Mapping Identity Exploration of Science Careers using Epistemic Networks

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Abstract: This paper reports findings from research project designed to test and refine Projective Reflection (PR) as a theoretical and methodological framework for facilitating learning as identity exploration in virtual learning environments. PR structured the design, implementation, and refinement of three sessions of *Virtual City Planning*, a play-based course that supported the exploration of environmental science identities mediated by a virtual learning environment (*Philadelphia Land Science*), and supportive classroom experiences. Epistemic Network Analysis was used to visualize different processes of identity exploration enacted by each session. Visualizations of class data by time period illustrated similar trajectories of identity exploration across sessions as an increase in personal interest and valuing of the domain over time, while paired-sample t-tests found chronological differences to be statistically significant across all sessions. Results further understanding of the ways in which virtual learning environments can support identity exploration and potential future acquisition of science careers, and illustrate the value of epistemic networks for illustrating identity exploration processes over time.

Keywords: Identity exploration, projective reflection, Epistemic Network Analysis, virtual learning environment, STEM learning

Introduction

Educational research has increasingly emphasized ways to develop learner skills in identity exploration, or a student's "deliberate internal or external action of seeking and processing information in relation to the self" (Kaplan, Sinai & Flum, 2014, p. 250). This process of self-directed learning can promote identity change in targeted directions over time, such as taking steps to attain a future career in science, technology, engineering, or mathematics (STEM) (i.e. Foster, 2014). Curricular interventions that support learning as identity exploration are therefore of particular value in a 21st century context in that they can support adaptive skill development and career preparation for emerging and under-accessed STEM careers (Callahan, Ito, Campbell, Wortman & Wortman, 2019). Facilitating identity change toward STEM careers among underrepresented minorities becomes an even more pressing imperative, given workforce statistics that illustrate limited gender and racial diversity in these fields (US Congress Joint Economic Committee, 2012).

Games and virtual learning environments have been increasingly identified and researched for their potential to support changes in both cognitive (i.e. knowledge) and affective-related (i.e. motivation) aspects of self (e.g. Kamarainen, Metcalf, Grotzer, & Dede, 2015). To rigorously leverage these affordances however, theoretical and pedagogical frameworks are vital to inform the use and design of virtual learning environments (Mikropoulos & Natsis, 2011; Fowler, 2015). The intentional design and inclusion of real-world supportive classroom curricula (Hanghøj, Lieberoth & Misfeldt, 2018) also remains a necessary and important feature. Finally, emerging research on games and identity exploration will benefit from the use of methodological approaches that can illustrate the nuances of student identity exploration as it unfolds across a designed game-based learning experience.

This work leverages the Projective Reflection (PR) theoretical and pedagogical framework to operationalize learning as identity exploration that leads to identity change over time, as facilitated by the immersive interactive affordances that can be found in many games and game-based learning environments (Foster, 2014). PR was used to design three consecutive iterations of a *Virtual City Planning (VCP)*, a course that leveraged a virtual learning environment (*Philadelphia Land Science*) and supportive in-class curriculum to promote identity exploration of urban planning and environmental science careers. *VCP* was implemented in a museum classroom context with a diverse sample of high school students (N=57). This paper examines group identity exploration trajectories over time in *VCP* sessions 1-3 using Epistemic Network Analysis, which is a quantitative ethnographic

technique of modeling the structure of connections in student data. Findings (a) illustrate how *VCP1-3* supported statistically significant shifts in student conceptualizations of self over time as defined by PR, (b) reveal similarities and differences in how identity exploration was supported and enacted in each session. Implications of these findings for games and education practitioners, designers and researchers are discussed.

The research question asks: *What is the nature of students' processes of identity exploration over time (as defined by Projective Reflection) in sessions 1-3 of Virtual City Planning?*

Games and Identity Exploration

Digital environments such as video games have designed potential to expand participants' social networks and help them perform and develop specific identities (Gee, 2000; Merchant, 2001). Shaffer (2006) posits that learning to think like a member of any given profession first requires learners to learn to think of themselves as members through reflection in action (Schön & Rein, 1994). For example, epistemic games, which include complex, non-routine problems solved through authentic professional practice (Bagley & Shaffer, 2015) have been found to support identity change by encouraging increasing individual affinity for the social identities within that community of practice (depersonalization) (Arastoopour & Shaffer, 2013). Becket and Shaffer (2005) also examined eleven high school students' experience using a designed augmented reality environment, and found that participants deepened their understanding of the complexity and interdependence of variables in ecological systems and were able to connect the authentic virtual experiences to their real-world contexts.

