the facilitator and Howie are blurred by the former’s question to Howie. Howie uses ellipsis to omit the clausal groups “that’s how energy is being” except for the verb he replaces, which is “Produced.” This use of ellipsis is a way of correcting the facilitator. The facilitator then repeats the newly supplied verb in line 247, which is a form of lexical cohesion, and the way that the facilitator attempts to state the correct word. The facilitator’s polarizing question, “Is that right?” as he refers back to “Produced” is a way of asking for confirmation. In short, this ellipsis – lexical cohesion combination is a form

of teaching which blurs their respective roles. It further points to how Howie belongs to a discipline (solar energy research) and the facilitator does not.

For the first time in the project, the facilitator positions Vic, Howie, and the other REUs as science game designers. The facilitator uses “your game”, a personal reference in possessive form in line 248 to define what the project is, that they have ownership of a game for the purpose of doing public engagement:

248 **F1:** And so sometimes your game doesn't necessarily have to be about all the
249 positive stuff. It can be a little bit controversial, you can bring up issues. It's
250 not all about saying it's all good, it's all perfect. It's like these issues are
251 important and you should bring them up. No reason to hide them.

In terms of lexical cohesion, the facilitator uses the demonstrative and modifier “the positive” and the general noun “stuff” to refer to the good aspect of PV solar.

Structurally, he refers to it in the negative as he suggests what to make their games about, meaning that their games do not have to promote solar energy. He then uses “issues” and “these issues” in line 249 to refer to the negative or controversial aspects of solar. He also refers back to these through the reference “them” in line 251. These instances of lexical cohesion and their references form the *issues lexical chain*, a series of words associated with content that is not technical in nature, but sociotechnical. Contrast this to the previous excerpt in which numerous instances of the demonstrative reference “the band gap” in lines 238 to 239 and many technical words such as “the highest electron state” and “the lowest level of vacant electrode states” (line 242) and the demonstrative reference to the band gap, “that” (line 243), form the *band gap lexical chain*. In both cases, the facilitator directs the REUs to design a game about either one, science concepts as shown by the band gap lexical chain and sociotechnical aspects of PV solar through

the issues lexical chain. These cohesive devices indicate how REUs are being encouraged and to think in terms of two related but distinct approaches to public engagement through game design. This choice is connected to their game as he uses “it” to refer line 249 first to the game they are designing and then the second instance of “it” at the end of the line refers to the endeavor of public engagement with science itself.

So far in the brainstorming meeting, the facilitator has positioned Vic, Howie, and the other REUs as belonging to the PV solar energy discipline and for the first time as it is related to game design, as in the latter social identity is an approach and way of performing the former. It is important to consider how Vic and Howie either take up these positionings and accept them or react otherwise. During this meeting, the REUs are asked about their experience with engaging the public with science. Vic shares her background, using the first person singular “I” and “me” to refer to a previous science communication experience:

252 **Vic:** Yeah. I've done a few. I've done more so on the music side as well.

253 **F1:** Oh we have not had any music examples so please share.

254 **Vic:** I actually have a video. If you would like to watch it.

255 **F1:** Yeah, let's do it.

256 **Vic:** In my past life I was a rapper so:

257 **F1:** Awesome. We all have a past life. I'm so glad that yours is being a

258 rapper. So maybe on YouTube?

Vic uses the quantifier “a few” and omits a reference to projects or experiences with science communication. She identifies herself as “a rapper” and she has a YouTube video of a previous science communication project. So in this moment she is asserting her social identity and how she used music in the service of public engagement. Then the facilitator accepts that bid for identity through the demonstrative referent “yours” in her having “a past life” as a rapper. These cohesive devices suggest that she is framing her

past experience in terms of public engagement with science. Moreover, Vic describes one of these experiences in which she organized a competition for Earth Week.

260 **Vic:** Yes. So there was actually a project that we did for Earth Week and we
261 decided to get the whole school involved and we had a whole competition
262 from 9th, 10th, 11th and 12th grade. And one of the things that we did to get
263 people interested was create a music video.

Vic uses the first person plural “we” in the excerpt above to including herself in the effort. Moreover, she uses the avowal conjunction “actually,” which expresses that what she is about to state is other than what is presupposed or different than how reality is perceived. In this case, she states her involvement in “a project” in these terms. What she may be considering unexpected could be that she used rap in connection with public engagement with science. In this way, Vic presents personal interest (rap) and social identity as a rapper in relation to public engagement with science. In addition, one detail relevant to the science game designer positioning is that Vic describes the project as “a whole competition.” The modifier “whole” implies the enormity of the project. The fact that it is a competition speaks to designing a public engagement event around participants competing against one another, presumably with rules, which resembles a game like format.

Similarly, Howie offers a personal anecdote about his past experience with public engagement with science. His use of personal references and demonstrative references indicate that not only does he accept the notion of taking on the social identity of science game designer, but he has considerable experience at it. In the below excerpt, Howie uses the first person singular “I” to refer to his past experience. He also uses “one” as in “one of the places” which presupposes that he volunteers at more than one place. Also, he

states “one big part” in reference to volunteering, which means he suggests he knows the other parts and so has expertise on the topic. Both demonstrative references convey a sense that he is already experienced in public engagement:

279 **F1:** Has anybody ever played a game like this before?

280 **Howie:** I've kind of ran a game like this.

281 **F1:** Great. Tell us about it.

282 **Howie:** So one of the places I volunteer at is called the Energy Research
283 Center. And one big part about volunteering there is going out to schools and
284 doing education about renewable and sustainable research. A program that we
285 do more often than not is called Watts Up. So like a watt. And what we do is
286 we get practically a voltmeter and a bunch of different household appliances,
287 measure how many watts they use, like an incandescent bulb versus an LED
288 bulb at the same light intensity. Show how incandescent is using 30 watts and
289 the LED is using around 7. And talking about energy and how we use it.

Howie uses “we” in lines 284 and 285 includes himself with an organization doing the public engagement work, associating himself with them and the endeavor, which confers on himself this particular aspect of social identity. He also uses “we” in line 289 in reference to every person, not just scientist and volunteer types at the organization, using technology. In line 287 when he states, how many watts they use,” he is referring to participants in his public engagement event, meaning that his role in that event is to explain or teach science concepts occurring in their everyday life.

So far, these two excerpts of Vic and Howie describing their past experience with public engagement with science through games indicates they make bids to be taken as a rapper and member of the discipline already involved in public engagement with science. They do this through personal references “I” for themselves and “we” to refer to groups and organizations in which they associate this type of work with, both contributing to the social identity. It is also worth noting how Howie’s example includes his role as science educator in conjunction with using a game-like event to interact with the public.

Difficulty with and Rejecting the Science Game Designer Role. Not all REUs accepted the facilitator's positioning of them as scientists who engage the public with science. At the beginning of the game modification activity, Newton suggests modifying the game in lines 326 to 327 in ways similar to Howie's characterization of the science educator role:

325 **Newton:** Do you want to just write you know we can change the first one.
326 We can draw on the board that paper say (.) like a (???) draw (.) people tell
327 us what they think it means. That's how they learn

Newton uses "they" to refer to players, who are the public, and "us" as himself and Carter. Moreover, the "it" refers to a science concept depicted in the game's design. These three references convey a relationship between expert and the public in which the latter attempts to interpret scientific information. This characterization is referenced in the next clausal group "That" in line 327 where Newton states "That's how they learn," the they referring to the public again. In short, Newton is conceptualizing the game in terms of using it to educate the public about science concepts, a similar role that Howie envisions for himself.

However, in the next part of the excerpt, Carter and Newton express doubt in their ability to execute this design idea for the activity. Both Carter and Newton use the first person singular to refer to themselves to make direct statements to this effect. In lexical cohesion terms, Newton states first "I'm really bad at" and Carter repeats this clausal group, adding the demonstrative reference "this" to indicate the activity. Carter echoes Newton's confirmation of being bad at this kind of work. Then Newton adds "last time," a temporal conjunction to link his difficulty with an earlier activity to the present moment:

328 **Carter:** I don't know
329 **Newton:** I mean if you have any other because I'm like really bad at like
330 **Carter:** No I also am really bad at this
331 **Newton:** yeah
332 **Carter:** yeah
333 **Newton:** like last time my paper was almost empty (.) like nothing was on
334 (????) [laughing]
335 **Carter:** (????)
336 **Newton:** Same! [laughing] Yeah
337 **Carter:** (????)

Another indication of this pair's difficulty with the activity is expressed through Newton's conditional conjunction "if" in line 329. It is a fragment, the conditional part of the conjunction being Carter having an alternative to what he himself has just suggested. Also, the "because" is a causal conjunction in which he expresses the cause of him asking for Carter's alternative suggestion. His reason is "I'm really bad at like" which is presumably a commentary on his ability to do this form of public engagement. Considering Newton expresses difficulty for both the past activity, which is the activity in which REUs write out what kinds of public engagement projects and topics they would like to do, and also the present activity, it is reasonable to assume he perceives that he is not good at some or any aspects of engaging the public by way being a scientist who engages the public.

In the next part of the excerpt, Newton uses "I" and demonstrative reference "this" to refer to the present activity in stating, "I hate this," in line 338. He then uses demonstratives "That" and "this" to refer to an academic article in the excerpt below to state what he would rather be doing:

338 **Newton:** I hate this (????) so (.) That's what I want to be doing. [pointing at
339 something in academic article] I want to be doing this. Do you know what I
340 mean?
341 **Carter:** Just like reading papers

342 **Newton:** Reading, projects, stuff. I don't know. Trying to find games for kids
343 **Carter:** Yeah

Analysis of the references in Newton's statements indicate a strong negative attitude towards the roles associated with engaging the public with science. Carter's response in 341 does not directly answer Newton's question as the latter seeks agreement to his sentiments. Instead, he elides "I don't like" or the personal pronoun or making a negative statement like "Just like reading papers is x" which could be "Just like reading papers is boring" for examples. In line 342, Newton also elides much of his statement, deciding to list the activities that he has a negative attitude towards or at least expresses doubt as to their relevance to him as a person learning to be a scientist. "Stuff" is a general noun that could stand for the activities not listed so far but implies that there is more to the list of activities that he has this attitude towards.

In line 339 Newton asks Carter a polarizing question—"Do you know what I mean?" to his rejection of the activity and potential social identity he has just expressed. Carter's answer in line 341 is an indirect answer. His answer elide what is possibly a clausal group such as "I don't like" or some other negative statement that works as a predicate for "Just like reading papers." The verb "reading" and noun "papers" form a lexical chain with Newton's statement of "Reading," and "projects" and "stuff" that are activities in the public engagement project and the research project REUs are involved with at Solar Energy Center. Since Carter starts this lexical chain as an indirect answer to the question, "Do you know what I mean?" they are listing the activities and work they do not want to do and/or do not like. Considering Newton first states that he wants to be doing lab research and does not want to be doing activities other than that, this suggests

they both are enacting a traditional scientist social identity that excludes public engagement and other roles they are being asked to take on during the program.

In summary, the cohesive devices that indicate roles and social identities being enacted during the introduction to the project are primarily through personal references, particularly in the second person singular and the possessive form as the facilitator addresses Howie and Vic as individuals doing science game design. The facilitator also positions them as experts of PV solar to which Howie asserts this social identity as belonging to the solar energy field and role of science educator as he corrects the facilitator on a technical point and the facilitator repeats back the correction. This is accomplished through ellipsis of the clausal groups except for the corrected word, followed by the facilitator repeating that word back, which is a form of lexical cohesion. Moreover, the facilitator's discursively presents two lexical chains, one about teaching science concepts and another about the sociotechnical aspect of PV solar. The first can be considered as offering to Howie and Vic as potential ways of approaching their game design task. Vic and Howie share their personal experience with public engagement in part or completely identifying with the notion of using a game to either generate interest in an environmental cause and/or educate the public on science concepts.

Two REU's express difficulty in enacting the public engagement role as well as strong disliking for such work and a preference for laboratory research, a more traditional way of being a scientist.

Game Design Event 3: Prototyping Meeting

During the prototyping meeting, the facilitator instructs Vic, Howie, and the other REUs into the prototyping design process for their game.

Game design role and scientists doing public engagement. The facilitator's lecture begins with positioning the REUs within specific work processes, ways of doing, and thinking that game designers use to develop a game. He does this first by using the "you" personal reference as a general exophoric reference to anyone involved in prototyping a design, which conveys the sense that these are principles that the REUs need to apply in this project since they are now doing this type of work:

469: **F1:** I think that a lot of people are familiar with the product development
470 cycle. It's really similar to game development. But what happens is you make
471 something, you test it. After you test it, you kind of evaluate how things went
472 and then you go back to it and you make another version of the prototype and
473 then you take that one again and do play tests. We'll have a chance to do a
474 few cycles of that maybe with different people before we get to the actual
475 thing.

Numerous instances of the *product development lexical chain* occur in the above excerpt. It includes many uses of "it" to refer back to it as well as "the prototype" in line 472, "a few cycles" in line in line 473 and 474. A number of verbs associated with this lexical chain include "make," "test," "evaluate," and including "do play tests," that convey the actions of product development as it pertains to game development. The series of conjunctions "After," "and," "and then," and finally "and" give a logical linear progression of these actions and steps. Then the facilitator uses "we" to refer to the REUs and himself in doing "a few cycles of that," which refers cataphorically to this process. In this way, the facilitator invites the REUs to take part into the steps of game development, giving a conceptual overview of the process. Naturally, this is another example of his social identity of teacher and the REUs as students of this process.

Another example of how the facilitator positions the REUs as game designers is when he highlights what decision REUs need to make regarding where and how they will

share their game with the public. He does this through the demonstrative reference, “Part of the process,” which implies that this is just one consideration of many in developing a game for the public:

375 **F1:** Part of the process, I think especially for yours [speaking to
376 Vic], is getting the location, for yours particularly, is going to be really
377 important because that'll tell you, kind of, a lot of your constraints. What are
378 some of the limitations? How much space do you have? How much time?
379 You know what kind of foot traffic are you looking at? What kind of people
380 are you expecting would show up to that kind of an event? I mean, like, a
381 larger event? Or is what you're making kind of, like, a standalone thing that
382 would be in a different space?

The facilitator refers to Vic specifically through the personal references “yours” along with a causal conjunction indicating why that is. He assigns concerns and questions for Vic and the other REUs to answer in order to design their game in the appropriate way. The lexical chain associated with “the limitations” includes “your constraints” and examples of the superordinate “an event” along with the comparative “a larger event” and “a standalone thing.” The question types are all questions about content (what) and degree or manner (how), which REUs are expected to answer not during the meeting immediately, but over the course of a few weeks in order to complete the project. In this way, the facilitator is positioning Vic and the other REUs as not just game designers, but scientists doing public engagement through game design. This issue, or constraint, is due to the logistical questions and how they might influence design choices during this prototyping phase.

In this meeting Howie gives an update on his progress designing his game. In describing the design thus far, Howie refers to his game as “the recombination idea” in line 395. The modifier “recombination” marks his game as one about how PV solar cells

produce electricity. The definite article “the” singles out this idea from the others he has, which suggests he has others to choose from, but he is going forward with this one. Also, Howie shares his decision making through this excerpt. In line 397 the corrective conjunction “But instead” expresses how he makes an alternative choice between types of games, deciding not to do “a call and response game.” Here he is showing a degree of knowledge about game genres, pointing to his social identity as a gamer. During his description, he uses cohesive markers in two important ways. First, the demonstrative references identify aspects of the game and aspects of the recombination process, until they overlap. Secondly, he uses conjunctions to express the game’s mechanics or the mechanisms by which it functions:

395 **Howie:** So I'm thinking of going down the recombination idea.

396 **F1:** Okay.

397 **Howie:** But instead of doing kind of a call and response type game, I was
398 thinking of making a, like using the chalk here or some colored tape, and
399 making a valence band and a conduction band and make rainbows in opposite
400 color schemes on both. And have random assortment of balls and we could
401 think of the balls as photons of energy. I'd pick up a random ball. If it's red, I
402 throw it to the red people and they grab it and run across the band gap. But
403 then I have three other colored balls, maybe like black, white, and I was think
404 pink or just not something in the rainbow usually

Howie uses demonstrative references to point to what scientific processes or concepts are going to be represented by what physical objects in his game. For example, “a valence band” and “a conduction bad” are represented by “the chalk” and “some colored tape.” Line 402 shows how the science references and physical space of the game merge into a representation. He states in describing how to play the game, “they grab it and run across the band gap,” where “it” refers to a ball but also a photon since “we could think of the balls as photons.” Howie’s use of conjunctions are a way of explaining the game’s

mechanics. The conjunctions in this excerpt have the conditional “if” and “but then” to indicate the logic of how his game functions in lines 401 to 403. They establish a relationship in which under certain circumstances, he or the player is to act in a certain way, creating a game mechanic or how the mechanisms of his game works.

Through analyzing these cohesive devices, it is clear that Howie is doing the thinking and design decisions of a game designer following certain aesthetic principles in the sense that the parts of the game and the game mechanics need to represent or at least deal with scientific concepts from PV solar energy.

In this meeting Vic also gives an update on her progress for coming up with a game for public engagement, which she has chosen as a rap battle. In line 419 she begins with her description with “your beginning, middle and end,” a personal reference that points to a suggestion the facilitator made for organizing her rap battle. She then uses a series of additive conjunctions to give a sequential description of her game as an event. If these steps of the rap battle event are conceptualized in a game form, the conjunctions also serves to describe how the game operates, the mechanisms by which it is played for the rappers and for the audience:

419 **Vic:** So I took your beginning, middle and end for the rap battle. I kind of
420 have four different battle rounds. One's renewable energy, solar energy, PV,
421 and sustainable. And then I found eight local artists that I'm going to get in
422 touch with and it's going to be kind of switched up with the demographics so
423 that'll be cool.

424 **Vic:** And then I kind of have it set up like an actual rap battle. So we'll open
425 with the master of ceremonies and the first battles with go and they'll rap
426 about renewable energy and then the master of ceremonies will kind of
427 decide, will determine the vote by the cheering crowd. And then that'll go on.
428 And the midway point, I'll kind of have an intermission where there'll be a
429 performance by a local artist or something and then we'll do the last two
430 rounds and that'll be it. And I'll kind of have a board, I guess, on the side or
431 something for keywords for the audience to keep an ear out for when they're

432 deciding to judge so this way I'm making sure they grab the content. In terms of science game design, an important part of Vic's design is in line 430 where she states "And I'll kind of have a board... for keywords for the audience." The demonstrative reference "a board" points to a physical display of science concepts, a kind of target vocabulary. She then uses a causal conjunction in line 432 "so this way" to express the purpose of the vocabulary is "making sure they grab the content." The "they" are the participants of the game, the audience, while "the content" is the science vocabulary. This shows how she is designing her game to educate players on science. In this sense, Vic is enacting the science game design social identity in terms of educating the public about PV solar vocabulary.

Game Design Event 4: Youth Scholar Critique Session

During the Young Scholar Critique meeting, Howie and Vic and the other REUs met with Young Scholars (YS) who are middle school and high school students taking part in another summer program at Solar Energy Center. At this meeting, the REUs share their game concept or prototype with the YS for a critique and the latter ask for feedback from the former about their own projects.