Immersive virtual environments such as games can also afford opportunities for shaping students' long-term interests in academic or career-specific domains. As semiotic spaces (Gee, 2005), games can shape identity exploration and change processes by providing socially safe spaces for players to explore new roles (Squire & Barab, 2004; Steinkuehler, 2004), and can connect in-game activities to real-world meanings to foster increasing personal relevance of a domain (Foster, 2008; Silseth, 2012). Miller and colleagues (2011) demonstrated these processes through their formal learning implementations of the game *CSI: The Experience* with over 700 middle school students in a repeated measures mixed methods study, which illustrated how the designed game experience offered authentic professional play that not only developed students' science content knowledge, but allowed players to explore identities and develop interests related to forensic science careers.

Despite the affordances of games, few empirically tested theories currently exist to operationalize processes of identity exploration along the complex, interconnected, and evolving cognitive/affective features related to learning and self. Research on games and identity has addressed this gap through the use of the Projective Reflection theoretical framework to structure assessments of student identity exploration. For example, studies of classroom interventions using commercially-popular games illustrated how game-based learning experiences can be designed to optimally support identity exploration and change if the affordances and constraints of a game environment are first assessed and then supplemented using external curricular activities (Foster & Shah, 2015; Shah, Foster & Barany, 2017).

Methodological approaches are consequently needed to complement emerging theories such as Projective Reflection by structuring assessment of learning as identity exploration in game-based interventions. Quantitative ethnography (Shaffer, 2017) offers one valuable method for exploring patterns of activity nested in situated discourse. Quantitative ethnographic techniques such as Epistemic Network Analysis (ENA) involve the quantification of qualitative data to generate visualizations that can represent the associations individuals establish across a network of constructs (i.e. identity exploration constructs). ENA has previously been used to characterize what players learn from gameplay in terms of knowledge, skills, values, and habits of mind (Shaffer, Collier & Ruis, 2016), further highlighting the potential of this methodology for illustrating processes of identity exploration as they are enacted by learners using games or virtual environments in formal learning settings.

Theoretical framework

Projective Reflection (PR) is a theoretical framework that defines learning as a process by which participants intentionally explore an activity-based identity through engagement with virtual learning environment, with the potential to engage in domain-specific self-transformation over time (i.e. environmental science and urban planning) (See Figure 1) (Foster, 2014). PR conceptualizes learning as identity change across four cognitive and affective constructs: knowledge, interest and valuing, patterns of self-organization and self-control, and self-perceptions and self-definitions (see Table 1). Conceptual definitions for each of the four PR constructs were developed from reviews of literature on 21st century learning, motivation, self-regulation, and identity.

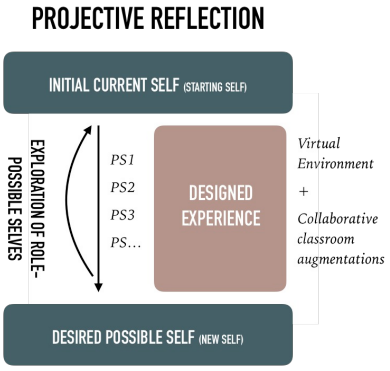

Figure 1. The Projective Reflection framework for conceptualizing learning as identity change over time

Table 1

Projective Reflection constructs to frame identity exploration and change in science games

PR constructs	Definitions	Sample literature
Knowledge	Shifts in what a player knows about environmental science, urban planning, and urban planning systems from the beginning to the end of an intervention: • *Foundational knowledge*: awareness of complex and domain-specific content and processes that includes the ability to access information using digital technologies • *Meta-knowledge*: awareness of how to use foundational knowledge in relevant socially situated contexts • *Humanistic knowledge*: awareness of the self and one's situation in a broader social and global context	Kereluik, Mishra, Fahnoe & Terry (2013)
Interest and valuing	• Caring about environmental science and urban planning issues and viewing them as personally relevant or meaningful • Shifts in identification with environmental science • Viewing environmental science/urban planning as relevant to the community or world • Seeing the need for environmental science for self and for use beyond school contexts	Wigfield & Eccles (2009) Hidi & Renninger (2006)
Self-organization and self-control	Shifts in behavior, motivation, and cognition toward a goal: • *Self-regulated learning:* goal setting and goal-achievement conducted independently • *Co-regulated learning*: regulation processes supported by more knowledgeable real/virtual mentors • *Socially shared learning*: regulation is socially negotiated in collaboration with peers	Vygostky (1934/1986) Hadwin & Oshige (2011)
Self-perceptions and self-definitions	Shifts in how a participant sees herself in relation to (environmental) science: • *Self-efficacy*: confidence in one' own ability to achieve goals and future roles • *Self-concept*: awareness of current aspects of self (i.e. skills, preferences, characteristics, abilities, etc.) • Specific roles one wants or expects to become in future	Kaplan, Sinai & Flum (2014)

The Play, Curricular activity, Reflection, Discussion (PCaRD) pedagogical model offers one way to design and implement a virtual learning environment that supports targeted, intentional, and situated student reflection on aspects of their identities as they shift through engagement with the game and curriculum. During *play*, student exploration of the role is guided by the design features of the game (i.e. what content is covered) and pedagogical supports within and outside of the game (e.g. virtual and in-person mentors). Depending on characteristics of a learner's starting self, and the extent to which the game supports role exploration, *curricular activities* that include opportunities for *reflection* and *discussion* are designed as augmentations to virtual environment. These curricular

augmentations draw upon students' academic, personal and in-game knowledge and experiences to make the identity exploration personally relevant to each student (Silseth, 2012).

To assess learner identity change over time, researchers and educators may leverage the four PR constructs as an analytical tool to compare a learner's starting self at the beginning of a designed experience to their new self at the end of the experience. Processes of identity exploration as defined by Projective Reflection are most valuable when students can enact them in an *integrated* fashion. In *VCP*, integration increases when students can begin to regularly connect their Knowledge gains, emerging personal Interests and Values, the enactment of Self-organization and Self-control strategies, and specific Self-perceptions and Self-definitions related to urban planning and environmental science. Given that identity exploration is conceptualized as a developmental process of change over time, it is vital to examine identity integration as not only co-occurrences in a single piece of student data (integration in that moment), but also as a longitudinal relationship between the way a student conceptualizes her "self" in one moment to the next across a meaningful unit of time (the course). As such, Epistemic Network Analysis is a valuable tool to visualize the intricate longitudinal relationships that emerge between PR constructs as students are encouraged to enact identity exploration of environmental science careers over time.

Methodology

This research was conducted as part of a 5-year NSF CAREER project awarded to develop theory and research on promoting student exploration of science identities using game-based learning experiences (Foster, 2014). Researchers designed and implemented three iterations of *Virtual City Planning (VCP)*, which featured weekly use of the virtual environment *Philadelphia Land Science* (*PLS*) and supportive real-world curricular activities (see Foster, Shah, Barany & Talafian, 2019). Fifty-seven Philadelphia high school students participated in *VCP*1-3 from September, 2016 to May, 2017 (See Table 2). Students were selected for participation by a science museum that coordinated weekly STEM career-related opportunities. Design-based research (Cobb, Confrey, DiSessa, Lehrer, & Schauble, 2003) informed the development and implementation of *VCP*1-3 to (a) develop analogous urban planning experiences given different course lengths offered by the museum and (b) refine game and curricular design to more comprehensively support student identity exploration. Though each iteration provided an analogous chronological student experience, (1) *VCP*1 relied heavily on the use of *PLS* with fewer external augmentations, (2) *VCP*2 balanced the use of *PLS* and external augmentations, and (3) *VCP*3 relied almost entirely on in-class gamified activities (for more information on *VCP* design choices and iterations, see Barany, Foster & Shah, in press).

Table 1**.** Student demographics for *VCP* sessions 1-3.