Science Game Designer and Near Peer Roles. In Howie's critique, he shares his concept for a children's game about the band gap. While describing his game to two YSs, he uses the causal conjunction "because" in line 502 in which he states that his game is not for older students because "my game lacks... a form of competition or getting out" (lines 502 to 503). This suggests he has evaluated his game in terms of what game experience it offers players and has found this shortcoming. Conjunctions function in the

excerpt below in an important way for the YS to make a suggested change to the design and Howie considering how it would fit into the game:

506 **YS1:** What if for the older grades you did a competition for whoever can do it
507 the fastest?

508 **Howie:** Then it just becomes whoever throws the balls the fastest. So, what
509 I've been thinking of is like I said, there's impurities in the cell. Maybe those
510 impurities, instead of jumping back to the other side, they just disappear.

511 **YS2:** Yeah. Unless it's a competition, wouldn't help it make it more
512 interesting.

513 **Howie:** Yeah, I'm just matching the "what happens in reality" and "what
514 makes the game fun" is the current barrier I'm dealing with.

In line 506 the YS asks a question using the conditional “if” to pose the question as a hypothetical in which he makes a suggested change to the design. Howie answers using “Then,” which conveys the result or consequence of the suggested change onto the game’s mechanic and player experience. This exchange is important because it shows the YS taking a playtester kind of role in which he gives feedback to a game designer, Howie. Moreover, Howie’s answer, which is a rejection of the suggestion, states that the change is not good because the game “just becomes whoever throws the balls the fastest” (line 508). Here “the fastest” is a comparative and relating to a physical act of throwing a ball. Because he rejects the suggestion on this basis, he conveys an aesthetic value for a different kind of game experience for players. In other words, he does not value a game determined by physical ability or actions. He then proposes another possible design change in line 510 using the corrective conjunction “instead” to remove one game mechanic and insert another. Again, this suggests that the YS is taking on the role of a playtester and is even thinking collaboratively with Howie to resolve the latter’s design issue.

The second instance of a YS making a design suggestion occurs in lines 511 to 512 in which YS2 uses the causal conjunction “Unless” to set a condition in which he states that the game would be better, “more interesting” with more competition. Howie answers “yeah” to agree or confirm this statement. However, he states another design aesthetic that he is attempting to achieve through his game. In line 513 Howie uses the demonstrative reference “the ‘what happens in reality’” to point to scientific phenomenon, presumably related to PV solar energy. Then he omits the definite article “the” in the second demonstrative reference, when stating “what makes the game fun,” which is a reference to the design goal of having a game that is fun to play or a fun experience. The additive conjunction “and” relates these two references, scientific phenomenon and fun, into a design aesthetic that expresses the goal of science game design. This is in the sense that the game represents science with fidelity to theory while also being fun to play. He then references this design aesthetic or design goal as “the current barrier.” In doing so, Howie expresses what aspect of science game design he is struggling with and attempting to achieve. Moreover, it is indicative of this REU’s instantiation of the science game designer social identity.

While meeting with two other YSs, Howie offers his advice about their PV solar project. In this exchange, he takes a near-peer role in giving advice as a fellow student but one more experience and knowledgeable than his younger and less experienced peers. This occurs through Howie giving technical advice on electronics and also while explaining his opinion about public engagement with science. First, YS1 asks the polarizing question in line 521 to determine if Howie has “any advice” for them positions him as knowledgeable and possibly an expert of some kind in electronics:

521 **YS1**: I mean do you have any advice for how we could-
(...)

538 **Howie**: Yeah. So, if your Arduino's down here and this is your little tube, I'm
539 going to say it's a tube for now. If you were to bundle the wires and use the
540 tube as basically a stand, and your solar panels were up here or somewhere.
541 That's one way to cheat it. But longer wires, more problems is the general
542 rule.

In the above excerpt, Howie gives suggestions to the YSs through conditional conjunctions “if” in this excerpt, to express how the result of changes to their electronics can make it work. The fact that he understands the consequences of these changes and they do not express it suggests his near-peer relationship to the YSs in the sense that though they are both students in the Solar Energy Center program, he is more experienced and knowledgeable. Another indication of this expertise and near peer relationship with the YSs is in lines 541 and 542, Howie references “the general rule.” The fact that he is aware of and able to bring up a “rule” or maxim of a particular area of knowledge is another indicator of his expertise. He also uses two comparatives, “longer wires” and “more problems” which indicate he understands the result of these variables, thus indicating his expertise on electronics another way.

Howie uses the same nouns in inverse order, showing an equal relationship, a cancelling effect considering it is in the negative “do not.” In this case, the meaning is that scientists and politicians cannot speak each other’s language. The YS repeats it in line 563, using a Latin phrase as a kind of reference and conjunction cohesion which recalls the idea and its relationship. To repeat this phrase by the YS indicates an understanding or an attempt to confirm that they understand it correctly, which Howie does confirm. This further demonstrates Howie’s expertise in the area of science

communication and the role he is taking on as near peer or expert to the YS who is meant to learn from him.

While meeting with a third YS, Howie gives his perspective on public engagement with science. In the excerpt below, he gives an idiomatic phrase which he uses “scientists” and “politics” in two separate clausal groups in parallel structure, a kind of lexical cohesion which translates *to a cannot do b* and *b cannot do a* in describing how politicians and scientists cannot speak the other’s language:

561 **Howie:** It's a lot of words just to say scientists don't speak politics and politics
562 don't speak scientist.
563 **YS3:** Scientists don't speak politics and vice versa.

In response, YS3 repeats the first of the parallel clausal groups Howie just stated. This example of lexical cohesion is an indication of accepting and, in this context, learning what is being stated by another. The YS does this with the second of the parallel clausal groups through the Latin adverb, “vice versa,” as a kind of substitution that references “politics don’t speak scientist,” which is another example of mirroring or echoing what Howie states. In this way, Howie is teaching the YS about public engagement with science, furthering his role as a near-peer teaching the YS.

Science Game Designer and Sociotechnical Role. Vic also describes her game, the rap battle, to two YSs. Demonstrative references such as “the locals” (line 575) express who her target audience she is designing for. Here, “locals” are taken to be people living in Arizona and maybe more specifically Phoenix. The next such reference “not too many people” includes a negative towards the modifier “many” to refer to the small number of locals who “know about solar.” She uses a causal conjunction “because”

to express that this lack of knowledge on the part of the local Arizonans is the rationale for her game:

575 That's pretty much it. I wanted to get the locals involved just because not too
576 many people know about solar. So I figured it's the best way to do it.
577 Everyone likes music and everyone likes a funny, good rap battle. I don't
578 know. It might just me. But, yeah. Any questions?

She restates the rationale through the extended reference, which is also a textual reference, “it” in “it’s the best way,” to refer back to her game. The next reference is a demonstrative with a superlative, “the best way,” which is her appraisal or valuing of her approach to public engagement as a good approach, or quite simply, the best. Her reasoning is expressed through personal references, the logical progression an additive conjunction offers, and how the relationship between a superordinate and its example can be equated with one another. To begin with, the two clausal groups “Everyone likes music” and “Everyone likes a funny, good rap battle,” refers to all people, giving her statement generality. Moreover, “music” is superordinate to “rap battle” in which the latter is associated with the former. Then the additive conjunction “and” between these two broad statements constructs an associative logic in which since everyone likes the first, they will then like the second, therefore her game is the best approach to reach her target audience, the locals. In short, Vic reveals her goal and some aspect of her design aesthetic in the sense of what she thinks is appealing and fun for players. She also reveals what design choice she has made and given a rationale for it.

After the YSs ask follow-up questions about Vic’s event, one makes a suggestion in the form of using conditionals “if” in lines 586 to offer hypothetical possibilities:

585 **YS5:** I was thinking maybe tying it to other public events that go on in the
586 city of Phoenix. If there was (????) event, you could (????). Or if there was a

587 Pride event, you could also do that there
590 **Vic:** That's a good one. It's just, again, since I'm from that side of the country
591 and you guys are over here, it would be my dry run. But I think it would be
592 something that I would like to continue to do. Since again, everyone loves
593 music.

Vic refers to these suggestions and her appraisal of it through the demonstrative reference “that” in “That’s a good one,” to refer to the suggestions and then “a good one” to express a positive attitude towards it. Then she uses a causal conjunction “since” in line 590 to give a rationale as to why the suggestion would not work. Moreover, she references her rap battle as “my dry run,” which is to say that it is a practice event or one that is not the final product. In this way, she is using the thought process of product development and iteration for an event she is developing. So Vic is explaining her rejection of their suggestion in game design terms, still treating a game as any kind of competition with rules and a goal participants are working towards. In this way she enacts the science game design social identity as she expresses the thinking and decision making of the role. Moreover, in giving design suggestions, the YSs take on the role of playtesters who have the responsibility to give feedback on the experience the game offers. Though the TSs do not play the game per se, they still give a critique of the game’s concept nonetheless.

When it is Vic’s turn to give YSs her feedback on their project, she also asks them clarifying questions which are not strictly about their project and are more about the YSs relationship to solar energy and the Solar Energy Center program:

594 **Vic:** So I have a question for both of you. What made you want to get
595 involved with Solar Energy Center and solar panels and solar energy and
wanting to help
596 your community? What inspired you guys to do so?
(....)

601 **Vic:** Sort of plan on being an engineer? You are going to be an engineer. You
602 have all these great ideas. You have to be an engineer.

Vic's content questions in lines 594 to 596 use the personal reference "you" and "you guys" which direct the YSs to speak from their perspective as to their involvement in the summer program and solar energy as well as their community. In order to answer, YSs are tasked with explaining their relationship to these organizations and things in the world, which possibly require them to make statements about their social identity in terms of how it relates to solar energy. This is a sociotechnical role that Vic is assuming in doing so. Moreover, in lines 601 to 602, she positions one of the YS as an engineer through using the personal reference "you" and the demonstrative reference "an engineer" in the clausal group. In one sense, Vic is taking a near-peer role because she is already an engineering student in university and encouraging a younger student to follow the same path.

Game Design Event 5: Howie Consultation

In a one on one meeting at the Solar Energy Center's meeting room, Howie meets with the facilitator to discuss his game. The REU expresses problems in his game's design in terms of the player's experience playing it. Analysis will demonstrate how Howie portrays his game design in a negative light, basing this on the player experience it offers. The facilitator invites Howie to see the game through the perspective of the player and suggests new game mechanics, but Howie disagrees with these suggestions and then introduces a new game design that also is a representation of PV solar concepts. This interaction demonstrates Howie's social identity as science game designer seeing

limitations of his own design, discarding it, and choosing another that meets his aesthetic requirements.

To begin with, the REU expresses problems in his game's design in terms of the player's experience playing it. He does this through personal references "you" as a general exophoric reference to anyone playing his game, then switches to "I" to speak as a player:

670 **Howie:** Going across and moving around the first time. After that you're
671 going like, "Okay, I played this once. I made it through the circuit. I don't
672 care anymore."

The temporal conjunction in line 670 "After that" also conveys the sequence of events as a player first playing the game and then having a reaction to that experience. The reaction is spoken in the first person singular "I" from the player's perspective where "played" and "made it through" are instances of lexical cohesion, both stating the same idea of playing the game. The numerative reference "once" refers to the number of times the player has played. The temporal conjunction "anymore" in line 672 conveys the sense of the player no longer being interested in the game. Combined together, Howie portrays his game in a negative light based on the player experience.

The facilitator responds to Howie's assertion by directing him to consider more game mechanics that can give the player experience the latter believes is missing from the design. The facilitator does this through using the personal reference "you" to refer to Howie as the designer in line 673 and then shifts to "you" to refer to Howie as either a player and/or designer in the game in "you're trying to do" and then clearly as a player in line 674 "You're trying to get across." Also in this line, the facilitator uses the

conditional conjunction “if” to set the condition of Howie envisioning his game as “a competition,” so that the result is considering difference game mechanics.

673 **F1:** If you imagine a competition, there's two things that you're trying to do.
674 You're trying to get across and either through different game mechanics
675 knock people out, off, back, or you can progress forward. I think there's
676 some—

The suggested game mechanics make up a *game mechanics lexical chain* which include “knock” and its accompanying series of prepositions “out,” “off,” and “back” in line 675. These are possible design choices that Howie can choose to improve his game. Also note that the facilitator states, “there’s two things that you’re trying to do,” and the first is the player attempting to cross a gap expressed in game terms through the *game mechanics lexical chain*. However, Howie interrupts in line 677 before the facilitator gets to the second thing a game designer is trying to do in the game. He uses the adversative conjunction “but” in lines 677 and 680 to disagree:

677 **Howie:** But making those game mechanics happen while making it pseudo
678 random still—
679 **F1:** It's doable
680 **Howie:** Random works, but random competition. If my movement's random,
681 and me crossing it is random, and my knocking people out is random, then it
682 is all random and no competition.
683 **F1:** Yeah. And people would like to see balance between randomness and
684 being able to makes choices and decisions

In line 680 Howie uses the “if/then” conditional conjunction to state an argument in which he states if A, B, and C are random, therefore all of it is random. Moreover, he uses the additive conjunction add to also conclude that such a design would result in “no competition,” and therefore, not a game that players would play more than once, which is an important criteria for his design aesthetics. The facilitator states, “Yeah,” agreeing with this conclusion and then using an additive conjunction “and” to build on Howie’s

point, further showing agreement. Essentially, Howie has argued against the facilitator's suggested approach to improving his game's design. This indicates that Howie follows his principles as a science game designer and considers it his responsibility to solve shortcomings in his design.

Then Howie explains that he will discard his game idea for a new one. He explains how he can use *Mancala*'s board as a representation for PV solar energy concepts:

688 **Howie:** Yeah. You get to make the choices. You can think of your opponent's
689 level as the conduction band and your level as the valence band

Howie describes this new version of Mancala from the perspective of the player by using the personal reference "you" and possessive form "your." He uses "your opponent's level" and "your level" to refer to parts of the Mancala game board. He also uses demonstrative references "the conduction band" and "the valence" band to indicate what the game parts represent in science terms. In this way, he is expressing his new game idea in terms of it representing PV solar energy concepts.

Another example of Howie designing Mancala to represent PV solar is how he assigns radiation, one of the three types of recombination in a solar cell, to be expressed through a game mechanic:

703 **Howie:** For radiation, if I might take all those beads from the other side and
704 just put it in my bin

In the above excerpt, Howie states game mechanics through a conditional conjunction "if" which sets a condition and a subsequent result. In line 703, the condition is "take all of those beads" and the result is "put it in my bin." These two steps form the radiation game mechanic for the game. It is important to note that this is a design modification for

the purpose of having *Mancala* express science concepts, making this an instance of Howie enacting not simply a game design social identity, but a science game designer social identity whereby the game is about science.

Game Design Event 6: Vic Consultation

During Vic's consultation with the facilitator, she informs him that she is dropping her rap battle concept for her public engagement game. She states what her goal is and what she is looking for in a concept:

750 **Vic:** If I could find a game that will allow for them to have a take-
751 home message and all ages, I think I would feel very accomplished. Those are
752 my two goals.

Vic uses the first person personal reference to refer to herself and speak from her perspective while the third person plural "them" refers to the players of her game. She uses the conditional conjunction "if" to express the circumstances in which she feels that she will be successful at creating a game. The circumstances have three components, first of which is for her to "find a game" which conveys the sense that she is searching for an existing game to modify for her purposes rather than start from scratch. The second circumstance or requirement is that the game educates players, the content of which she expresses through the demonstrative reference "a take-home message." The modifier "take-home" implies that some content has been learned or effect is made with the players that is important and relevant to them. The third aspect is that this message be applicable to "all ages" and/or that the game is playable by children and adults. The result for Vic if these three conditions are met is she "would feel very accomplished." In this way she expresses her design aesthetic as in what are the requirements and qualities of a good public engagement game.

The facilitator responds with three points he wants to make which he organizes through the use of the general noun “thing” to create a series of points, which is lexical cohesion through repetition. He does this through “One thing” (line 753), “one thing” (line 770), “Another thing” (line 777), and “one more thing” (808) which form a refrain in which he responds to Vic’s situation of needing a new game concept and her criteria. In the first instance, the facilitator responds to Vic’s demonstrative reference “take home message” (line 750 to 751) through the reference “The message” and “it” in line 753 forming a *message lexical chain*. His use of the additive conjunction “and” conveys two aspects of this message which are different from what Vic uses:

753 **F1:** Yeah. Okay. One thing. (...) The message can be kind of subtle, and it
754 can come through playing the game or doing the game. So I would say you
755 don't need to feel like you don't need to prepare a set bunch of content and
756 be like, "Okay, these people need to know this," in the same sense that a
757 textbook or an article is presenting information

After stating his criteria for a game’s message, the facilitator uses the causal conjunction “So” to give his conclusion based on this characterization of the message and speaks to Vic directly as a scientist doing public engagement through game design using the personal reference “you” in lines 754 and 755 and directs Vic in the negative “you don’t” as he expresses what she should not do. Moreover, at this point the *message lexical chain* resumes and is expressed as “a set bunch of content,” the modifier “bunch” implying a large amount. Then “a textbook” and “an article” cohere as genres associated with communicating disciplinary knowledge and the message lexical chain occurs again as “information.” So what is happening is that as the genre changes from a game to textbooks so does the nature of the message. Moreover, the facilitator directs Vic to not do the latter, to essentially not try to create a game that conveys information like a

textbook. In short, the facilitator is attempting to guide Vic away from creating a game that teaches disciplinary knowledge or attempting to maximize the volume of information it conveys. In this way, the facilitator is responding to Vic's statement about her aesthetics for designing her public engagement game by adding to hers and characterizing the goal of communicating a "take-home message" according to his aesthetics.

Another noteworthy exchange during the consultation occurs when Vic responds to one of the facilitator's other points he makes. He suggests she look to her research project for inspiration, as he did previously during the introduction to the project meeting. Her response however uses two conjunctions that convey the idea that her games message will not be based on science concepts per se:

777 **F1:** Another thing you might think about is like, well, is there something that
778 you found really cool from your research project? That maybe you're like,
(....)
781 **Vic:** I don't even know
782 if it would be our project, but I would even say go back to presentations that
783 we had

In this conditional, Vic's use of "if" to draw a causal or associated relationship between two things, the first referred to by "it" and the second "our project." In the first case, "it" is an extended reference to the facilitator's idea of getting inspiration for a game from her lab research (lines 777 to 780). The possessive reference "our" of "our project" is Vic referring to the research project that she belongs to. In this case, Vic first states doubt, "I don't know" before this phrase, indicating she does not think there is an association or causal relationship between her inspiration and her lab research. As a result, the facilitator's suggestion is rejected by Vic's use of the contrastive conjunction "but" and then supplanted by her notion that she finds inspiration from a presentation she attended.

These presentations were less focused on the technical aspect of PV solar energy, but rather on the energy industry and the relationships between it and society. For Vic to show preference for drawing inspiration from this is an indication of how she enacts the science game designer social identity. Moreover, what her game will be about and its “take-home message” is based on sociotechnical aspects of solar energy as opposed to its science concepts.