VCP sessions	Sex	Race/ethnicity	Total
***VCP*1** 9 weeks 10/16 – 01/17	6 male 12 female 2 other/no response	4 Caucasian American 6 African American 5 Asian or Pacific-Islander 1 Hispanic or Latino/a 4 Multiple/other	20
***VCP*2** 8 weeks 01/17 – 03/17	10 male 8 female 1 other/no response	8 Caucasian American 6 African American 0 Asian or Pacific-Islander 3 Hispanic or Latino/a 2 Multiple/other	19
***VCP*3** 4 weeks 03/17 – 05/17	8 male 9 female 1 other/no response	4 Caucasian American 7 African American 0 Asian or Pacific-Islander 3 Hispanic or Latino/a 3 Multiple/other	18

In *VCP*, groups of students were synchronously guided by online and in-person mentors to change zoning districts applied to downtown Philadelphia. As structured by the PCaRD model, each weekly class involved one or more periods of uninterrupted play. The virtual environment *Philadelphia Land Science* (*PLS*) guided students through roleplay as interns in a fictitious urban planning firm that models real-world professional settings. In *PLS*, students conducted research on stakeholder issues (i.e. carbon monoxide pollution), then iteratively designed city

zoning plans on interactive virtual maps that enacted necessary changes. Students then reflected on various aspects of the process in the form of professional emails (See Figure 2).

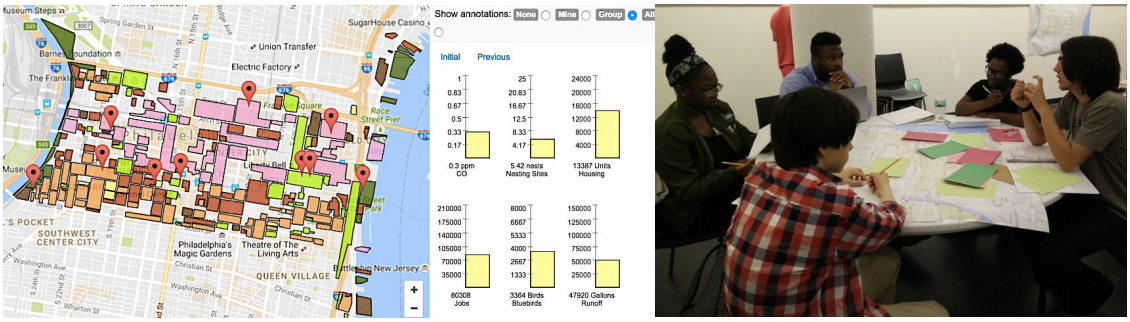

Figure 2. The city design tool in *Philadelphia Land Science* (left) and in-class supportive roleplay (right)

Real-world curricular augmentations were designed to leverage affordances of classroom context to further support identity exploration. For example, museum staff asked students to wear lab coats and act as science professionals, so researchers roleplayed as urban planners to more immersively support individual, small group, and large group reflection and discussion. Another class activity involved group negotiation of city zones on paper maps that allowed learners to reflect on their values and discuss zoning merits with peers (See Figure 2).

Data Collection

Qualitative and quantitative data was obtained through in-game (e.g. written reflections as urban planning interns) and classroom artifacts (e.g. survey responses). Text data was organized chronologically for each student to track changes in identity exploration processes from beginning to end of *VCP*. After each class, researchers collaborated to write detailed memos of interactions with students; memos were segmented by discussion of student and organized chronologically in each individual's data file. Player data was collected from the following sources:

- A pre and post survey consisting of a) 5-point Likert-style questions (ranging from Strongly Agree to Strongly Disagree on questions such as "I can see myself in an urban planning career in the future") (pre $\rho' = .969$, post $\rho' = .993$), and b) short answer questions (e.g. "describe your interests in learning about cities and the environment"). For the purposes of this study, quantitative data was treated interpretively.
- Responses to writing prompts in *PLS*, framed as professional emails to the design firm.
- Written posts made on an online forum website as a curricular activity.
- Written researcher memos on student interactions, discussions, and activities.
- Screenshots and images of student map designs, from the virtual internship tool and from in-class design activities using paper maps. Images were examined for qualitative analyses but not ENA.

Data Analysis

Once data collection and organization was completed, researchers then engaged in a deductive or directed coding process for each case (Krippendorff, 2004) in which each line of data was coded for self-reflection on/demonstration of one or more aspect of identity exploration (as defined by PR), with agreement reached by two graduate-level coders. Lines were coded for the occurrence (1) or non-occurrence (0) of the four PR constructs to prepare for visualization of identity exploration patterns using Epistemic Network Analysis (ENA). For example, a student's reflection reading, "the big ones [issue] I care about is pollution," was coded (1) for interest and valuing.