This interpretation is further illustrated in the excerpt below in which Vic explains why she considers the presentations as sources of inspiration and potential messages to convey to players. Her demonstrative reference “it” in line 798 refers to a presentation on the efficiency of solar energy technology versus coal power plants:

798 **Vic:** I was going to say, I didn't know about it, which is shocking. I was like,
799 "Oh." And it makes you think, so then what is the reason for the race to solar?
800 Why is there such a push for it? And then you can go further

In line 799 Vic uses the additive conjunction “And” to add the utterance of surprise “Oh” she expresses in response to information about solar versus coal energy efficiency to “it,” which is a reference to the information in the presentation and the action of pondering. Also, she shifts to the general exophoric reference “you” in this clausal group, meaning that any person confronted by the information will ponder. Vic states what they ponder through the temporal conjunction “so then,” which conveys the resulting event as asking two questions. These “what” and “why” questions include demonstrative references “the race” and “a push” which point to the urgency and efforts by Solar Energy Center and other organizations to improve and spread solar technology. She also uses “And then” to express persons continuing questioning and pondering. In short, Vic considers the questioning of the scientific community and governmental efforts in solar energy

development and proliferation as potential content for her game and a “take-home message.” As a result, Vic’s approach to science game design incorporates a socio-technical agenda in terms of what to educate players on.

The facilitator makes a final response to Vic’s situation brings up what games Vic likes to play. This could be in response to Vic searching for a game to modify for her public engagement game. Her response indicates that she has little background with games to draw on:

808 **F1:** There's one more thing. Did I mention (.)? Oh what kind of games do you
809 like to play?

810 **Vic:** I don't know. Can't remember the last time I played a game. That's
811 another thing

812 **F1:** Video games? Or arcade?

813 **Vic:** Mahjong. It's a Chinese board game

The facilitator’s question is one of content as he asks for the genre or type of game she likes. However, Vic’s answer is indirect in that she does not name any game genre. She uses the demonstrative reference “the last time” as a point of reference to her game experience. The fact that she cannot recall the game she played then, it indicates her lack of experience with games and suggesting that games do not fit in strongly with her other social identities. In lines 810 and 811, the demonstrative reference “that” of “That’s another thing” refers cataphorically her lack of experience with games. The general noun and modifier “another thing” coheres with the facilitator’s use of “thing” to organize the points he is making. To connect her lack of experience with games in this way to the larger text is to raise the importance of the issue, to put it at the same level of a main point. This suggests she is stating that her lack of knowledge on games is a problem in regards to doing the public engagement game project at this particular juncture.

Game Design Event 7: Playtest Meeting

In the playtest meeting, Vic and Howie and the other REUs brought their public engagement games to share with YSs.

In the beginning of the meeting, the facilitator talks with the REUs and positions them in the science game designer social identity and in the playtesting and refining step of the development process. The facilitator uses personal reference first person plural “we” and the possessive form “our” in addressing the REUs as individuals involved in the same process. In lines 853 and 854, the facilitator uses “our process” and “our prototype” to do this. Moreover, the additive conjunction “and” is used to add “play testing” and “refining” together as steps in the process:

853 **F1:** (...) All right, so here we are in our
854 process. We're at the point of play testing and refining our prototype, and
855 play testing is this amazing, interesting point that lasts a really long time.

The demonstrative reference “here” is an anaphoric reference to the development process he then refers to. It refers to both the external environment of himself and the REUs in the room together as well as the point in the development process in which they are at. With the “we” reference explicated in the previous paragraph, and this demonstrative reference, the facilitator positions the REUs as persons doing a development process as well as situating them in that process.

Through the causal conjunction “And so” in line 872, the facilitator gives the rationale, the reason behind this step. He attempts to explain the purpose and thinking behind the present step they are at:

872 **F1:** And so the purpose is getting the feedback, exposing flaws. And so there
873 might be some things about your game that you may not realize until
874 someone else plays it and probably breaks it, right? Or they get stuck or you

875 get stuck and you're like, "Where do we go from here?"

The second instance of the causal conjunction “And so” states that the result of the testing may reveal shortcomings of their game. Moreover, the facilitator poses questions, particularly "Where do we go from here?" This question of location, where, refers to a successful outcome that may not be clear to a designer. In this way, the facilitator is attempting to prepare them for the typical experience of a game designer who goes through the playtesting step.

The facilitator then shifts the positioning from game designer to a scientist engaging the public through the game. He does this in lines 876 to 879 in which he uses the personal reference in possessive form to refer to “our public engagement game.” There are also three instances of a think lexical chain which includes “think,” “visualizing,” and “imagining” to direct the REUs to put themselves into that situation in which they would enact that role:

876 **F1:** Now let's think back to our public engagement game. If I'm visualizing
877 right now, if I'm imagining you sharing your game, what's happening? What's
878 happening?

The facilitator also uses the conditional conjunction “if” to establish this hypothetical situation in which he directs REUs to imagine being with the public “sharing your game.” The result of the conditional conjunction is in the form of a question, “what is happening?” a question that the facilitator repeats, amplifying this positioning of the REUs into the situation.

Howie responds to this question in lines 883 to 885 in which he uses the conditional conjunction “if” to establish the hypothetical of him being at an arts festival.

In the result of the conditional, he shifts to first person personal reference “I” to speak as a member of the public:

883 **Howie:** Mine's a board game per se. So if I were to be doing it at First Arts
884 Festival or just being a passerby, I'd probably want to keep moving, keep
885 doing stuff. So need to explain the game quickly and not have it last forever.

In the capacity of being a member of the public, Howie states that such a person is thinking as desiring to “keep moving, keep doing stuff.” The repetition of “keep” is important as it conveys the sense of continuing doing what the person is doing rather than interact with Howie and his game. Howie’s expression characterizes the public as busy and not necessarily interested in the game. Moreover, he elides the pronoun in line 885 for who is explaining the game. It could be a general pronoun of “you” to refer to any person as it would apply more broadly and not be limited to just himself. The demonstrative reference “the” of “the game” suggests this interpretation as he is no longer referring to his game, but the game in the situation being described. Moreover, the causal conjunction “so” at the beginning of the line indicates that this is a conclusion that he is drawing and so perhaps it is closer to a maxim that would apply to not just himself but others. In short, Howie responds to the hypothetical by stating that his role needs to include being succinct and having the game not go too long because the public in that situation will be busy or reluctant to participate. This indicates that Howie accepts the facilitator’s positioning, at least at a hypothetical level, of him being an expert engaging the public through sharing his game.

In the next part of his presentation, the facilitator takes another approach in positioning the REUs as experts engaging the public through sharing their game. He does this by expressing the public engagement event in terms of a narrative of what happens

and what they need to do in order to do this activity. In the below excerpt, the facilitator structures his statements into a narrative through temporal conjunctions “And then” and “And” which continue events from one to the next. For example, in line 897 the temporal conjunction “and then” which is sequential, adds another event to the situation. The other cohesive markers from 897 to 901, such as the personal references “you” refer to the REUs individually and “they” to people who play their games. In this way, the facilitator continues elucidating the hypothetical situation in which he is positioning them within:

897 F1: And then after they've played the game is sort of that reflection moment.
898 And this is really important for what we're trying to do, especially with the
899 public engagement aspect, is that you want to ask them about their sort of
900 story, the player's story that they've sort of put together in their mind through
901 playing it. Like I did this, I did that, this happened as a result, I won, I lost, or
902 this person won. That's kind of like a story that someone has experienced.
903 And what you want to do is ask them a few questions to kind of tease that
904 out, and get them to kind of maybe solidify it and make it an actual thing that
905 they can talk about and think about. And that can lead to discussions about
906 science, maybe about solar, what it means to them.

In this narrative that the facilitator is generating, the facilitator is defining the REU’s role in facilitating the activity, much like enacting an interviewer role. The verb “ask” has many instances in this excerpt and forms an *ask lexical chain* and is also the task that the facilitator is giving to REUs to do after players have finished the game. In a telling instance of the *ask lexical chain*, the facilitator uses the verb “tease...out” in lines 903 to 904, which implies that asking the player questions is a delicate process that may happen gradually. Then starting in line 901, the facilitator defines the player’s role in this situation. He does this through shifting to the first person personal reference “I” to speak from the players perspective in line 901. Another cohesive device at play is a lexical chain called that *reflection moment*, starting in line 897 which is used to refer to what

exactly the situation is that the REUs and players are participating in with the question asking and the storytelling. In short, the facilitator outlines the REUs role as eliciting the player's experience of the game and the player's role of constructing a narrative of their game experience. Moreover, the facilitator is attempting to establish expectations of how the REU is to perform the interviewer role and what the interviewee (the player) can be expected to do.

Lastly on this point of the facilitator detailing the REU's role as interviewer in the player reflection, he gives a series of questions for the REU's to use when they are doing a player reflection:

907 **F1:** (...) And some basic questions that you want to ask is what did you do?
908 How did you win? When X happened, what did it make you think about? So
909 you're kind of getting them to talk about it.

In line 909 the facilitator uses the causal conjunction "So" to convey the purpose of these questions. That purpose is expressed through another instance of the *ask lexical chain* which is "getting... to talk" which puts the emphasis on the REUs and player's respective roles.

At the end of the playtest meeting, Vic gives an update about her game design progress. She has set aside the rap battle idea and is now sharing her new game, *Solar Uno*, which is a modification of the family card game *Uno*. Her description of her changes to the game indicate she is changing *Uno* cards into cards with words associated with PV solar energy science concepts. Vic uses the causal conjunction "So" in line 922 to explain the result of these changes:

921 **Vic:** Yes. So I'm swapping the cards out from what they would normally be if
922 you were usually playing a game of Uno. So the skip card would be the
923 combination. Reverse would be reverse bias. The numbers would just be

924 electrons, and then you'd just have a normal draw four, a normal draw two.
925 And then the wild card would be doping. And that's all I have for right now.
926 But yeah

Vic's modifications to give the game a PV solar theme occurs in line 922 where "the skip card" is now "the combination" and in lines 923 to 924 "the numbers" on the cards are now "electrons." In the first case, the latter demonstrative reference refers to a scientific process in solar energy production. In the second case, the latter noun is also a term referring to a scientific concept. In doing so, Vic is demonstrating how she designs as a science game designer. Her instantiation of this social identity is further expressed as when she explains the purpose of *Solar Uno*. She uses the causal conjunction "Because" in line 930 to express this purpose:

930 **Vic:** Because then there's also the vocabulary that they need to learn, as well
931 as the information. So they're kind (????) of while learning and going on
(???)

What she intends for players to learn is expressed through the demonstrative reference "the vocabulary" which refers back to the science terms she just mentioned. Who is to be learning is expressed through the personal reference "they" which presumably refers to anyone playing the game and likely members of the public. There are two instances of verbal cohesion in the words "learn" and "learning." In the first instance the players are the ones doing the learning and in the second instance it is not clear because of the gap in the transcript however it also seems to suggest that the players are meant to learn PV solar concepts. In this way, Vic expresses her aesthetic for her game design which is to teach players, presumably members of the public, about PV solar energy.

Two notes about Vic's enactment of the science game designer social identity. She only modified the content words of *Uno*, but has not changed any of the game

mechanics or rules for playing the game. Another important note is her use of an adversative conjunction in line 926. The adversative “But yeah” is dismissive of what it points cataphorically too, which can be either “that” as in her game *Solar Uno* and or the sentiment of “that’s all I have for right now” as in her level of progress on the project. Dismissive conjunctions can express the attitude that what it points to is irrelevant or is an attempt to change the topic of conversation. What exactly she is expressing dismissiveness towards is not clear, but generally speaking, she expresses some kind of negative attitude towards either the game she has made, the degree of progress she has made, or both.

Game Design Event 8: Playthrough Meeting

During the playthrough meeting, REUs share their games with YSs and RETs (research engineering teachers) who play the games and give feedback. Moreover, this meeting is meant to be practice for the REUs sharing their game with the public at a public engagement event.

Howie shares his game *Solar Mancala* with a group of YSs by first explaining the rules and then overseeing them play the game. In the beginning of the playthrough, Howie introduces himself in line 967 stating, “Hello. My name is Howie and I’m an intern at [university]. I made a game” Howie’s use of the first person personal reference “I” is a direct statement of social identity as he states he is “an intern,” which is curious in how it is not his formal title in the program, research engineering undergraduate, or REU. He chooses to use the demonstrative reference “an intern” which has its own association with being a student worker or a university student working in an organization to gain experience. That being said, he associates himself with the university

through the preposition “at [university].” Also, he states the he is the creator of “a game,” which is a demonstrative reference without a modifier, which also expresses a lack of information and vagueness. However, he does communicate that he is the one who made the game, so it is a bid to be taken as a game designer. The science aspect of his role become clear in his subsequent description of his game.

During his explanation of the game, Howie acts as a science game designer by explaining the modifications he made to traditional *Mancala* and how they differ. He starts this with the demonstrative reference “the big difference” in line 973 to refer this change that he is responsible for making in the game’s design. Essentially, this change is making some modifications to game mechanics and the game board to represent processes in PV solar energy. He expresses this first of all through the demonstrative reference “the normal game” to refer to traditional *Mancala*, the modifier “normal” expressing the idea of how it is a standard version. Then he uses a corrective conjunction “Instead” to convey how the clausal groups that follow modify that standard version of *Mancala*:

973 **Howie:** Here's the big difference in the game. Instead of in the normal game
974 Mancala where you land in a spot and your turn ends, when you land in a
975 spot, one of three types of radiation or recombination happens (...)

The numeral “one” of the numeral reference “one of three types of recombination” refers to PV solar energy concepts and is the modification that Howie refers to as “the big difference.” Another way of explicating this in more detail is to point out how Howie uses the generalized exophoric general reference “you” in line 974 to refer to anyone playing the game. Also, the demonstrative reference “a spot” refers to the cups in the game board where beads are placed by the player. The possessive form of the exophoric

general reference is used in “your turn ends” to refer to the result of the player’s action. These two references fall within the traditional or “normal” version of *Mancala* that is being changed. The change is expressed in lines 974 and 975 where the result of the corrective conjunction is stated as “when you land in a spot, one of three types of radiation or recombination happens.” This is where the demonstrative references refer to the game itself, the game mechanic, and the science concepts. To refer to the game mechanic as “one of three types of radiation or recombination happen” is an important discursive choice. Howie could have stated that X happens to the beads or one of three things happens to the beads. However, he chose to refer to what the mechanics represent in scientific terms. This points to his science game design social identity in that he is using the game to express science concepts:

975 spot, one of three types of radiation or recombination happens. This is when a
976 solar cell has a defect, and it doesn't work as well. So there's radiation where
977 if I were to land here, everything would radiate down. There's (????) where if
978 I land there, half rounded up, and half rounded down would fall down. And
979 then crazy French name, Auyer, where if I land in a blank spots, both sides
980 will disappear. That makes sense?

Another way of demonstrating how Howie is using his game to express science concepts to his players is examining how he describes the game’s game mechanics, how actions in the game are made possible and the game functions. Howie uses “if” three times in the above excerpt—twice in line 977 and a third in line 979—to express three game mechanics, one for each of the three types of recombination. In the first game mechanic, the conditional situation is “if I were to land here,” which refers to a player ending their turn in one of the cups marked radiation. The result of the conditional conjunction is the following clausal group, “everything would radiate down.” This is important in that he

uses a conditional to express the rules of the game. The other important aspect is how he shifts from referring to the game board in the first part of the conditional to a science concept in the second. In other words, the effect or result of the player's action is characterized in science terms, to "radiate." Moreover, the verb "radiate" is part of a *recombination lexical chain* started in line 975 and continued here in this game mechanic.

The *recombination lexical chain* is a series of verbs and heads associated with the PV solar energy and references that refer to them. Alongside of this lexical chain, are verbs, head, and their references that are instances of the game lexical chain. This chain is made up of "land" that is a verb to describe an action a player makes in game terms and other game-related terms that refer to the board and pieces, such as "a spot" and "your turn." There are two points to make about these two lexical chains in the above excerpt. First, is he uses the *recombination lexical chain* at times to refer to the game mechanic and its representation of science, referring to both at the same time. This happens in the result clausal group of "if I were to land here, everything would radiate down," the verb *radiate* being used to describe the removal of beads from the game and the scientific concept of radiation. This demonstrates his acting as a science game designer in the sense that he is explaining what his game means and represents in PV solar terms along with it being a part of the "big difference" between his version and traditional *Mancala*. In addition, the act of explaining each modification and their name is to also begin a science educator role in which he attempts to teach the players about PV solar. In effect, he is performing both simultaneously.

Another example of Howie enacting the science educator role and science game designer social identity is when he describes the goal of the game. In line 986 he uses the

verb “going around” to describe a player moving beads around the game board and also uses the verb “complete” and demonstrative reference “the circuit” both of which refer to a solar cell generating electricity. The first is part of *the game lexical chain* and the second is part of the *recombination lexical chain*. He uses them to describe the goal of the game as he refers to the player, “you” and his game with the demonstrative reference, “this game.” In other words, playing the game is to simulate or make the game into a metaphor for a scientific process:

986 (...) And going around trying to complete the circuit,
987 and noticing that there are some issues when you're trying to do that might
988 come out of this game

Another important example of the *recombination chain* is “some issues” used above to refer to the defects and low efficiency of PV solar cells converting sunlight to electricity. The additive conjunction “and” connects the idea of playing the game and the player becoming aware of the inefficiencies. This expresses his design goal as a science game designer at the same time drawing the player’s attention to his game’s message and what he wants to communicate. In doing so, he is in effect teaching the players about it.

After playing the YSs finish playing *Solar Mancala*, Howie continues to enact the science game designer social identity by seeking feedback from them on their game experience. To question a player to elicit feedback is to do playtesting, which is what game designers do to test their game. Howie accomplishes this through using the second person personal reference “you” to refer to the YS directly within the question. Also, the question is a content question “what” to which the YS is being directed to answer to in regards to his perspective in regards to “the game”:

1017 **Howie:** (...) So what do you think of the game?

1018 **PT 4:** So I like the idea of it, and the concept. It does show that this one
1019 is more common. The radiation. And this one is more--
1020 **Howie:** Second most
1021 **PT 4:** Second most. And then this one it's the one we can't control?
1022 **Howie:** Yeah

PT 4 answers Howie's question directly, starting with the causal conjunction "So" to state he "[likes] the idea" of the game, a demonstrative reference which is another instance to the recombination lexical chain and references perhaps the modifications and/or its science content. The next clausal group is added to this through the additive conjunction "and" and includes "the concept" which also may refer to the game's modifications or the science content. His use of the reference "It" in line 1018 in "It does show" refers to the game itself and the verb "show" also coheres with Howie's intention of science content to "come out" of the game. So, PT 4 is praising the game's representational aspect. He states that what is being represented is "this one" which is an anaphoric reference to "the radiation," one of the three types of recombination. Another interesting point is that PT 4 uses the comparative to describe it, "more common," which is a comparison among the three types. What is significant is that this comparative is part of Howie's earlier explanation about recombination, so in a sense, he is stating new information he learned from Howie. At this point PT 4 is now taking on the role of learner as he restates Howie's description.

So in giving feedback and performing the playtester role, PT 4 has also begun enacting a learner role as well, the latter continuing in lines 1019 to 1021. He performs this by referencing another of the recombination types represented on the game board through the additive conjunction and demonstrative reference in "And this one is more—" He is about to use another comparative "more" however Howie responds in a way that

he enacts the science educator role. His response has an ellipsis for the clausal group, which is likely “And this one is” but he replaces PT 4’s comparative with an ordinal reference with a superlative, “Second most.” To omit the clausal group, thus referring directly back to what PT 4 states and replacing it is to correct what he is saying with the accurate information. This is a discursive move that is teacherly and is how Howie enacts the science educator role, correcting the YS’s description of the three types of recombination. In line 1021, PT 4 repeats the correction which is a way of expressing that he accepts the correction and is attempting to state the right information. Through this repetition, the YS is accepting his role as learner.

PT 4 continues to enact the learner role in the rest of line 1021 where he asks a confirming question, “And then this one it's the one we can't control?” The demonstrative reference “this one” refers to one of the types of recombination represented on the game board. He links to it again through substitution “the one” and describes it. The confirming question prompts Howie to answer yes or no. The former would indicate that PT 4’s statement about recombination is correct while a no means he is wrong. With Howie stating, “Yeah,” he answers the former. In doing so, Howie is enacting the science educator role in that he is performing a teacherly act of confirming that a statement about science is correct.

Moreover, throughout this playtest between Howie and PT 4, they use the game’s mechanics and game board to refer to science concepts. Howie uses it to describe and list types of recombination. Also, PT 4 uses it to restate Howie’s explanation, referring back to it in a kind of review of the content. In this way, they use *Solar Mancala* as a tool to teach and learn about PV solar energy.

In the course of the playthrough meeting, Vic combined her *Solar Uno* game with another group's game, *It's a Trap*. Vic describes the process and acts as a science game designer through seeing similarities between her game and the other group's game and making a design decision to combine them:

1094 **Vic:** So I had created the cards for *Solar Uno* and what I have for my
1095 electrons, the numbers just so happened to match what they had for the
1096 numbers and the colors. So we were kind of just like, "Oh well we can
1097 recombine it. We can combine them." And it worked that way as well.

The personal references in line 1097 refers to herself and her new collaborators. The "them" in line 1097 refer to their two respective games which they combined together into a single game. The demonstrative "that way" in line refers to the process by which they combined together, or the manner, while referencing the process with the extended text of "it" which covers a few lines of text. The conjunction "And" in line 1097 and "as well" is interesting. She adds the point about this process working as in it is successful. That is a form of recap and commentary in of itself. But she also adds "as well" which is an additional additive conjunction at the end of the sentence and the "that way" which is quite similar of a reference as "it" in that they refer to the same thing. It may come off as an attempt to be okay with the result or trying to prove or convince others that this design choice is the right one as a science game designer.

For findings on player reflections, see Part 1 of this chapter.

10) Group Reflection Meeting

During the group reflection meeting, Vic and Howie answered questions about their experience developing their public engagement game and sharing it with players at an arts festival. Howie enacts the science game designer social identity by characterizing

his conversations with players as player feedback and informing his design process. He treats the feedback as information to help him iterate the next version of *Solar Mancala*. He does this role taking first by using demonstrative references to characterize his game as “a more in-depth proof of concept” in line 1207. Within this demonstrative reference is a comparative modifier “more in depth” for the head. The comparative aspect conveys change and progress towards a better version. Also, the head itself is a term for a design stage in which an idea is being tested for its viability. Taken together, the modifier and head indicate a progress in terms of design. This indicates him enacting the thinking of a designer by conceptualizing his game in these terms, particularly as he expresses it in terms of a stage in the design process:

1207 **Howie:** It was enough to kind of have a more in-depth proof of
1208 concept. And from talking to people that did play, I got the answers that I
1209 wanted to hear from it, like when I was asking questions.

The demonstrative reference “the answers” as in the “the answers that I wanted to hear” in lines 1208 to 1209 refers to responses players gave him during the event about would they want to play again and what they learned from playing it. These references suggest that he views the event in terms of supporting his design process.

The facilitator accepts Howie’s social identity as science game designer through his follow up question about Howie’s characterization of his game as a “proof of concept” in line 1210 to 1211. Within the question, the facilitator uses “if,” a conditional conjunction that poses a hypothetical situation to Howie. The condition is about making “another version of your *Solar Mancala*” and the result is the changes or modifications Howie would make. Such a question further reinforces Howie’s discursive actions as a science game designer as it prompts him to consider the next step in the design process:

1210 **F1:** Yeah. You mentioned proof of concept, so what changes do you think
1211 you would make if you made another version of your Solar Mancala?

1212 **Howie:** The guy with the Beyonce shirt, actually. He suggested, "Oh, so
1213 we're supposed to think of it almost like a circuit?" I'm like, "Yeah." "Oh,
1214 you should have drawn wires like circuitry."

1215 **Vic:** Oh, wow. That's good.

1216 **Howie:** So little details like that. I was rethinking about where the
1217 positioning of the beads. One big thing that was on my mind is if I were to
1218 mass-produce, what would the rules be, and getting that down solidly and
1219 easy to understand

Howie's response to the hypothetical question is a further enactment being a science game designer. Howie refers to one player in particular who asked if the game is supposed to represent "a circuit" and since that is the case, the player directs Howie to change the design. He uses the second person personal reference to refer to Howie to direct the suggestion to Howie who it is assumed can and wants to make improvements in the game. Moreover, Howie is answering the facilitator's question about changes by way of retelling player feedback. In other words, Howie is incorporating player feedback into the next iteration, which is how game designers make decisions about improvements.

Another example of Howie thinking about the next step in the game design process is in lines 1217 to 1219. He uses the conditional conjunction "if" to express what he would do if he were to manufacture his game. This would be predicated on more changes, particularly to "the positioning of the beads" and "the rules." Moreover, this is thinking about the step after iteration is complete when a finished game is ready for distribution, meaning Howie is looking at the end of the design process, as a designer would.

Vic does not attempt to assert her social identity as a science game designer during the group reflection meeting. Moreover, she expresses little ownership of the

game she used during the public engagement event. The excerpt below demonstrates her doing this through adversative conjunctions as well as her use of demonstrative references and personal references:

1153 **Vic:** (...) It actually turned out really well,
1154 even with the game. At first, I was a little nervous because I'm like this isn't
1155 my game. I don't know what to do. You guys kind of just threw me in it like,
1156 "Hey, well, we have Vic over here."
1157 **F1:** I know. We did
1158 **Vic:** I was like, oh my gosh. It made me think on my feet kind of quick, and
1159 even though we only had two questions, it worked out very well (...)

To begin with, she uses the avowal “actually” in line 1153 which expresses that something is contrary to what is expected and is making an affirmation of reality. She makes this avowal in regards to the public engagement event, which is referred to by the demonstrative “it,” having “turned out really well.” In other words, for Vic the event was good which defied her expectations. Why did she assume that the event would not go well? She uses the adversative conjunction in line 1154 “even” in relation to “the game,” referring to the game she used at the event, *Solar Trivia*. This use of the conjunction conveys that the event went well in spite of the game she used. Why would she cast the game in such a light? She uses the causal conjunction “because” to give her reasons. She refers to the game using the possessive form of a personal reference through “my game” however it is through the negative, as in “this isn’t my game” (line 1155). Clearly, she does not express ownership of the game. Then in line 1159 she uses the first person plural “we” to refer to who herself and the facilitators being a part of the game, which does associate herself with the game but nearly as much as my game would have conveyed. Her second use of an adversative conjunction “even though” relates having “two questions” to the event having “worked out very well.” Again, the conjunct means in

spite of. So she is expressing the idea that even though they only had two questions for the game, the event still went well. In short, the game not being hers and the game only having two questions are negatives and would presumably caused the event to go badly, at least from her perspective.

In casting *Solar Trivia* in this light, Vic makes no attempt to assert a science game designer social identity. Recalling that she came up with the two questions she refers to, she still does not express ownership or express any sense of having designed the game either. She only goes as far as associating herself collectively with the game, but not as a designer of it. Moreover, after Vic states that the game is not hers, she also states, “I don’t know what to do.” This is indicative of her lack of ownership of the game, not knowing how the game functions or its message, which the designer would know. Lines 1155 to 1156 also speak to Vic’s sense of unpreparedness for taking on doing the player reflection activity. She states, “You guys just threw me in it like, / “Hey, well, we have Vic over here.” The personal references set herself apart from the facilitators, referring to the latter through the personal reference “You guys” and herself in the first person, but distinct from those making the decisions. Also, she uses the continuative conjunction “Well” as what Halliday and Hasan consider an “explanatory comment” in relation to what came before (p. 269). The comment is “we have Vic over here.” First of all, she shifts to the first person plural “we” in line 1156 to speak from the perspective of the facilitators and refer to Vic in the third person, again making the distinction between herself from those organizing the event. Also the demonstrative reference “over here” to convey the proximity of Vic also conveys an attitude of her being at hand, available, almost as a cog in a machine that is as good as anything else. In this sense, she is being

put into the situation irrespective of other considerations, such as the ones she raises in the excerpt, like her having no connection with the game she is being asked to use at the event.

In line 1157, the facilitator confirms Vic's characterization of events. He does this by using the first person plural personal reference "we" which reiterates Vic's portrayal of the situation. He also uses the verb "did" which substitutes for either of Vic's clausal groups in lines 1155 to 1156 that characterize the facilitators as inserting Vic into the situation with little consideration. In short, in the above excerpt Vic expresses the attitude that she was put into the role of scientist engaging the public with little regard to herself or preparation. That being said, two instances of lexical cohesion also convey that overall the public event was successful. In line 1153 the verb "turned out" coheres with "worked out" in line 1159 to express the unfolding of the event. Likewise, the former has the near repetition through "really well" and "very well" respectively. This example of lexical cohesion, which occurs at the beginning and ending of Vic's response bookends her characterization of the event. This further echoes her point, which she makes through adversatives "even" and "even though" which relate to this lexical cohesion, that in spite of the game not being hers, her being unfamiliar with the game, and being thrust into the situation without regard for her, she considers the event to be successful.

Howie expresses that the event helped him progress in developing his game, which is a continuation of the science game designer role. If it is not the science game designer role that Vic associates her success with, then what role is it? In the next extract, Vic continues her account of the public engagement event in lines:

1159 **Vic:** (...) As I

1160 started to get the hang of it, I was able to read people as they were walking
1161 by or as they were coming up I started to notice some people would shy
1162 away when they saw that it was something science-related because they
1163 were like, "Oh, I don't think I would know."

1165 Vic: I hate that, when people see science and they're like "Oh, I think I can't
1166 do it. I'm just like, "Well, you haven't even tried it," you know? Just maybe
1167 because you may have had that one bad experience in high school, or in
1168 middle school, or whatever, and then you're just like oh, I'm never going to
1169 do it again. That still doesn't mean you can't try it.

1170 **F1:** Right

1171 **Vic:** That was something I had to read. The people that were really scared or
1172 did not want to approach me ended up having the most fun, and I was able
1173 to discuss some things a little bit more (????)

There are a few key lexical chains with which her description hangs on. As in the previous excerpt, Vic bookends her account with cohesive markers that express her interpretation of the situation. The verb "get the hang of" in line 1160 coheres with "able to" in lines 1160 and 1173, and "started" in line 1161. This verbal cohesion is associated with learning and having capability. Moreover, she relates the *started lexical chain* to another lexical chain which is focused on reading people, hence the name the *read lexical chain*, which occurs as "read" in lines 1160 and 1171 and "notice" in line 1161. In these instances, Vic is describing being able to size up or observe certain behaviors in members of the public passing by the Solar Carnival and those that played her game. In short, Vic expresses the notion of her learning to be able to read members of the public. What behavior she is observing is related to another important lexical chain, which is the *try lexical chain*. Vic uses "try" (lines 1166 and 1169) and "do" (1166 and 1169) in association with members of the public getting involved with anything science-related. So Vic expresses the notion that doing the public engagement event, she learns to be able to read members of the public's involvement with science. Perhaps this relates to being a

scientist doing public engagement in the particular context of a face to face conversation in a general sense.

This involvement can be further interpreted through the implication of the verb “try” of the *try lexical chain*. It implies the members of the public are attempting or doing something that they are not familiar doing or have no experience with. This positions the public as having little background in science. However, Vic uses the demonstrative reference “some people” to limit her portrayal of the public to not all, but a small quantity through the modifier “some.” Her use of the causal conjunction “because” goes a long way in expressing her reasoning for this assertion in line 1162. She states her reason as “Oh, I don’t think I would know,” where she uses the first person personal reference “I” to speak from the perspective of these segment of the public. The two clausal groups “I don’t think” and “I would know” relate the ignorance about science that Vic portrays them has having. She attributes this negative reaction to science prior to the causal conjunction stating basically that the cause is this segment of the public if they “saw... something science related.” Essentially, Vic constructs this cause and effect reaction in which this segment of the public automatically reacts negatively towards anything that reminds them of science.

Before continuing with the rest of the analysis of the excerpt, it should be noted that Vic explaining that she learned to read the public’s reaction in this regard and identify them by this observation relates to role taking in that she is explaining her thinking as a person doing the sociotechnical role. So she is explaining she learned one trick or one aspect of the role. In short, she learned to spot members of the public who have a negative relationship to science and for her this is part of doing the sociotechnical

role. Vic also bases her conclusion on them having prior “one bad experience” with science, which she expresses through the causal conjunction “because” in line 1167. In Vic’s way of explaining the bad relationship, she sees the “one bad experience” as being a defining moment in their life and since then poisoned the well to sort of speak.

The extended reference “That” in “That was something I had to read,” in line 1171 points to as much. Moreover, she refers to the segment of the public who have a negative relationship with science through the demonstrative reference “The people” and she further describes them with the alternative conjunction as “really scared” or “did not want to approach” Vic. Both clausal groups characterize this segment of the public clearly as turned off to science, further characterizing them as having a negative relationship with science. Ironically, at the end of the excerpt she also characterizes them as having a positive relationship with science through the comparative “the most fun” in line 1172. She uses the verb “ended up” which coheres with “turned out” and “worked out” in the previous excerpt, to convey the end result of the event. So Vic identifies members of the public by their negative relationship with science and notes that by the end of playing her game and speaking with her, events which she does not mention but is presumed happen, they have a new relationship with science, one based on “fun.”

Also, Vic uses the additive conjunction “and” to add to this positive change in the public with “and I was able to discuss some things a little bit more” in lines 1172 and 1173. Though it is not clear what “some things” refers to from the text, it refers to any number of her conversations with her players during the public engagement event (Presumably, this does not refer to Players 7 or 9, both of whom express a strong positive relationship to science compared to Players 13 and 14 who have no science background

and possibly even Player 10, though this cannot be determined definitelvy from the context. Please see the first part of the Findings chapter). What is clear is that she uses “a little bit more” in relation to talking about solar energy with some of her players. The comparative “more” expresses an increase in conversation on the topics and since the clausal group is being connected to “fun” through the additive conjunction, the comparative reference can be interpreted as another positive change that occurs by the end of the encounter.

In summary, it is Vic’s assessment that she learned how to be able to spot members of the public who have a negative relationship to science and she also noticed that they had the most positive experience during the public engagement event, presumably counteracting their prior negative experience with science. As such, she is reflecting on her development in the sociotechnical role where she seeks to improve the public’s relationship with science for those who have a negative attitude towards it. Moreover, this role fits prominently in the ways she acts as a scientist who engages the public with science.

Relationship between Lab Research and Public Engagement Roles

During the introductory meeting and the prototyping meeting, the facilitator makes statements about the project’s schedules which conveys a hierarchical relationship between the lab research role and the social identities and roles associated with public engagement with science that the REUs are involved with in the program. The following section describes each of the types of statements that were identified through analysis of discourse.

Throughout the introduction to the project, the facilitator positions the REUs as scientists and scientists who engage the public. At the very end of the meeting, the facilitator establishes how the role of the latter relates to the role of the scientist as a person doing experiments in the lab. In the excerpt below, the facilitator references the REUs work as scientists through the usual personal references (you/your) positioning them as scientists doing the work of scientists. A reading of the content of the excerpt shows that the doing science role is more important than the doing public engagement role. However, as the extract below indicates, the facilitator's use of the adversative conjunction "but" in line 217 is an attempt to make the latter role important still:

215 they're going to have you working in the lab, and our project will be running
216 in parallel to your laboratory projects, your experiments. And that's the
217 priority, that's what you came here for. But we also want you to have
218 experience engaging with the public

Part of the facilitator's attempt to give value and importance to the public engagement project occurs in line 217 the "we" references himself and not the REUs but the leadership or the directors of the summer program who are making this decision and expressing their wishes and intentions. In a sense, this is a bid at having authority and a leadership role and decision making relationship to the REUs. Perhaps more importantly is how the cohesive markers are functioning in regard to positioning the REU roles of a scientist. The "you" and "your" cohesive markers position the REUs as individuals doing science in the traditional sense first and the "but" as scientists doing public engagement second, the latter important but less important to the first.

As a result, competing demands are placed on the REUs, but the doing science aspect of the scientist social identity is being given greater value than the public engaging

aspect. The fact that these practices are characterized as separate and unequal arise again later as REUs set their priorities and choose how and when to participate in the public engagement project and thereby enact this aspect of the scientist social identity. And the facilitator is attempting to place value on the public engagement role in the face of the priority placed on the lab research role.

At the end of the prototyping meeting, the facilitator makes an announcement about scheduling their next meetings. In line 459 he uses the demonstrative reference “the” of “the schedule” to imply there is one schedule, but he does not use personal references such as *our*, suggesting that the schedule is outside of the facilitator’s control and is the one that he himself must follow. His use of possessive personal references is telling in that “you” and “your mentors” and “your projects” and “your research groups” refer to the REUs doing work in the lab and generally doing the work of science in the program. However, he does not use *we* or *our* in these instances, which suggests that there is a separation between what REUs are doing with the facilitator and what they are doing with their mentors. This separation is also expressed in the pronouns in line 465 of “I” and “us” and “everybody” as it becomes necessary to distinguish and separate himself from the REUs as a group and then the REUs as individuals:

459 **F1:** Okay. So the schedule is still being ironed out. I'm not sure if we're going
460 to have time to work tomorrow. And one thing that we're going to be needing
461 to do for next week is sort of figure out times where you won't be with your
462 mentors and you're working on your projects so next week I might work with
463 a couple of groups at a time. We may not be able to coordinate everybody's
464 schedule because everybody, you know, you're starting your research groups.
465 So I might be able to meet with maybe half of us at one time, the other half
466 another time. So I'll just keep everybody posted about this. And when
467 you have a spare minute, keep this game going, keep your
468 ideas going

Essentially, the facilitator expresses a clear separation between the public engagement project and the lab research, which also by default conveys a sense that these two aspects of a scientist are also distinct, related because they are both what a scientist does according to the facilitator, but distinct nonetheless. Numerous demonstrative references associated with time, such as “the schedule” in line 459 and “tomorrow” in line 460 and “times” in line 461 are instances of a *schedule lexical chain*. When it occurs in relation to the public engagement project, there is a sense of the lack of time. For example, in line 467 when “a spare minute” includes the modifier “spare” which implies extra or leftover time. The facilitator is asking the REUs to work on the public engagement project when they are not doing lab research or with their mentors. Moreover, he uses the conditional conjunction “if” where the conditional situation that would give them enough time to meet is unstated, unknown. The facilitator attributes the cause of this uncertainty to the REU’s lab research activities as expressed through the causal conjunction “cause” in line 464 when he states “cause... you’re starting your research groups.” The effect of this is also expressed through a causal conjunction “so” in the following line in which the facilitator states how it will affect their meeting together as a group. In this sense, the REUs doing their lab research activities disrupt the public engagement project or at least introduces uncertainty. Moreover, this implies that the lab research aspect takes precedence or has more importance than the public engagement. It should be noted that this conclusion is an interpretation of the facilitator’s portrayal of the project within the program.