We applied ENA (Shaffer, 2017) to our data using ENA1.5.2 Web Tool. ENA is a quantitative ethnographic technique for visualizing the connections between constructs. ENA assumes: (1) that it is possible to systematically identify meaningful features in data (codes); (2) that the data has local structure (conversations); and (3) that an important feature of the data is the way that codes are connected to one another within conversations (Shaffer et al., 2016; Shaffer and Ruis, 2017). For example, a single piece of student data (written, observed) may be representative of individual change in one or more codes (the four PR identity constructs).

ENA generates network visualizations of the co-occurrence of codes within a moving stanza window, which means that codes applied to one line of student data are connected to each other and to codes applied to the previous 3 lines of chronological student data (as recommended by Siebert-Evenstone et al., 2017). This process is

appropriate given the conceptualization of identity exploration as a developmental process of change. Epistemic networks for code relationships were generated for the first half (Time 1) and second half (Time 2) of class for *VCP* 1-3 to explore how student identity exploration shifted over time as supported by each iteration. ENA also analyzes all chronological networks simultaneously so that they can compared visually and statistically. To achieve this, ENA models normalize the networks for all units of analysis before they are subjected to a dimensional reduction, which accounts for the fact that different units of analysis may have different amounts of coded lines in the data (see Shaffer et al., 2016). Epistemic networks were generated for Time 1 and Time 2 for each session to compare differences and similarities within and across them over time. In addition, paired-samples t-tests were completed to test whether changes from Time 1-2 in each session were statistically significant along the X and Y axes. The results also reference themes we identified from qualitative studies of the data (i.e. Foster et al., 2019) to close the interpretive loop and provide deeper understand the phenomena visualized in the models.

Findings and Discussion

To answer the question "What is the nature of students' processes of identity exploration over time (as defined by Projective Reflection) in sessions 1-3 of *Virtual City Planning*?" the overall means for Session 1-3 are presented to understand design or cohort differences across sessions. In addition, means for Time 1 and Time 2 for each session are presented to illustrate chronological trajectories of identity exploration enacted by each cohort over time. Figure 3 illustrates the positionality of (1) squares that represent the overall means for sessions 1, 2, and 3 network data, and (2) labelled circles to represent the breakdown of Time 1 and Time 2 means for each session. The movement of means from Time 1 to Time 2 for each session is illustrative of the changing ways in which the same cohort of students connected the four Projective Reflection constructs to each other (e.g. changes in integration) across two time periods. The different locations of the 3 summary means for sessions 1-3 are illustrative of differences between cohorts in terms of how they enacted their identity exploration processes (which may have been influenced by some elements of curricular design).

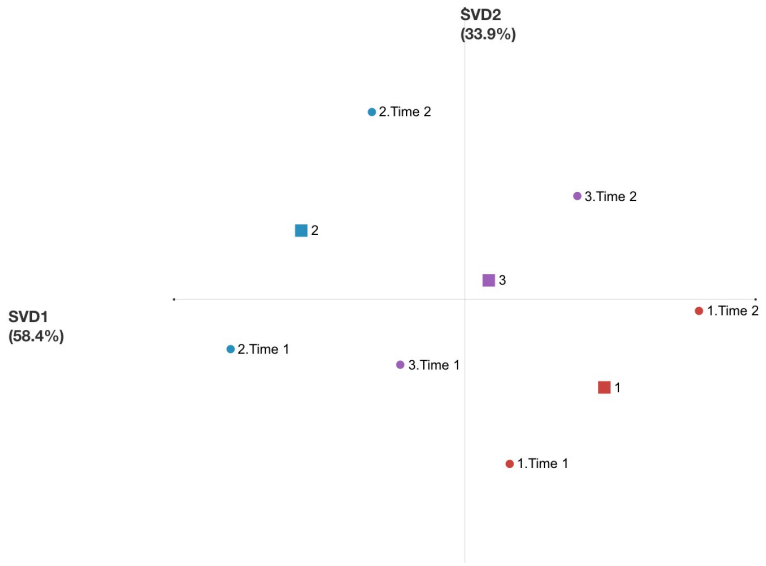

Figure 3. Network means by overall session (square) and broken down by time period (circle)

Figure 4 presents the same network means (overall and by time) with the epistemic network of relationships between the four Projective Reflection constructs overlaid. This epistemic network serves as a map for interpreting the direction of mean differences and movement over time. For example, compared to the overall means for Sessions 2 and 3, the overall mean for Session 1 is skewed toward the Knowledge construct, suggesting that students in Session 1 more regularly discussed or demonstrated knowledge-related growth or change. This finding is supported by prior examinations of the *curriculum elements* in *VCP1,* which featured more student use of the virtual city zoning tool and more reflections on their emerging understanding of the role through professional emails.