CHAPTER 5

DISCUSSION

The purpose of this study was to explore what opportunities a game design project offered REUs (Research Engineering Undergraduate) to enact roles and social identities associated with public engagement with science. This includes REUs designing the game and sharing the game at a public engagement event followed by a player reflection to discuss the player's experience. This qualitative study examined player reflections between 11 REUs and the 39 players who took part in player reflections, then concentrated on two REUs as focal participants as sources of data for the facilitated design process. Discourse analysis guided this analysis, specifically an analysis of cohesive features in the verbal interactions of participants (Gee, 2014c; Halliday & Hasan, 1976). This included the four types of cohesion – reference, substitution/ellipsis, conjunction, and lexical cohesion (Halliday & Hasan, 1976). These cohesive devices were used to determine what roles and social relationships the REUs enacted during the design process as well as those enacted by REUs and the public during player reflections. Such enactments would indicate what opportunities this public engagement project offers STEM undergraduates to take part in practices of public engagement, particularly dialogue.

Through interpreting participants' attempts to enact roles and identities discursively, analysis indicates that for the most part REUs took on the social identity of scientist engaging the public through game design during the facilitated design process. Both Howie and Vic's instantiation of this social identity indicate they connected it to other social identities available to them, gaming in Howie's case and music in Vic's.

These enactments roughly follow the game design process from meeting to meeting. However, they enacted the science educator and sociotechnical roles to a lesser degree leading up to the public engagement event. At the event, their difference in approach to public engagement became even more pronounced as they diverged in what roles to enact and how to enact them. Overall, Vic and Howie and most of the REUs enacted the scientist doing public engagement social identity in ways that exemplify the dissemination model of science communication, though as just mentioned, the same social identity can be enacted in different ways. Moreover, Vic's enactment of the sociotechnical role is an important instance of public engagement that expresses the dialogue model of public engagement in some ways, which is the approach this study sought to foster in the project. This chapter will analyze these findings in greater detail and compare them to one another as well as how they relate to the research questions:

- 1) Given the challenge of designing a game to engage the public with science, what social identities and roles do undergraduate engineering students enact during the facilitated design process?
- 2) During the public engagement event(s), what social identities and roles do these students and members of the public who play the game enact through the player reflection?

As each of the research questions are addressed, this study will compare participants' enactments to highlight differences and similarities first with the focal participants then compare them with the other REUs participating in the study. After that, this chapter turns to how this analysis speaks to the existing literature, contributes new knowledge to understanding how undergraduate STEM students learn science communication, and

describes implications for improving the public engagement games project and similar educational efforts in future iterations.

Review of Findings for Focal Participants

In summary, data analysis for the two focal participants indicates that Vic and Howie participate in the public engagement game design process as science game designers, though with important differences. Designing a game to teach players about the solar energy concept of recombination aligns with Howie's social identity as a gamer. Moreover, he has prior experience using games to engage the public with science so to do this study's project is a continuation of this practice and social identity. He enacted the science game designer social identity in every aspect of the design process as facilitated in the project and even exceeded it in the end in considering changes to make to his game to mass produce it. Vic on the other hand enacted this social identity to a lesser degree and differently. She started two separate game design concepts, abandoning the first and then subsuming the second into another team's design. However, she was not able to take ownership of this combined game, nor did she share it at the public engagement event. She modified another REUs game for that event, making it a third game she worked with. However, in the last phase of the process, she expressed not owning the game and no longer spoke in ways that would associate her with science game design. Her difficulties are in part due to her not being a gamer and so not knowing about games she could modify on her own, though she was successful in modifying *Uno*, though she did not pursue it. However, she did position herself as a person who had taken part in public engagement activities in the past. Moreover, like Howie, she related to the game project through her social identity, in her case, as a rapper during her initial concept.

During the Young Scholar Critique that was enacted mid-way through the game design process in order to get feedback on their game designs, Howie enacted the science educator role and a near-peer role with younger students in the Solar Energy Center program. He enacted the science educator role in a similar way as he did with players in the public engagement event. Vic enacted the sociotechnical role during that phase of game development, though not in the same way that she did at the public engagement event, using different questions.

During the player reflections at the public engagement event, in general how the REUs positioned themselves in terms of social identity and role influenced what roles and social identities players enacted. In general, at times Vic conducted her player reflections by using open-ended questions, which can be called an enactment of an interviewer role, in which she asked about the player's experience of *Solar Trivia* and/or the experience of specific parts of the game. Her players then enacted roles, such as learner, and sometimes in conjunction with social identities, such as a local Arizonan or a consumer. In reaction, Vic then took up a corresponding role/ social identity, such as the science educator or promoter, depending on the role/ social identity players enacted. Vic also took on the sociotechnical role in which she put the player on the spot to define themselves or express their relationship to science and solar. This gave rise to players asserting social identities such as Phd student, interior designer, and consumer as well as the role of critic. In considering Vic's approach to player reflections (interviewer and sociotechnical), players were given opportunities to enact a number of different roles and social identities. This is far more than the roles/ social identities that Howie's players

enacted as he approached his player reflections with the assumption that players needed to learn science content and they could provide feedback for him to improve his game.

That being said, some of Howie's players actively took part in the role of learner. Howie and these players collaboratively performed a review of the science concepts and Howie corrected them, much like how a teacher checks for learning and corrects mistakes with a student. Moreover, the feedback from players validated his design and some of his game mechanics expressed the science concepts both visually and metaphorically through the game mechanic(s). Also, a player suggested an improvement in his game's visual design which Howie agreed would improve his game's metaphorical expression of science concepts. This example and the earlier description of checking for learning, reviewing, and correcting both show the greatest degree of participation in the player reflection for Howie's players.

Comparing the Findings of Focal Participants to those of Other REUs

The findings of these two focal participants express fairly well what most of the other REUs in the study did in terms of enacting roles and social identities. In terms of designing the science games, Cherry is a good analog to Howie in that they both enacted the science game designer social identity at the outset and throughout the project and actively iterated their designs. She also took up the science educator and science game designer social identity in the same ways that Howie did, including reviewing and correcting player's understanding of her game's science concepts. In fact, her game, *It's a Trap*, also is about the same science concept, recombination in PV solar cells, though the game mechanics and visual design are different. Her game's mechanics are akin to a

children's game like *Sorry* or *Candyland* where players compete to being the first to the other side of the board.

Another point of difference between the focal participants and some REUs is how the latter associated themselves more closely with the scientific community and research. Cherry went the farthest in this regard in that she directly associated herself with research in the lab, research initiatives in the scientific community concerning solar energy. She characterized solar energy as bettering society. These are clear indications of her enacting the scientist social identity during her other enactments during player reflections. To a lesser extent Carter associated himself with research as well as current scientific literature. The latter occurred because players and the facilitator asked about the differences between types of solar energy and if particular innovations had taken place. This occurred with Vic only with one player who took on the role of critic of solar energy research.

The three-person team, Newton, Jordan, and Xavier, also took part in the game design process fully as a team. However, out of the group, Jordan most often enacted the science game designer social identity. Also, their player reflections were the largest in terms of having three REUs present, two to three players, and a facilitator. Also, Newton and Jordan took turns leading the player reflections, resulting in fewer interactions compared to the games where only one REU led the player reflection. Yet they still enacted the science educator role and science game designer social identity. Carter, with his *Tilt Game* enacted the game designer role in what could be considered in a way adequate enough to have a working prototype of his game to participate in the public engagement event, but not to such a degree as the REUs mentioned above.

The REUs mentioned above, excluding Cherry, enacted the science game designer social identity similarly as the focal participants in that they appropriated an existing game and modified it with a solar energy theme. For example, Xavier, Jordan, and Newton took *Monopoly* and re-themed it with solar energy content to make it *SolarPoly*. The game mechanics remained the same, though the visual design was changed to express the solar energy industry. However, Cherry's design for *It's a Trap* is not a modification of an existing game, but a new game falling within the children's game genre. Moreover, she expressed ownership of the game and took the lead in sharing it and making design decisions throughout the project.

The remaining five REUs took part in the public engagement project differently from the focal participants either in what they were designing or what level of participation they chose to give the project. In the first case, the three female REUs who worked together on *Cel-O-Brate Solar* acted as science game designers in a limited sense in that their final version was not a game. It had no game mechanics or goal in a game sense. It was an arts and crafts activity for children designed to teach PV solar energy manufacturing to children at the latter's level. During their public engagement event, they enacted what could be a version of the science educator role that is geared toward children 4 to 8 years old. So while this group of REU's enactment of public engagement fell outside of the scope of this study, they actively took part in the project as kinds of designers and educators for children to learn science.

Two REUs, Yana and Larry, in many ways avoided and resisted enacting the roles and social identities that the rest of the REUs enacted. Yana teamed up with Cherry to work on *It's a Trap!*, however, she rarely discursively indicated doing design work,

thinking, or identifying with the game. Moreover, she did not conduct any player reflections at the public engagement event, though her partner, Cherry, spoke with six players. Larry, on the other hand, enacted the science game designer social identity haphazardly, missing many meetings, though enacting the role during consultations meant to keep him on schedule. However, he chose not to participate in the public engagement event and ended his involvement in the project.

Carter stands out from the focal participants in terms of how he enacted roles and social identities during the public engagement event. As noted in Findings, he progressed from initially declining to enact the role of science educator in his second player reflection to gradually accepting the positioning and enacting roles/ social identities without prompting by the facilitator. Carter's development shows how the facilitator's positioning of Carter and participation in the player reflections, at times as an interviewer, can scaffold the public engagement activity for a learner who is hesitant to start.

Moreover, the two facilitators also took on the sociotechnical role, as Vic had done, and the players responded in similar ways as her players had done. For example, at the end of Howie's player reflection with Player 5 and Player 6, Facilitator 2 asked, "So do either of you have a science background?" to which the latter explained that they had been an engineering student for a time and the other "I just like it." Facilitator 1 also took on a sociotechnical role, to which players made statements about their social identity in relation to science and engineering. This indicates that it was not just Vic could enact the role and that others can attempt the role with similar positioning of players.

Another point in regards to players taking up roles and asserting their social identities. As explained above, players enacted a number of roles when positioned as an interviewee and when the REU/facilitator took on the sociotechnical role. However, sometimes players took the initiative on their own to assert a role or social identity, usually after the REU had finished asking questions as a science educator or science game designer. This indicates that these roles tend lead to players taking up its corresponding role while other roles, like interviewer and sociotechnical can lead to a multitude of roles, a choice that the player makes given a number of apparent factors such as the content of the game and their own identities and interests.

A final finding to review is that the REUs used their games to enact the science educator role as the focal participants. However, a difference in the content of the games demonstrate how the game's design influences what roles and social identities players may take up. Cherry, for example, used the visual design of her board to refer to science concepts she was reviewing with players. Moreover, she also referenced the central game mechanic itself, which is players randomly progressing across the board, is a metaphor for the randomness during PV solar cell energy production which leads to inefficiency. In addition, she referenced the player's game experience to help with her explanations as well. In these three examples, Cherry used her game's design to enact a science educator role. This is similar to how Vic directed players to reflect back on her game's trivia questions, which had to do with Arizona's ranking as a solar energy producer. Often, players took this as an opportunity to respond as a local Arizonan, expressing surprise at how highly ranked their state is. Vic too took the opportunity to be a science educator. However, while Howie, Cherry, and most of the other REUs usually concentrated on

teaching disciplinary knowledge, Vic presented scientific facts that were relevant to the local social identity. The content of her game was about what locals could consider their local knowledge based on their life experience. Moreover, Vic was the only REU to assert her own local identity, which she did while enacting the science educator role to give a player perspective on his local attitudes and values about solar energy. In this way, both Vic and the other REUs used their games to enact roles, but the content of their respective games were different, which in part led players to respond with different roles/ social identities. As explained above, what role the REU enacted also contributed to which roles/ social identities players enacted. This relationship between REU role and game content will be examined further in the next section as well as other insights based on the findings.

Insights from Analysis

Findings indicate that the public engagement project allowed REUs to enact a version of the scientist social identity which practices public engagement with science. They acted as scientists that took on the science game designer social identity for the purpose of spreading their specialized knowledge and educating the public. This claim is made because the science game designer enactments were to a large degree predicated on their involvement in lab research, specialized knowledge, reading of the literature and other activities at the Solar Science Center that enabled them to be scientists as far as that was possible through the summer program and become steeped in its knowledge. The content of their games and the intention behind their design process point to how they practiced public engagement. To begin with, all of the REUs used the game design process to communicate foundational knowledge of PV solar energy research, such as

recombination, except for Vic who used it to convey “take-away” information to players about solar energy, but still based on specialized knowledge. In this general comparison between the enactments of the scientist and science game designer social identities, it can be said that REUs by and large practiced a version of the dissemination science communication model during their facilitated design process. However, their various approaches to the face-to-face public engagement events, as in what roles and social identities they enacted, is where their instantiation of dissemination shows variation from the standard model as well as aspects that can be considered promoting the dialogue model.

Dissemination with an Element of Reflexivity

Most of the REUs continued the dissemination model of science communication from the design process into the public engagement events by their approach to enacting the science game designer social identity and science educator role. To begin with, Cherry, Howie, and other REUs acted as science game designers by eliciting feedback on their game’s design during the player reflections. The players’ feedback and evaluations validated the game’s effectiveness to teach about solar energy, or disseminate knowledge, or revealed its shortcomings in this regard. In the latter case, the REU could then take that information and use it to improve the design to make their game better at disseminating science knowledge. It is worth considering this in terms of the roles that the public were being positioned to perform in this way of doing dissemination. The public is asked to play the game in order to learn science and also asked to play the game to give feedback that can feed into the design cycle of iterating on the game’s design based on its performance with real players. This adds reflexivity to the dissemination practice in that

part of the purpose of interacting with the public is to enable the REU to do a better job, via the game's improved and validated design, to disseminate knowledge.

REUs enacting roles in terms of dissemination is perhaps even more evident in how the REUs enacted the science educator role. The REUs attempted to review with players what the latter was supposed to have learned about solar energy as a result of playing the game. Some players could recall key words or concepts, but not their full meaning, while other players refuted the claim that the game taught the concepts to begin with. From a serious game design perspective, this should have raised alarm bells as to shortcomings in the game's design or at least the achievable goals of playing such a game can accomplish or both. However, in nearly every case, the REUs approached the lack of learning on the player's part by taking on or continuing with the educator role by reviewing the science content either again or more in depth with additional strategies that will be explored in more detail below. This choice by REUs indicates that an important purpose for interacting with the public was to educate them. And even while it was also important to get feedback on the game's design, the purpose of the player reflection became in part to improve the game's ability to also educate the public. So taken as a whole, both the science game designer social identity and the educator role were practiced during player reflections as dissemination of science communication with reflexive elements. Moreover, the public most often enacted the roles of player and learner as recipients of specialized knowledge as well as playtester to improve that system of transferring knowledge. As such, most player reflections promoted the one-directional flow of information from the scientific community to the local community, typical of dissemination.

That being said, the reflexive element of these enactments suggests that the REUs and the public are co-constructing the game's recipient design. Recipient design here meaning an object, like a game, being designed in such a way to engender an intended effect in the audience much in the same way that a speaker's language is designed to have an effect on their listener (Gee, 2014a; 2014b). Involving the public in the game design process has been considered a potential avenue for developing games relevant to the public and promoting dialogue in what is called participatory design (Forlano & Halpern, 2016). However, it must be kept in mind that in this study the public's involvement is taking place after the initial concept of the game has been developed into a working prototype. This limits the public's input to either giving a thumbs up to the design or feedback that suggests some elements of the concept's execution needs re-working. In actual practice, more of the former occurred. Cherry and Howie indicated that they wanted to make another version which would incorporate feedback from the public engagement events into their game. However, Carter did not nor did the team of REUs who made *SolarPoly*. During the project, none of the REUs made an additional version.

This degree of participation in the design process is reminiscent of other forms of public engagement, such as citizen science, where the public is often invited to participate in the scientific process as labor for data collection, but not upstream when the research is being conceptualized (Bonney et al., 2009). Involving the public in aligning the goals of the project so that they connect with the interests of the local community suggest the quality of the participation while the amount of time the public is involved can be considered the degree of participation (Shirk et al., 2012). In the case of this study, the public had a small amount of participation in terms of both degree and quality. In this

sense, the public continue to be treated as a recipient of the endeavor, the ultimate beneficiary in fact, while giving minimal input in terms of influencing the purpose of the project or how it might be executed. As such, how the REUs enacted their science game designer social identity and science educator role perpetuate the scientist-centric focus of dissemination with only a limited element of participation from the intended audiences.

Closed- Ended Enactments

In the above section where REUs almost always acted as science game designers and science educators and positioned the public as playtesters and learners, respectively. Howie's approach to player reflections is indicative in this regard (see Table 5.1). By and large, his players enacted only enacted a handful of roles and social identities. The exceptions to this are when players responded to a statement or question of the facilitators, such as Player 3 identifying herself as an undergraduate science student and speaking a person who likes to "geek out" on science. One exception to this pattern in Howie's way of conducting player reflections is when he takes on an interviewer role and asks the players to express their game experience in terms of a story. Player 6 describes his experience in positive terms, but Player 5 asserts that the game "was very confusing" (line 2129) and that he "[didn't know exactly how it applies to solar" (line 2130). In the face of this negative feedback, Howie had at least two options in terms of enactments, namely the science game designer or the science educator role. In terms of responding as a science game designer, he could have considered Player 5's response as feedback and attempted to figure out what was wrong or lacking in his design by asking follow-up questions along these lines. Out of the REUs, he was capable of approaching the problem from that social identity since he was also a gamer and knowledgeable about game genres

and game mechanics. However, he chose to enact the science educator role and re-explained the science content of his game.

Table 5.1

Roles and Social Identities Players Enact with Howie

Player Number(s)	Howie's Roles/ Social Identities in	Player(s) Roles/ Social Identities
1, 2, 4	science game designer / science educator	playtester/ learner
3	science game designer / science educator	playtester/ learner/ science student* / geek*
5, 6	interviewer (limited)/ science game designer / science educator	playtester/competitor/ learner/ friend / (former) engineering student*

Note: Social identities are in bold to distinguish them from roles.

*These social identities are enacted in response to a facilitator's questions and not Howie's.

On the one hand, this is indicative of how the REUs reproduced the dissemination model of science communication model in the sense of shaping the conversation to be a transfer of knowledge from the scientific community to the local community. However, Howie's apparent choice in responding to the criticism as a science educator, and thereby switching roles, shows that participants in the conversation are not locked into corresponding roles/ social identities. For example, just because Player 5 acts as a playtester does not mean Howie must respond through the social identity of the science game designer. In addition, when Cherry encountered negative feedback in regards to what her game taught about science, she asserted her scientist social identity in conjunction with speaking as a science game designer, stating that the purpose of the game is to teach about concepts she is dealing with in the lab. She also continues the

science educator role, stopping to explain the science concepts along the way. In this example, an REU pulled in additional social identities to the role she was enacting.

In simple terms, speakers in a conversation assume roles and social identities that are available to them, as Goffman would argue. In one sense, Howie's response demonstrates this in that being a science game designer and a science educator are available to him, based on his enactments in player reflections prior to the one with Player 5 and Player 6. He chose the latter. However, a review of how Howie conducts his player reflections indicates that his questions often position the players as a learner or playtester. In other words, analysis indicates the way he asks presumes the member of the public is a learner or is a playtester. To ask a person what they learned from playing the game, puts them on the spot to respond as a learner. The member of the public can either take on that role of learner, reject it, or respond possibly indirectly by talking about the question or with a non-sequitor raising an altogether different topic of conversation (Halliday & Hasan, 1976). The latter two responses might be considered impolite and/or disruptive, even cause a loss of face for Howie. This puts pressure on the public to accept the positioning and essentially play along with being a learner or a playtester.

This study does not attempt to interpret the player reflections in terms of face maintenance (). The point is that during player reflections what roles and social identities appeared available and relevant to the conversation were influenced by what roles and social identities the REUs enacted, how they enacted them, and when. When REUs position the member of the public in a particular role, such as learner, then the latter's options were restricted and, in a sense, closed. As explained above, the public can either accept this role or resist it somehow. In this way, this study argues assuming a role or

identity in a way that positions the other speaker into a single corresponding role or social identity is to enact a close-ended role or social identity. When an REU, or scientist for that matter, takes this approach to public engagement, they decrease or limit what ways the member of the public can interact with the REU and take part in the event.

Essentially, to do so is to make the public's other potential roles and social identities unavailable and/or not relevant to the social situation, unless the member of the public takes the initiative on their own and asserts a new role/ social identity, but this occurred less often.

Open-Ended Enactments

Unlike close-ended enactments, analysis indicates that when REUs enacted the interviewer and sociotechnical roles, members of the public enacted a much wider range of roles and social identities. This is hinted at by Table 5.1 where Howie's use of the interviewer role with Players 5 and 6 was connected to the player identifying the other player as a friend (social identity), and one revealed his past as an engineering student when the facilitator took on the sociotechnical role. Conversely, Vic's player reflections demonstrate a wider range of roles/ social identities corresponding to her enactments of the sociotechnical and interviewer roles (see Table 5.2). Unlike the player reflections where REUs positioned the public in particular roles, when Vic enacted the interviewer or sociotechnical role, it is unpredictable how players will respond in that sense of enacting a corresponding role because they are not being positioned in the same way. For example, when Vic assumed the interviewer role with players 13 and 14, they responded by enacting the learner role. But when she assumed the same role with Player 10, the latter assumed the local Arizonan social identity. In this sense, Vic enacted roles that

were open ended in the sense that the public had a greater degree of latitude in their enactment as well as it was not predetermined by assumptions in her question. This is not to say that it is completely open and the member of the public can be any kind of person in the conversation. In fact they are being questioned and are expected to give answers as an interviewee. However, they demonstrate the license to be other roles and social identities discursively as well.

Table 5.2

Roles and Social Identities Players Enact with Vic

Player Number(s)	Vic's Roles/ Social Identities	Player Roles/ Social Identities
9	interviewer/ sociotechnical/ environmental science undergraduate	PhD chemistry student/ Arizonan
13, 14	interviewer/ sociotechnical/ science educator/ promoter	learner/ consumer
8	interviewer/ sociotechnical/ solar energy expert	interior designer/ Arizonan/ environmentalist
10	interviewer/ sociotechnical/ science educator/ local person*	Arizonan/ undergraduate
7	interviewer/ sociotechnical/ solar energy expert/ undergraduate engineering student	critic/ science buff/ alumnus/ Arizonan
15	interviewer/ sociotechnical	(supporter of solar)**
6	interviewer/ sociotechnical	paramedical student/ (loves trivia)**

Note: Social identities are in bold to distinguish them from roles.

*This REU spoke as a local person from a city on the East Coast and not Arizona.

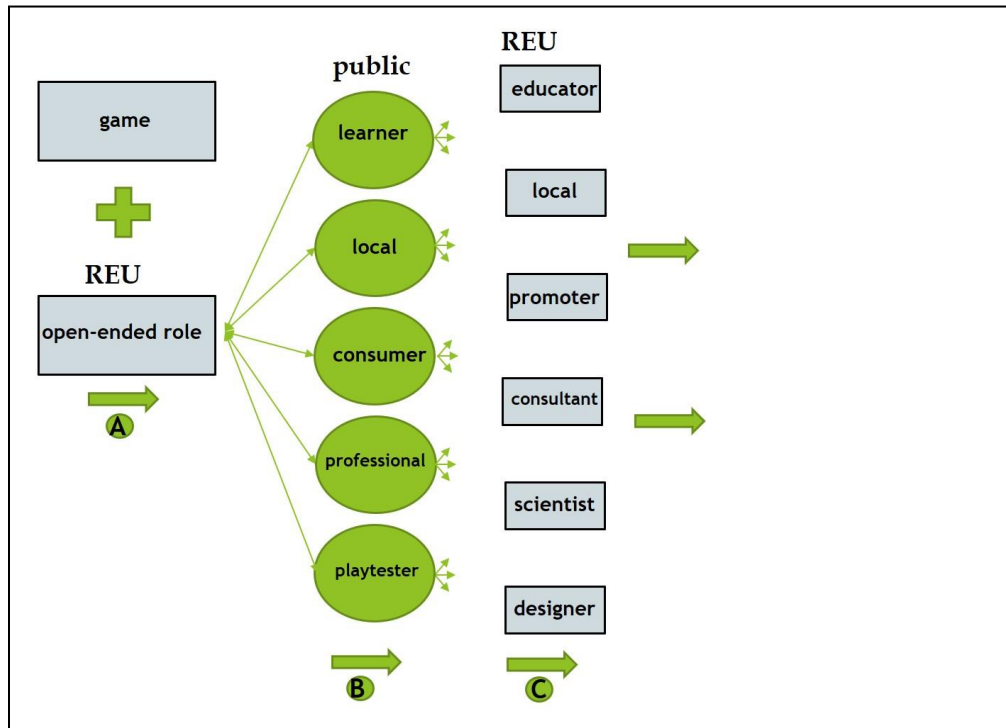
**Player expresses aspects of a social identity, but not in such a way that can be determined to make up a recognizable way of thinking, doing, acting, and being (Gee, 2014a). For example, Player 6 “loved trivia” but there is not enough data to label him a “gamer” in the sense of a social identity.

Another factor that corresponds to the publics' enactments in response to Vic's approach as an interviewer is that of her game's design and the player experience it offers. Solar Trivia is a trivia game about solar energy where the player answers questions based on the solar industry's knowledge system. Most players answered wrong the question about Arizona's ranking in solar energy production. When Vic asked the players about their experience playing the game, they often responded by enacting a learner role and at times in conjunction with the local Arizonan social identity. These players characterized the experience to a large degree as educational, which is positive in the sense that Vic's overarching goal was to educate the public and give "take home" messages. Moreover, their responses indicate that learning was a meaningful aspect of the game experience, as in this is how they interpreted what was happening during the game.

This raises a number of possibilities in terms of supporting dialogue during the player reflection as well as issues arising from privileging scientific knowledge. In terms of supporting dialogue, enacting the interviewer role allowed the public to tell the REU what was meaningful to them about playing the game. Even more interesting, is that Vic then shifted roles and took on a science educator role in response to the players enacting the learner role. This means that Vic exhibited flexibility and responsiveness in adjusting what she was attempting to accomplish discursively based on the public (see Figure 5.1). Rather than essentially pushing her players into one role or another, she let them position themselves and then reacted in kind to a corresponding role. In this way, she not only enacted a role in an open ended fashion, but demonstrated a willingness to be responsive and let the public influence the direction of the conversation.

Figure 5.1

Open-Ended Roles, Reformulation, and Responsiveness for Dialogue



Note. This figure describes how a) an REU can begin a conversation at a public engagement event with an open-ended role. The REU possibly can do this by referencing the game. Then b) the member of the public can assume a role or social identity available to them. Next c) the REU responds to the public's positioning by assuming a corresponding role or social identity.

Returning to the putting the definition of the dialogue model of science communication into practice, a non-policy forming dialogue event is supposed to allow for both sides of the conversation to contribute and benefit from the interaction equally (Davies et al., 2009; Trench & Bucchi, 2014). To determine if both sides of Vic's player reflections in the cases outlined above benefited from the player reflection is difficult to determine from this study's data. However, if contributing to the conversation is conceptualized as setting what roles and social identities are available and taken, then

Vic's open ended role taking and responsiveness can be said to be supporting dialogue to a degree. In the above examples, Vic's players shape the context of the conversation to be about a learner-educator relationship, but the important point, is that it was done by the public's choice based on their experience of the game and their social identities/ roles available to them.

The way Vic enacted the sociotechnical role also is indicative of the open-ended role taking and being responsive to player enactments. Typically, Vic either asked if the player had a science background and at times in conjunction with the question what attracted them to the game and why they are interested in solar energy. Also, this role attempts to establish discursively the player's relationship to science and/ or solar energy. As Table 5.2 shows, when Vic assumed the sociotechnical role in this way, players enacted social identities such as PhD chemistry student, interior designer, local Arizonan, science buff, and critic of the solar energy research field. Out of all of the roles and social identities that REUs enacted during player reflections, this approach is associated with the widest range of social identities on the part of the public. Like the above case with the interviewer role, Vic also reacted responsively to these enactments by assuming some corresponding role or social identity. For example, when Player 8 assumed the social identity of interior designer and spoke about green design, Vic assumed her engineering social identity by noting the history of that type of design as she was aware of it as a person from the East Coast, which essentially connects two of her social identities as she relates to the player as a colleague or peer. Again, Vic shows flexibility and responsiveness in shifting her way of being present and active in the conversation to correspond with what the player is doing discursively.

This dynamic between an REU and the public via the sociotechnical role enacted in an open-ended way as well as being responsive to the member of the public further suggest that dialogue is being supported in the sense of enabling the latter to contributing to the conversation. Moreover, the lexical chains also indicate that the topic of conversation is being steered to a large degree by the players during these enactments as they relate to science and solar. With the interviewer and sociotechnical roles enacted in an open ended way and the REU being responsive to the player's enactments, members of the public are able to be present in the conversation in the sense that they enact roles and social identities that are available to them and relate to science and are connected to their profession, interest, background, aspirations, etc. These are indications that the dialogue model of science communication was produced in these instances during the public engagement events. Moreover, instances of the facilitators taking a similar approach as Vic and data indicates that the public's enactments correspond in a similar way, suggesting that these occurrences are not limited to one particular participant.

Moreover, non-policy informing dialogue events (Davies et al., 2009) are characterized as learning opportunities in a symmetrical fashion, as in both the scientist and member of the public should have the opportunity to learn. Here "learning as more than an accumulation of facts: learning involves emotions, empathy, and social understandings" (Davies, et al., 2009, p. 341). The conversation is an opportunity to appreciate other perspectives on potentially complex sociotechnical issues. To assume open-ended roles and be responsive to the member of the public, Vic's approach demonstrates how multiple perspectives can be present through the enactment of social identities such as the consumer and especially the local Arizonan. In the case of the latter,

numerous players gave their perspective on solar energy in ways that indicate the local community's beliefs, knowledge, and values in regards to solar. The relationship that was constructed between the science Discourse and local Arizonan Discourse is not unproblematic and will be discussed shortly.

However, it is important to recognize how Vic's questions as an interviewer and her trivia game's content engendered the enactment of the Arizonan social identity among others. How that occurred at a discourse level will also be considered below. As a dialogue event, Vic's approach to the player reflections allowed differing perspectives and the potential for symmetrical learning to occur. At the least, Vic's approach suggests how might a scientist *not* begin the conversation with the assumption of what the public perceives as important in terms of learning and gives it latitude to be present in a number of ways that are relevant to the public engagement event's theme. To assume that the public wants to learn about one thing or restrict them to a pre-determined set of roles is to miss the opportunity face-to-face conversation presents.

While Vic's approach provides a promising direction for conducting non-policy informing dialogue events, many issues arise in regards to how the scientific community is privileged during the conversations and their implications in regards to historic inequality between it and the public (Cooter & Pumfrey, 1994). Often Vic's way of enacting the sociotechnical role was to ask the player, "Do you have a science background?" To begin with this is a polarizing question where the answer is either yes or no. The indefinite article and noun "a science background" refers to some kind of association with science, possibly a degree in it or a job related to science. Moreover, *who* is asking this question makes it an even more peculiar question because Vic is

associated with the scientific community by virtue of having conducted the trivia game, asking questions and supplying the right answers, and numerous cues to signal her connection to science. In effect, Vic is asking if the player belongs or a part of this Discourse that she is a part of. Moreover, she is not asking the player what is their background or job or education? She is asking the player's background, job, or education *only* in relation to science, the thing that she is a part of.

This is problematic because science holds a high status in American society (Cooter & Pumfrey, 1994). The players are being put on the spot to declare whether or not they belong to a group that is being singled out as significant (Gee, 2014a), which to have no connection with could be perceived as a negative. Perhaps that is why almost all of Vic's players managed to find some association or connection to science, even if it is through a science class in college or simply wanting to own a house with solar panels because solar panels, a connection to science as promoted by the Solar Carnival, is a social good. It is possible to consider Vic's enactment of the sociotechnical role on these occasions as either boundary work (Gieryn, 1983; 1999) or evaluating the science literacy of her players. Boundary work is the marking and negotiating of the edges of a group by a person, at times done to exclude others and assert their own position within it. From the way Vic's players respond, this may appear to be the case. Most of the players had distant connections to science except for a PhD chemistry student who in a sense had a closer connection to the scientific community than Vic in that he was further along the career trajectory than her. In this way her approach established the player's, and her, proximity to the social good that is science, which was the effect, intentional or not. In terms of the question being a way of determining the player's level of science literacy, this is not

likely because Vic did not follow up that question by assuming a science educator role which would have been the logical progression of enactments if that were her intention.

The other problematic aspect of Vic's approach was that scientific knowledge held a privileged position in her player reflections. To begin with, her game's content, which she referenced in her interview questions, are based on the solar industry knowledge system and provides the "right" answer for the game. A few of the players who enacted the Arizonan social identity, or spoke as a local person, expressed surprise, and in the case of Player 10 disbelief, that their state produced so much solar power compared to other states. In terms of Discourses, these interactions can be seen as two Discourses negotiating meaning in the sense of their perspectives differ on this issue since players express a more is better attitude toward solar and that they do not see many solar panels in their daily lives. As a result, Vic's information contradicts this and in every case trumps the local knowledge as players concede to science's perspective. Historically, it is common for scientists to consider local knowledge as inferior to that produced in the scientific community which can lead to frustration on the part of the publics who are the intended beneficiary of the endeavor and misapplication of research on the part of scientists who poorly understand the context in which they are working (Wynn, 1992). In the case of Vic's player reflections, this would seem to be a reproduction of the privileging of science over local knowledge. Moreover, scientists often find it a part of their role to correct misinformation they encounter when interacting with the public in regards to science facts at least one study indicates for an online context (Sharon & Baram-Tsabari, 2020). It is possible that Vic interpreted the local

community's attitude, values, and local knowledge of solar energy entirely as misinformation and then sought to educate them.

While Arizona was the number two producer of solar energy in America at the time of the study, that science fact should not necessarily override the attitude of the local community that sunlight is a vast resource that is not being sufficiently exploited. If solar energy production is not yet a part of their daily experience, then perhaps no comparative ranking can alter a local's opinion that their state needs more solar energy production. On the other hand, perhaps at this point in time PV solar cells are not efficient enough to meet the state's energy demands and so it is not technically possible to rely on solar energy until an engineering breakthrough occurs. To have had the local community's perspective framed in this way and the scientific community's response to it possibly could have made Vic's player reflections more symmetrical and so support dialogue to a greater degree.

In summary, analysis indicates most of the REUs participated in the public engagement project in ways that reproduce the dissemination model of science communication with an element of reflexivity in which they sought to validate or improve their games to better educate the public on solar energy. In addition, Vic's approach shows how enacting open-ended roles and being responsive to players' enactments can support dialogue to a degree. It is also important to note problematic aspects of this participant's approach in that she privileged science in some ways that precluded dialogue with the local community in regards to solar energy.

Verbal Strategies Using Game Design Features and Player Experience

During the design process, most REUs expressed their game's message or science content in terms of representations and metaphors through game mechanics and visual design elements. For example on *SolarMancala*, the letters "A" and "R" and "T" painted next to cups on the board represented types of recombination, a science concept that Howie wanted players to learn. His game's design features took on a metaphorical expression with the game mechanic radiation "R" where beads are removed from the game, which mimics the phenomenon of electrons radiating out. During player reflections, REUs used cohesive devices in their discourse to refer to their game's design features, content, and the player experience while enacting social identities and roles described in previous sections. This section will consider how REUs used the verbal strategies of reformulation and illustration during these enactments. Moreover, it will explain how this use of science games fits into dissemination and dialogue models of science communication.

To begin with, Güllich notes that medical experts use metaphor, exemplification, scenarios, and concretization as discursive moves or strategies to communicate with patients and others labeled non-experts (1999; 2003). While REUs were assuming the science educator role during player reflections, they tended to use metaphors to communicate their game's science concepts. They also use exemplification or explain a science concept in terms of daily life, such as explaining that the silica has impurities just like diamonds have flaws and lightning is a kind of radiation in the sense of electrons being released. At times they explained the science concepts in concrete terms as well. However, the REUs rarely used scenarios during player to express their science concepts.

In this sense, REUs demonstrated that the public engagement project gave them many opportunities to use illustration in their role as science educator. Moreover, this is how REUs produced the dissemination model of science communication in that they conveyed science knowledge in a one-directional flow of information from the scientific community to the public. So while the design process allowed REUs to reify illustration into a physical artefact, they also used illustration in a face to face context to educate members of the public.

Often REUs did not use illustration alone while enacting the science educator role. In fact, they used reformulation in conjunction with illustration. Reformulation is a verbal strategy to recontextualize disciplinary knowledge into layperson's everyday speech by way of references for the purpose of transferring knowledge (Gülich and Kotschi, 1995; 1996; Gülich, 2003). Essentially, reformulation is the "expert" returning to and rehashing and rephrasing what has already been stated in specialist language. It is also a discursive move to categorize, or position, one's self or others into a particular social identity. While enacting the science educator role, REUs often used reformulation as they referred back to their game's content, design features, and the player's game experience. For example, when REUs check for learning, review, and correct players during player reflections, they reference their game's game mechanics or design feature. This shows that REUs used their games during player reflections as a teaching tool, sometimes like a visual aid.

There are key points about how REUs performed reformulation and illustration that diverges from how the verbal strategies are conceptualized by Gülich and Kotschi (1995; 1996) and Gülich (2003). To begin with, when the REU performs the role of

science educator, they do not act alone and often with the cooperation of the player who has assumed the learner role. Their interaction shows a back and forth, a collaborative nature by which they work through the process to transfer knowledge as described in the checking for learning and reviewing process described before. So even though in one sense, the information is flowing in one direction, it is negotiated between the REU and player as the latter is not a passive recipient if knowledge is being transferred. It should be noted that Gülich's (2003) context is medical experts giving lectures and speaking to patients, a different context than the public engagement events certainly. But it is more precise to say that the roles the experts were enacting were different and perhaps just as important, the role that the players assumed as learners is different than that of the patient. A learner's role includes the expectation that they acquire new information and should ask questions and participate in the learning process. However, a patient may have no such responsibilities placed on them and so such interactional involvement may not be expected or even encouraged.