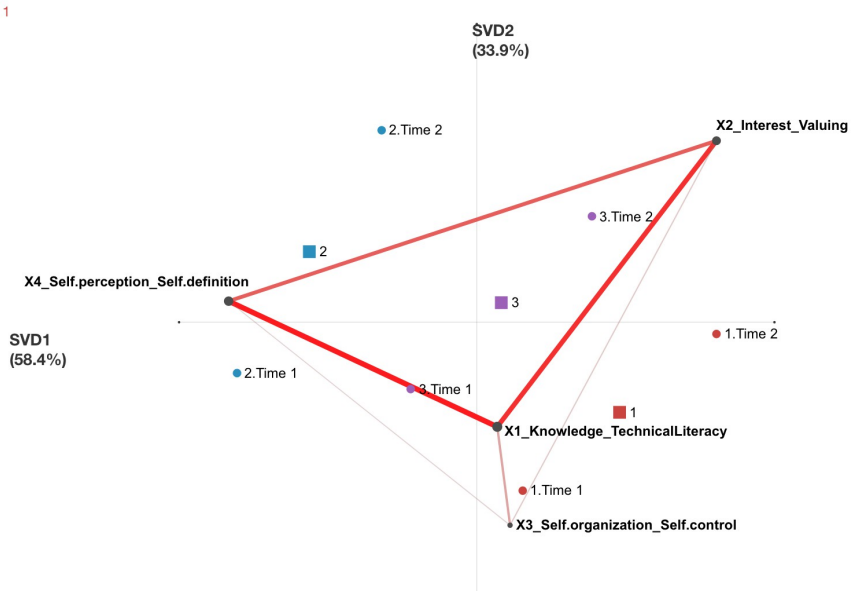

Figure 4. Network means with the epistemic network of constructs overlaid

Characteristics of *the cohort of students* also had potential to shift the overall mean of a session. For example, a qualitative review of Session 2 student data revealed that more members of this group were able to explicitly discuss their self-perceptions and self-definitions as they related to their urban planning identities over time. For example, Bethany reflected early in the session that this was the first time she had been prompted to think about future careers or roles, while students such as Mateo were thinking about looking for jobs near the end. Some students in Session 2 reflected that they could see themselves as urban planners, either during the course itself or potentially after, while others remained unsure of what future roles they might pursue, but did not rule out urban planning. Students such as Elijah recognized how urban planning was valuable topic for him to understand as a future business owner. While the ways in which students in Session 2 described their self-perceptions and definitions differed in content, the group was more able to explicitly engage in reflection and discussion on the topic, as demonstrated by the skewing of the Session 2 overall mean toward this construct.

The overall mean for Session 3 is more centrally-located than those for Session 1 and 2, which suggests that students' discussions of and connections to the four PR constructs may have been enacted in a more balanced or integrated manner. Quotes like the following from Emil (pseudonym) suggest that students were able to more readily connect emerging knowledge, strategies for success (i.e. self-organization) and self-perceptions/definitions as active participants for change over time: "I'm very scared for the health of not only our city, but our planet. We destroy natural ecosystems to create businesses and heat up the Earth just to run our cars. I'm hoping by adding more green open spaces, we will create a better Philadelphia."

An examination of shifts in mean positionalities from Time 1 to Time 2 for each session reveal striking commonalities with regard to the trajectory of identity exploration that students enacted over time. First, to deterime whether student changes from Time 1 to Time 2 were statistically significant for each session, three paired-samples t tests assuming unequal variance were conducted between the X and Y axes of Time 1 and Time 2. Along the x axis for each session of *VCP*, a two-sample t test assuming unequal variance showed that Time 1 *was* statistically significantly different from Time 2 at the alpha=0.05 level. Along the y axis for each session of *VCP*, a two-sample t test assuming unequal variance showed that Time 1 *was not* statistically significant from Time 2 at the alpha=0.05 level (See Table 2).