Another key point is that the game experience is a useful anchor with which to use during reformulation and illustration. To begin with, in many of the player reflections, players indicated that they learned only some of the game's science content, however, they could recall game rules and other game design features having just played the game moments before. As Gee points out (2014b), playing a game often results in players learning how to play the game and the game's perspective or imaginative reality which embodies values and assumptions. The player learns the rules by which the game world works, makes moves in attempts to reach a goal, learns from mistakes and successes. So the player's game experience can be used as a touchstone with which REUs

can reference and use reformulation in conjunction with illustration to teach the science content. REUs refer back to the game experience as a touchstone, a reference point by which REUs then connect the science concepts onto when they review the game's educational message.

So in a sense, this shows how playing the game is learning one half of a metaphor and the player reflection makes the second half, the science concepts which the game is intended to express and embody, clearer. This is particularly relevant for abstract games, such as *It's a Trap!*, *Tilt Maze*, and *Solar Mancala* where the science content is often in the form of visual designs, game mechanics, and other representational forms rather than language based or so explicit. And to add to the relationship between the way that the REUs enacted the science game designer social identity and science educator roles, they asked players to evaluate their game and give feedback. This is essentially a way of potentially feeding back into their game design process, helping them make their game more effective in teaching science.

The other key point is that Vic also used reformulation while enacting the interviewer role, referencing the player's game experience and her game's trivia questions, or content. These aspects of the game are about Arizona as it relates to solar energy, so to use reformulation is to make available to the players social identities, particularly the local Arizonan. Players spoke through this social identity, as noted in the previous section, leading to an interaction between Discourses. This is remarkably different than attempting to teach members of the public science concepts, especially in their original form. So while Vic and other REUs both used reformulation what role it was being used with, as well as what game content and game experience was being

referenced, influenced what social identities were available to players. This suggests that game content can be conceptualized not just in terms of science content and information, but content relevant to particular social identities in order to bring about dialogue.

A final note about reformulation is how Cherry and Carter used self-categorization to associate themselves with the scientific community. They used the same personal reference “we” to do so as Gülich’s example. However, REUs did not refer to players as “learners,” as that happened discursively through positioning the players into that role. Moreover, when player reflections are viewed as a whole, there are numerous potentialities in terms of how REUs and players can relate as they assume and are positioned in roles and social identities. Moreover, the players themselves took the initiative at times towards the end of the player reflection to enact a role or social identity.

Insights for Science Communication Education

In regards to speaking to current STEM undergraduate science communication learning goals considered in the literature, this study is exploratory in nature, so does not attempt to evaluate the participants on these criteria. However, the analysis indicates that with the support and scaffolding by the facilitator as executed in this study, participants took part in key practices of science communication that can be compared to the learning outcomes outlined by Mercer-mapstone and Kuchel (2017). To begin with, Mercer-mapstone and Kuchel prioritize students finding and understanding their target audience. Within the public engagement project of this study, the REUs were not required to identify or research a specific community in the sense of target audience. They did pick an age group (young children, teenagers, or adults) as the criteria for their game design

and worked with that as a constraint. This aligns with science game design, but misses the purpose of connecting to specific communities or publics. The next learning outcome is using language that is suitable to communicate. The REUs' use of verbal strategies, such as illustration and reformulation described above, indicate that they had numerous opportunities to speak as an expert while communicating science concepts during player reflections and to a lesser degree during the design process. This is not to say that some REUs' always modified their language when talking about science concepts. In fact, some REUs attempted to teach science concepts while including many specialized words and jargon and seemed to resort to illustration/ reformulation when players informed them that they did not understand.

Mercer-mapstone and Kuchel recommend that STEM undergraduates also be able to identify why they are doing the science communication and to what end. This project directed REUs to engage the public through a game as well as consider what they would like to talk about with the public when sharing that game. Analysis indicates that all of the REUs set out to educate the public as shown through their enactments such as the science educator role and reproduction of the dissemination model. Their enactment of the science game designer social identity in conjunction with this role also demonstrates the purpose of teaching science to the public as well as developing a game that could be used to that end. However, it is not clear in what ways REUs might have attempted to determine the prior knowledge of their players, if at all. Moreover, Vic's use of the sociotechnical role demonstrated her goal of understanding her player's relationship to science and improving that relationship as well. So while supporting dialogue was one of

the goals set out by the facilitator, the REUs enacted roles and social identities that reproduced the dissemination model.

The learning outcomes of “promoting engagement” and “encouraging two-way dialogue” (Mercer-mapstone and Kuchel, 2017, p. 191) are particularly important to consider for this study. As noted before, Mercer-mapstone and Kuchel consider dialogue as an advanced capability that perhaps should be left for graduate students and professional scientists. Analysis indicates that this project afforded REUs the opportunity to engage the public by way of an interactive and reflexive dissemination approach. Both sides, the REU and the public, are involved in the conversation and cooperate to accomplish the goals, such as learning and playtesting. So it is this study’s conclusion that the project afforded REUs the opportunity to engage the public in an interactive way that they were able to take part in fully.

Moreover, Vic’s approach to player reflections indicate that the project also affords the opportunity to practice dialogue. Her open-ended role taking as an interviewer and sociotechnical, made it possible for members of the public to take part in the conversation in ways that were relevant and possible to them in terms of social identity and roles. Moreover, the public was able to influence the topic of conversation as well. For example, many of her players enacted the local Arizonan social identity, putting a local Discourse into conversation with the scientific Discourse. The privileging of the latter, as noted in the prior section, is a shortcoming of her approach. This is an aspect of public engagement that was addressed by the facilitator during a meeting in abstract terms, but not scaffolded. Moreover, this privileging of science in relation to the local Arizonan Discourse falls short of Baram-Tsabari and Lewenstein’s expectation that to

practice dialogue a scientist needs to “Acknowledge and show respect to multiple worldviews” (p. 60). Analysis indicates that while Vic recognized the different perspective, she treated it as misinformed and not important.

Because Baram-Tsabari and Lewenstein’s (2017) outline of learning objectives for science communication includes a strand specifically on conducting face to face communication with audiences in informal settings, it is necessary to consider it in light of this study’s analysis. They argue for students to learn how to “manage and facilitate public discussions” (p.292) which possibly could include a large gathering, small group, or individual conversation. Often a “discussion” is envisioned in terms of argumentation and the airing of differing views which could potentially be confrontational, even a heated debate (Horst, 2008). This study’s participants can only speak to non-policy informing public engagement events which are small in scale and not designed to shift public opinion (Lehr, McCallie, Davies, Caron, Gammon, & Duensing 2007). The public engagement events analyzed in this study show REUs conducting numerous player reflections, each one an opportunity for them to engage the public in a hands-on way as well as form strategies to accomplish their discursive goals through roles, which are two aspects of the strand detailed by Baram-Tsabari and Lewenstein (2017, p. 292). The REUs had to negotiate enacting their roles with the players and use illustration/reformulation in explaining science concepts. The fact that some players refuted the assumption that the REUs game expressed the science concept or they had adequately explained the science-game connection, prompting REUs to explain it again, indicates both failures, second tries, and opportunity to communicate effectively in a real situation.

When taken together, the public engagement project provided numerous real-world opportunities for STEM undergraduates to engage in practices identified as important to learning science communication. For the most part, they designed games and conducted player reflections in ways that were more dissemination than dialogue. This raises the point that not all public engagement is going to necessarily be dialogue-focused all of the time. Analysis indicated that with a format like player reflections, different roles and social identities provide different opportunities to engage. Moreover, how the player reflection was conducted by the REU and the game's content/ design also contributed to its focus in terms of dissemination or dialogue. But it must be kept in mind that members of the public are not all the same and bring to the interaction certain opportunities for dialogue to happen or not happen. This would also count for dissemination.

This contact between stable, pre-planned approaches by REUs, and the unpredictability of public engagement events speaks to the event as a situated educational activity for REUs. Non-policy informing dialogue events where scientists intentionally place themselves into contact with local communities entails this kind of variability. There is no guarantee that a player reflection with a particular game and the same approach would yield the same enactments when members of the public who attend arts festivals are not identical. Recall the diverse range of roles and social identities Vic encountered, as illustrated in Table 5.2. It can be said that this activity was situated squarely in the real world, which is where STEM undergraduates learning science communication are expected to take part in practices of public engagement. This and the other indications of situatedness that will be discussed shortly are instances of how this project can be considered a situated learning experience for REUs. To take part in the

practices of a discipline with experts (Lave & Wenger, 1991) and to take on ways of being, thinking, speaking, and doing in the actual context means that the learner is involved in a situated learning experience (Gee, 2003).

Returning to the game design process for the public engagement project, analysis indicates that the REUs took part in the practices associated with game design in many ways. They engaged in the developmental process of beginning with a concept, creating a prototype with working game mechanics and a physical form, playtesting with players, and considering the next iteration. Moreover, their design goals and aesthetics demonstrated that they were designing a serious game, as in a game whose purpose is other than to entertain (Michael & Chen, 2005). For example, Cherry and Howie's goal was to educate players on the science concept of recombination. Howie reasoned that if the game is fun and replayable, then players will play more and have more exposure to his game's science concepts. For this particular REU, the entertainment factor served the overall goal of teaching players about science. However, few REUs took part in the later stages of game development, such as iterating repeatedly until the game is ready for mass production, though *Solar Trivia* and *SolarPoly* printed their game board, assembled other game components, and had what could be considered a clean, presentable product. In addition, the REUs served as their own subject matter experts for their design process. They acted as solar energy experts explaining their game's concept and content to the facilitator and playtesters. In this sense, they performed both the content expert and the game designer social identity. One important limitation, however, was that REUs did not associate with game designers other than the facilitator or take part in a broader serious game design community that might allow them to belong to it in a situated sense.

It is also important to note that REUs performed the science game design social identity in the service of and as an instantiation of a scientist doing public engagement. However, two indications suggest that the public engagement practice was secondary and subsumed by the traditional researcher role of being a scientist. Twice the facilitator positioned REUs as scientists conducting research first and doing public engagement as a tangential role in terms of priority and time management. In addition, in one meeting early in the game design process, two REUs rejected being positioned as science game designers and expressed difficulty in performing the role. They asserted the traditional role of laboratory research as their primary focus. This privileged status of the research role and sense of the task of public engagement as being an imposition for some participants, is not at all unlike the situation that scientists find themselves in. As a result, an important aspect of the project's situatedness is how REUs had to contend with competing demands and how to take part in practices of public engagement (game design and public engagement event) while still fulfilling the role of researcher.

Research Questions Revisited

With the analysis of findings explored in light of the literature on science communication education and how public engagement is practiced by practitioners, this section returns to the research questions which guided this study's inquiry. Below is an overview of how the study addresses each question in regard to REUs enacting roles and social identities related to public engagement with science through game design.

Research Question 1

Given the challenge of designing a game to engage the public with science, what social identities and roles do undergraduate engineering students enact during the facilitated design process?

Analysis indicates that during the design process, some REUs identified themselves directly as scientists by associating themselves with laboratory research and other scientists. The facilitator positioned all of the REUs as scientists throughout the design process. At times he positioned their laboratory researcher role above their public engagement role in regards to prioritizing time and attention to the former. Moreover, most of the REUs enacted the science game designer social identity throughout the project as they demonstrated the actions, thinking, and decision making discursively in ways indicative of designing a game. For example, REUs described game mechanics and used illustration/reformulation to express how they game is supposed to teach science concepts. Also, they elicited feedback from playtesters, then made design decisions based on the information or justified their design based on their own aesthetical criteria for what their game should communicate and offer in terms of player experience. Some REUs closely identified with the science game designer social identity while most related to it in terms of a scientist doing public engagement through this particular approach. However, two REUs rejected the positioning of science game designer, identifying themselves more closely to the traditional role of scientists conducting research in the laboratory.

In addition, certain activities during the project offered REUs opportunities to enact roles and social identities other than science game designer. For example, during

the critique session where REUs and Young Scholars shared their respective public engagement projects for feedback, it was an opportunity to enact the science educator and sociotechnical roles. This was likely possible in part because the REUs are older, more knowledgeable students who acted as near-peers. Moreover, the play through activity in which REUs went through a dress rehearsal for the public engagement event gave REUs some opportunities to enact science educator and science game designer social identity as they took part in what was essentially a roleplay. These two activities, the critique and the playthrough, are important in terms of being instances in which REUs enacted some of the roles in some of the same ways that they would during the actual public engagement event. This suggests that these activities served some purpose as scaffolding and climatizing REUs to public engagement in this regard.

Research Question 2

During the public engagement event(s), what social identities and roles do these students and members of the public who play the game enact through the player reflection?

The roles and social identities that REUs enacted during the public engagement event was primarily the science educator role and science game designer social identity (see Table 5.1 and 5.2). Members of the public enacted the corresponding roles, learner and playtester in relation to the REUs. As a science educator, REUs checked for learning, reviewed science concepts, and corrected players with the goal of teaching about solar. They positioned players as learners as they initiated this science educator-learner relationship. During review and correcting, REUs referred to their game and the player experience to explain and describe science concepts. So REUs used the verbal strategy of

reformulation to perform the science educator role. In effect, they used their game while doing illustration to teach the players. At times players refuted the assumption that the solar energy game taught science concepts and/or they did not see the connection between the two. REUs reacted by assuming a science educator role while they could have assumed a science game designer social identity to treat the situation as player feedback. A few REUs approached the science educator role not to teach science concepts, but sociotechnical and industry information which was relevant to many of their players. In this case, the engagement was a meeting of Discourses as players enacted a local Arizonan social identity that had differing values and perspective on solar energy than the science community.

For the most part, players limited their enactments to learner and playtester in the above examples when the REU taught science concepts. However, some players took the initiative to assert social identities such as consumer, student, and geek at the end of the player reflection.

Conversely, an REU, Vic, took on a sociotechnical role by which she put players on the spot to relate to science. This did not position the player in a pre-defined role, unlike the other enactments just described, but asked that players search their background, profession, and other aspects of social identity to find how they relate to science. This prompted players to enact the widest range of roles and identities. For example, players expressed aspects of social identity such as Phd student in chemistry, interior designer, what could be called a science buff with a life-long interest in solar energy, and consumer (see Table 5.2). Also, Vic at times enacted an interviewer role asking players about her game and the player's game experience, which did not position

the players in roles other than that of interviewee. For example, Vic's approach to the interviewer role did not contain the same intentionality as the science game designer social identity role where the latter sought the player's evaluation or feedback on the game. As a result, Vic's performance of the sociotechnical role and interviewer role was considered open-ended and is different from the other REUs who positioned their players as either learners or playtesters, hence a close-ended way of enacting a role. Moreover, Vic displayed responsiveness to what role or social identity a player enacted by shifting to a new role or social identity to correspond to the player's. This responsiveness and flexibility promotes dialogue in the sense of letting the public influence the priority and topic of conversation during the public engagement event.

Analysis indicates that game design features were relevant primarily when REUs enacted the science educator role and science game designer social identity. In general, REUs referred to their game's visual representations of science as well as game mechanics that mimicked and were metaphorical of solar energy concepts. As explained above, REUs used these design features while using the verbal strategies illustration and reformulation in communicating these concepts. Just as important, REUs also referred to the player's game experience in these efforts. The player experience included impressions, decisions, feedback, and in general learning how to play the game (Gee, 2014b). At times REUs referenced and used that player experience, what the player just learned from playing the game, as one half of a metaphor whereby the REU then tries to connect science concepts to it as the second half to complete the metaphor.

Another design feature is the game's content and genre. The visual representations and game mechanics mentioned above were done in abstract games

designed to teach science concepts, such as recombination. On the other hand, Vic's game *Solar Trivia* belongs to the trivia genre and is about Arizona's production of solar energy and how much power solar panels produce. One of her game's questions was about Arizona's ranking in solar energy production, which most of her players answered through their local Arizonan social identity. This social identity is tied to a social group's values, beliefs, and perceptions based on lived experience and local knowledge. In a sense, this alignment between game design and target audiences is what science communication scholars hope to see in public engagement because the "messages... resonate with audiences' pre-existing values" (Besley, Dudo, & Storksdiel, 2015, p. 199). Players who enacted the Arizona Discourse spoke and thought in relation to solar energy, particularly the industry's conceptualization of what they deemed important to their identity. However, the game's answers were based on the PV solar energy industry's conceptualization of energy production and its values, another key aspect of the game's content in that the source of knowledge was not local knowledge and turned out to be in conflict with the latter. In effect, the scientific community's knowledge was privileged over the local knowledge, resulting in the reproduction of the unequal relationship between science and society (Cooter & Pumfrey, 1994).

Overall, these game design features did not automatically result in REUs and players enacting roles and social identities pointed out above. The enactments were done through an orchestration of REUs questions, their discursive goals, and the games design features, such as visual representations and game mechanics embodying science concepts, content in the form of specialized knowledge, and genre. And of course, this

happened in conjunction with what the player brought to the situation in terms of their own social identities and agenda.

Limitations of the Study

Before considering how this study's insights can contribute to science communication education, the practice of public engagement, and methodology, the study's limitations must first be acknowledged. As noted in Chapter 3, the author's dual roles of facilitator and researcher placed important limitations on the data collection strategies that were possible. As a facilitator of the public engagement project, the author was in a position of authority as a kind of instructor to the REU participants. This precluded the role of observer or participant observer where this study could take an ethnographic approach and collect data, which is a common method for discourse analysis (Gee & Green, 1998). This ethnography/discourse analysis would work towards a more wholistic conceptualization and appreciation of the practices that REUs took part in at the Solar Energy Center. However, it was logistically impossible for the researcher to be in two places at once, making observations and conducting interviews of a context he was responsible for contributing to at this level.

As a result, the primary source of data was audio recorders of the participants discursively enacting roles, relationships, and identities in the game design process and the public engagement events. This leaves out how participants likely performed these same enactments and others not identified in this study through other forms of tool use, gesture, proximity, and other modes of communication. This is particularly relevant to when participants worked on their project outside of meetings and also the more private conversations between participants when they might be more forthright in their attitudes,

beliefs, and opinions. Also, discourse analysis while able to support its claims with evidence and is reproducible (Gee, 2014a), it is still a researcher-centric approach to inquiry. In sum, this study does not attempt to represent the experience of REUs or the constellation of practices and how they are expressed in the course of a public engagement project through game design.

In addition, the Solar Energy Center's summer program for REUs cannot be considered a typical learning experience for STEM undergraduates. The program selects participants from around the country and must meet requirements set up by its recruiters. There should be some caution in directly transposing this study's implications to a traditional university classroom or science program. The REUs in this study had a focused context in which they were expected to devote most if not all of their working time to lab research under the direction of a graduate student or scientist. This kind of one on one mentoring and situatedness is part of the overall strategy at the Solar Energy Center. Lastly, solar energy is a visible example of technology in practice and relates to the natural environment in obvious and important ways for the local community. In this way, the public engagement event chose a topic with at least some relevance to the potential audiences who the REUs would encounter. To not align the topic of the public engagement event, games, player reflections, and players is to overlook a key aspect of this study's context.