Table 1. Paired sample t-test statistics.

		N	Mean	SD	t	df	Sig. *(2-tailed)*	Cohen's d
Session 1 X-axis	Time 1 (Week 1-4)	264	-0.10	0.71	-3.29	500.18	0.00	0.27
	Time 2 (Week 5-9)	365	0.07	0.59				
Session1 Y-axis	Time 1	264	0.00	0.59	0.00	574.43	1.00	0.00

	Time 2	365	0.00	0.61				
Session 2 X-axis	Time 1 (Week 1-4)	229	-0.20	0.87	-4.89	461.17	0.00	0.44
	Time 2 (Week 5-8)	287	0.16	0.78				
Session 2 Y-axis	Time 1	229	0.00	0.61	0.00	477.83	1.00	0.00
	Time 2	287	0.00	0.58				
Session 3 X-axis	Time 1 (Week 1-2)	95	-0.14	0.43	-3.83	205.00	0.00	0.52
	Time 2 (Week 3-4)	113	0.12	0.55				
Session 3 Y-axis	Time 1	95	0.00	0.40	0.00	205.97	1.00	0.00
	Time 2	113	0.00	0.47				

The statistically significant changes across the X axis can be understood from a visual examination of the network means (See Figure 4) as a universal shift across sessions toward deeper and more frequent student connections to their interest and valuing around urban planning and environmental science careers. This shift in means towards the Interest and Valuing construct suggests that regardless of differences in cohort or in the design and implementation of *VCP,* the course encouraged deeper, more frequent, and more integrated student reflections on the value and relevance of urban planning and environmental science roles for themselves and their communities, as well as usefulness of the science domain across a variety of contexts and identities. This shift is evidence that virtual environments and supportive curricula whose design was informed by Projective Reflection can support domain-specific identity exploration as Kaplan and colleagues (2014) defined it: the "deliberate internal or external action of seeking and processing information in relation to the self" (p. 250). This change is evident in the final reflections of students such as James, who wrote that "My interest in learning about my Philadelphia's environment is really [of concern], because I live here and it's not a pretty site to live in quite frankly, and I think that should change," and of Ali, who wrote "i can see myself being a construction worker, on the urban planning things that i know that i can change, it would be easy for myself to create the open space for the people in my neighborhood."

Conclusion and Implications

Results illustrate the utility of educational experiences designed to facilitate Projective Reflection (Foster, 2014) and the Play Curricular activity Reflection Discussion (PCaRD) model for supporting students' increasingly-integrated processes of identity exploration related to STEM domains (i.e. environmental science and urban planning). Though characteristics of a specific designed experience or student cohort may result in some differences in the overall identity exploration process, trajectories of identity exploration over time manifested as increasing and statistically significant change toward student discussions of their interest and valuing of a topic. Over time, students used science knowledge to achieve personally-relevant learning goals in the situated environment, and demonstrated more detailed awareness of the relevance and value of the topic for themselves in the present and future. Given these findings, designed virtual learning environments such as *Virtual City Planning* serve as particularly valuable avenues for promoting the exploration (and potential future acquisition) of STEM identities across a more diverse group of students based on the capacity of such environments to adapt to individual and contextual needs and connect learning to the self.

Quantitative Ethnographic (QE) (Shaffer, 2017) techniques such as Epistemic Network Analysis (ENA) (Arastoopour et al., 2015) served as a valuable and innovative approach for understanding whole-group trajectories of identity exploration as operationalized by Projective Reflection. The use of ENA not only allowed researchers to examine large quantities of student data related to identity exploration by providing a nuanced view of the relationships between identity constructs (integration), but also supported comparison of group characteristics over time (Time 1 to Time 2). Future reports will expand on this inquiry to interpret and compare the weighted connections (line thickness) between PR constructs across different times and sessions. Future studies will test and refine new virtual learning environments that can facilitate Projective Reflection in different contexts, and also incorporate methods such as Social-Epistemic Network Analysis (See Gašević et al., 2018) to examine identity exploration as both an individual/developmental and collective/situational process of change over time.

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