Lastly, the program's focus was essentially for REUs to take part in the production of knowledge within the scientific community and to disseminate knowledge to the public through the public engagement project. The program's scientists and mentors were not conducting any citizen science projects or participatorial approaches

involving the REUs. Such a research projects could provide additional public engagement opportunities, possibly collaborations between scientists, the REUs, special interest groups, and other stakeholders. As such, the public engagement project could be characterized as promoting and popularizing science as opposed to engaging the public in the scientific process.

Implications for STEM Undergraduate Science Communication Education

The science communication field has argued that science programs should teach students how to engage the public with science (Brownell, Price, & Steinman, 2013). In particular, Baram Tsabari & Lewenstein (2017) argue for university students to take part in practices whereby they learn to express themselves through various media, use artifacts, and interact with the public in informal face to face settings with language appropriate to the situation. This includes supporting dialogue in that the communication is two way and both sides benefit and contribute to the conversation. However, research focused on STEM undergraduates currently argue that dialogue is an advanced practice, if not out of reach for students at the undergraduate level (Mercer-mapstone and Kuchel, 2017; Sharpe & Blanchfield, 2014). This study makes recommendations in terms of what scaffolding should be in place for undergraduates to help prepare them for taking part in non-policy informing dialogue events as well as use game design in conjunction with such an event. These recommendations were not in the study's research questions, but are based on its findings and the author's experience as facilitator of the project.

To begin with, the public engagement project must take into account the REUs level of disciplinary knowledge, knowledge of game design, and previous experience taking part in public engagement activities. In order for an REU to be an expert in the

science of having specialized knowledge in a field and applying it outside of its original context, the REU must have sufficient disciplinary knowledge. The timing of the start of the game design process and the public engagement event must be orchestrated so that REUs have learned the content knowledge and ideally taken part in practices of laboratory research and studied the literature of the field. In addition, they should also be exposed to how this knowledge is being used in industry and commercially. The reason for such background knowledge is because this allows the learner to enact a wider range of roles and social identities with members of the public. A non-policy informing dialogue event is an opportunity for a STEM undergraduate to be an expert in the general sense and talk about current trends in research and the science concepts behind the phenomenon. But also as a consultant as members of the public turn to the student for suggestions and advice and as a promoter of the field as the public are potentially receptive to hearing about how it relates to daily life and issues, such as the environment. This study is not arguing that learners without this background knowledge would not be able take part in a public engagement event. However, the public may put them on the spot to take on these roles and the social identity of a kind of scientist or representative of the field.

In terms of game design, a public engagement project using games should not assume that REUs have a background in game design or much knowledge about analog and board games. They must be introduced to game design's conceptual components, purpose, final products, and practices that lead to a finished game. This aspect of the project was scaffolded to a high degree which was appropriate considering few of the REUs had experience designing games or could be considered gamers. In this regard, it is

important that the facilitator have experience with serious game design and public engagement in order to lead REUs through the process with hands on, realistic activities and structure. Moreover, it can be anticipated that some REUs will not consider game design, and public engagement in general, as a relevant role for a person learning to be a scientist.

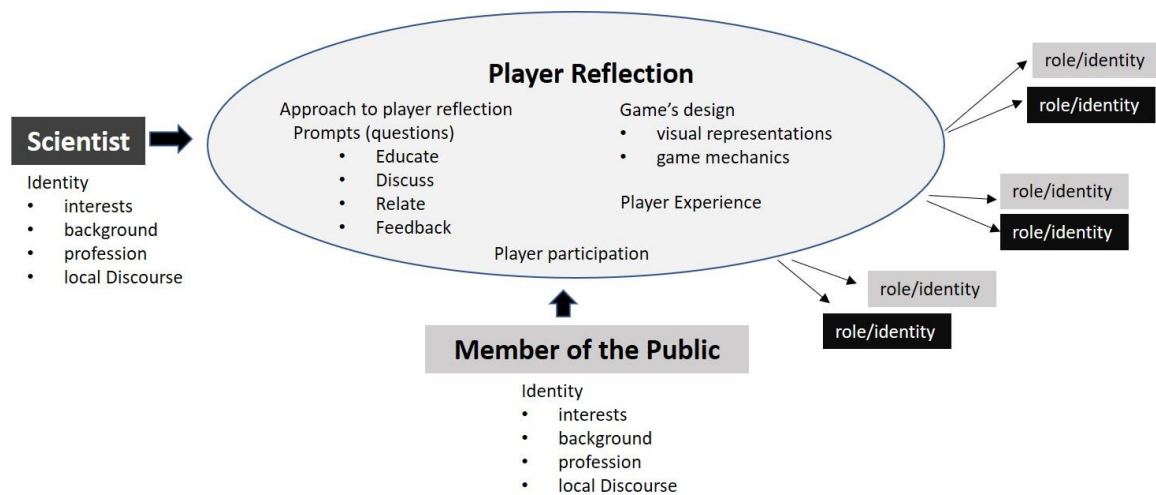
In an intensive program such as the one examined in this study, it would be recommended to present these dual roles together from the outset of the program and convey to REUs that the program envisions scientists as doing public engagement as well as lab research. Ideally, the scientists and graduate students mentoring the REUs should be doing public engagement projects themselves, possibly doing citizen science, and can then incorporate the student into the public engagement project. Perhaps at least illustrate what a scientist doing public engagement looks like rather than having the project as a completely tangential endeavor.

In order to present the game design process and public engagement event as an integrated endeavor, the facilitator should give direct instruction on key concepts of science communication as well as begin having the REUs take part in public engagement events. To aid in teaching the project as an integrated whole, the model shown in Figure 5.2 is meant to convey the many factors that contribute to the public engagement event. On a conceptual a level, it must be stressed that the game that the learners design is not the end goal, but simply as a jumping off point for goals for the player reflection. The REUs should consider goals such as to enable players to relate to the content, express concerns or opinions touched on by the game's content, educating about science, and promoting the field are some of the possible goals. Moreover, the game's content is a

special consideration because it should be relevant to the target audience, yet it is still important to frame game design as a means of self-expression based on the learner's interests. To fall too heavily on the side of creating content relevant to the audience may miss out on the project being relevant to the learner and affect their motivation.

Figure 5.2

Enactments during Public Engagement through Games



Preparing REUs and other types of learners for the public engagement event deserves special attention. The project should begin with an overview of science communication models and issues so that they can begin to appreciate the difference between disseminating science information to the public and supporting dialogue. Learners need conceptual knowledge of how a public engagement event and its player reflection is orchestrated by the REU with a number of factors influencing the conversation, but not in their control and subject to the player as an individual as well as a member of the local community, profession, interests, etc. (see Figure 5.2). Hopefully, this leads to meta-awareness of how what the REU states during the player reflection can

influence how they relate to and what they accomplish with the player as well as the game and game experience. Moreover, conducting player reflections should be scaffolded so that REUs can enact open-ended roles in that they do not lock the public into particular roles (like learner or playtester) at the outset of the conversation. They need to become practiced in being responsive and shifting their role based on what the public does in terms of assuming a role or indicating intentionality of what they want to accomplish in the conversation. Also, they need to become practiced in assuming roles other than the science educator role, such as the sociotechnical role, where they let the player position themselves first in a meaningful way to science. At the same time, it is still necessary to be practice using the verbal strategies of illustration, so that the students are accustomed to using metaphor, concretization, exemplification, and scenarios to express science concepts since it is likely they will need to adopt the science educator role.

Ideally, REUs would take part in public engagement practices in a hands-on and realistic sense at the early stages of the project after they are acquainted with it at a conceptual level. This study recommends that they take part in an initial public engagement event to better acquaint them with what is they are designing their game for and have a frame of reference to connect the instruction on a meta level of how player reflections can be conducted. Presumably this will help guide their design process of their game in terms of content, visual elements, and game mechanics so that the game can be a platform for dialogue. In practical terms, the REUs could use a game already developed and designed specifically for this type of public engagement event. Then REUs could design their own and then use it at a public engagement event at the end of the project. In addition, the project could only focus on the public engagement event all together and

leave out the game design aspect. However, this would likely eliminate roles and relationships from the player reflection and greatly alter the overall educational experience examined in this study.

Clearly, public engagement with science is a set of interconnected and at times complicated practices that are still being explored in the science communication field. As new insights are developed, there will be new recommendations. Moreover, one project should not be considered capable of involving learners into all of these practices to such a degree that they are at the level of practitioners by the end of it. As such, these recommendations for a public engagement project through game design are meant to provide STEM undergraduates with an opportunity to begin taking part in the practice of public engagement and dialogue in ways that will help them become practitioners in the future.

Implications for Science Communication Practitioners

This study used STEM undergraduates learning science communication as its participants. As such they are not full practitioners as of yet, though analysis demonstrated that in many ways they took on roles and social identities associated with the practices of public engagement with science. Moreover, how scientists are supposed to conduct non-policy informing dialogue events in such a way that they promote dialogue is still poorly understood (Davies, 2013a). As a result, this study's insights can speak to how scholars might consider practitioners approaching player reflections, also known as debriefing (Crookall, 2010; Wu & Lee, 2015).

Many of the recommendations made in the above section for undergraduate learners also apply here, such as conducting player reflections with an open-ended role,

using reformulation to use the game as a springboard for conversation, and being responsive to how the public positions themselves and what role the public wants to assume in the conversation (see Figure 5.1). Being flexible and responsive in shifting their role to correspond to the public's can take the form of a player expressing concern about how the science or technology relates to them, perhaps speaking as a consumer or a member of the local community, and the scientist can shift to speaking as a consultant trying to troubleshoot the situation. Or perhaps they can speak as a scientist of the field and attempt to show how their field perceives and approaches the issue. Then again, the scientist can relate as a fellow member of the community, not attempting to give solutions, but listen to the public's concerns.

Another key consideration in terms of design and player reflection is for practitioners to explore other formats and mediums by which they prompt players to take part in a player reflection. Players could be asked to draw, write their first thoughts on a sticky note, or other arts-based forms of meaning making (Leavy, 2015). The point is that there are other modes of expressing ideas, rather than just language. Moreover, the game itself could be designed to promote discussion, debate, or even collaborative storytelling by which to engage players, in addition to the genres of trivia and board games designed by participants in this study.

Implications for Methods and Future Research

A final consideration for implications which this study presents is for methodology and future research in science communication. Building off of Davies (2008; 2011; 2013a; Davies, McCallie, Simonsson, Lehr, & Duensing, 2009) and Gülich (2003), this study's insights suggest that one way of viewing role taking and social

identity in this context are that enactments are open- or close-ended, meaning that the scientist assumes a role that will either let the public assume a wider range of enactments and position themselves or push the public into a role or social identity that the scientist wants them to. For example, if the scientist assumes a sociotechnical role discursively that lets the member of the public assert a range of roles or social identities available to them, then the open-ended approach to the role is conducive to supporting dialogue. However, future research should consider how this process can be enacted through other modes of communication and not just through language (Kress, & Van Leeuwen, 1996). How might scientists and members of the public enact roles and social identities through ways and other modes to support dialogue remains an elusive process. Moreover, how might a practitioner utilize other types of media in a face to face conversation to these ends is also an interesting avenue to pursue.

One way this could be done is by scholars collaborating with exemplar practitioners to develop such strategies and formats, testing and fine tuning them in an iterative process. In the long term, this could yield useful strategies, models, and perspectives by which STEM undergraduates, graduate students, and practitioners could be taught to conduct public engagement events in ways that support democracy, productive relationships between science and publics, and offer personal expression for scientists.

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APPENDIX A
PLAYER CONSENT FORM

Title: Fostering an intellectual and social support network for PV engineering
I am a graduate student under the direction of Dr. Michelle Jordan at the Mary Lou Fulton Teachers College at Arizona State University. I am conducting a research study to understand how games can be used to teach about communicating with the public. I am inviting your participation, which will involve me audio recording your conversation with the game designer, a university student, about your game experience. You have the right to stop participation at any time. Your participation in this study is voluntary. If you choose not to participate or to withdraw from the study at any time, there will be no penalty. You must be 18 years or older to participate in the study. There's no direct benefits for you. There are no foreseeable risks or discomforts to your participation.

Your responses will be anonymous. We aren't recording personal information. The results of this study may be used in reports, presentations, dissertations, or publications but your name will not be used.

I would like to audio record our conversation. It will not be recorded without your permission. Please let me know if you do not want the conversation to be recorded; you also can change your mind after the conversation starts, just let me know. If you have any questions concerning the research study, please contact the research team at: [phone number], Dr. [professor] or Mathew Evans at mathew.evans@asu.edu. If you have any questions about your rights as a subject/participant in this research, or if you feel you have been placed at risk, you can contact the Chair of the Human Subjects Institutional Review Board, through the ASU Office of Research Integrity and Assurance, at (480) 965-6788. Please let me know if you wish to be part of the study.

APPENDIX B
PUBLIC ENGAGEMENT WORKSHEET

Name: _____

Genre

- What hobbies do you have? What genre would you like to try? Already work in?

Topics

- What surprised you about PV solar? What has been the most interesting thing you've seen so far?

Participants

- What groups would be interested in PV solar? Who could benefit?

Platform/ Setting

- online platform or community would be good for engagement? What physical place?

APPENDIX C

GAME CONTENT EVALUATION FORM

Game Title:					
Description of game by designer:					
	What science concepts or ideas about PV solar energy is this game conveying?	How accurate is this statement about science/PV solar? Please mark 1 -4 Inaccurate – 1 somewhat accurate – 2 mostly accurate – 3 completely accurate – 4 x – cannot be determined			
Concept #1		1	2	3	4 x
Concept #2		1	2	3	4 x
Concept #3		1	2	3	4 x
Concept #4		1	2	3	4 x

APPENDIX D
IRB APPROVAL

EXCEPTION GRANTED

Michelle Jordan
 Division of Teacher Preparation - Tempe
 480/965-9663
 Michelle.E.Jordan@asu.edu

Dear Michelle Jordan:

On 5/21/2017 the ASU IRB reviewed the following protocol:

Type of Review:	<u>Initial Study</u>
Title:	SEC Summer Program: Evaluating a program with a diverse cohort of participants
Investigator:	<u>Michelle Jordan</u>
IRB ID:	STUDY00006290
Funding:	Name: SEC
Grant Title:	
Grant ID:	
Documents Reviewed:	<ul style="list-style-type: none"> • mentor post survey, Category: Measures (Survey questions/Interview questions /interview guides/focus group questions); • RET pre survey, Category: Measures (Survey questions/Interview questions /interview guides/focus group questions); • recruitment email for parents, Category: Recruitment Materials; • example written assignments, Category: Participant materials (specific directions for them); • semi structured interview questions, Category: Measures (Survey questions/Interview questions /interview guides/focus group questions); • adult consent, Category: Consent Form; • YS pre survey , Category: Measures (Survey questions/Interview questions /interview guides/focus group questions); • mentor pre survey, Category: Measures (Survey questions/Interview questions /interview guides/focus group questions);

	<ul style="list-style-type: none"> • REU pre survey, Category: Measures (Survey questions/Interview questions /interview guides/focus group questions); • IRB Application_SEC_Summer Network_REU_RET_Mentor.docx, Category: IRB Protocol; • SEC Full Proposal from Fastlane (2).pdf, Category: Sponsor Attachment; • parent consent, Category: Consent Form; • RET post survey, Category: Measures (Survey questions/Interview questions /interview guides/focus group questions); • Solar 101 survey, Category: Measures (Survey questions/Interview questions /interview guides/focus group questions); • YS post survey, Category: Measures (Survey questions/Interview questions /interview guides/focus group questions); • REU post survey, Category: Measures (Survey questions/Interview questions /interview guides/focus group questions); • youth assent, Category: Consent Form;
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The IRB determined that the protocol is considered exempt pursuant to Federal Regulations 45CFR46 (1) Educational settings on 5/21/2017.

In conducting this protocol you are required to follow the requirements listed in the INVESTIGATOR MANUAL (HRP-103).

Sincerely,

IRB Administrator

cc:

Christiana Bruchok

Mathew Evans

Eugene Judson

Wendy Wakefield

Kristin Elwood

Nicole Bowers

Michelle Jordan
 Division of Teacher Preparation - Tempe
 480/965-9663
 Michelle.E.Jordan@asu.edu

Dear Michelle Jordan:

On 6/25/2018 the ASU IRB reviewed the following protocol:

Type of Review:	<u>Modification</u>
Title:	SEC Summer Program: Evaluating a program with a diverse cohort of participants
Investigator:	<u>Michelle Jordan</u>
IRB ID:	STUDY00006290
Funding:	Name: SEC
Grant Title:	None
Grant ID:	None
Documents Reviewed:	<ul style="list-style-type: none"> • IRB SEC summer consent _public communication writing project.pdf, Category: Consent Form; • IRB Application_SEC_Summer Network_REU_RET_Mentor_modified1.docx, Category: IRB Protocol; • mentor pre survey, Category: Measures (Survey questions/Interview questions /interview guides/focus group questions); • Spanish Parent Consent , Category: Consent Form; • RET pre survey, Category: Measures (Survey questions/Interview questions /interview guides/focus group questions); • adult consent, Category: Consent Form; • Spanish parent recruitment email , Category: Recruitment Materials; • Post Public Communication Writing Project_New_Interview Protocol.pdf, Category: Measures (Survey questions/Interview questions /interview guides/focus group questions); • parent consent, Category: Consent Form; • YS pre survey , Category: Measures (Survey questions/Interview questions /interview guides/focus group questions);

	<ul style="list-style-type: none"> • mentor post survey, Category: Measures (Survey questions/Interview questions /interview guides/focus group questions); • REU pre survey, Category: Measures (Survey questions/Interview questions /interview guides/focus group questions); • example written assignments, Category: Participant materials (specific directions for them); • Solar 101 survey, Category: Measures (Survey questions/Interview questions /interview guides/focus group questions); • recruitment email for parents, Category: Recruitment Materials; • semi structured interview questions, Category: Measures (Survey questions/Interview questions /interview guides/focus group questions); • RET post survey, Category: Measures (Survey questions/Interview questions /interview guides/focus group questions); • REU post survey, Category: Measures (Survey questions/Interview questions /interview guides/focus group questions); • HRP-502c - Public CONSENT DOCUMENT - SHORT FORM.pdf, Category: Consent Form; • YS post survey, Category: Measures (Survey questions/Interview questions /interview guides/focus group questions); • Certificate of Accurate Spanish Translation, Category: Translations; • youth assent, Category: Consent Form; • SEC Full Proposal from Fastlane (2).pdf, Category: Sponsor Attachment;
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The IRB determined that the protocol is considered exempt pursuant to Federal Regulations 45CFR46 (1) Educational settings on 6/25/2018.

In conducting this protocol you are required to follow the requirements listed in the INVESTIGATOR MANUAL (HRP-103).

Sincerely,

IRB Administrator

cc:

Mary White

Clark Miller

Christiana Bruchok

Adam Carberry

Eunsil Lee

Danielle Simonet
Mia Delarosa
Mathew Evans
Eugene Judson
Wendy Wakefield
Carla Firetto
Kristin Elwood
Carlo Altamirano Allende
Nicole Bowers