Virtual Learning Environments for Promoting Self Transformation: Iterative Design and Implementation of Philadelphia Land Science

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Abstract. The objective of this design-based research study was to develop, implement and refine *Philadelphia Land Science (PLS)*, an interactive web-based experience designed to support learning framed as identity exploration over time, leading to identity change around environmental science and urban planning careers. *PLS* was developed using Projective Reflection (PR) and tested with high school students at a science museum in Philadelphia as part of a larger on-going study funded by the National Science Foundation (Foster 2014). Projective Reflection (PR) frames learning as identity exploration and change to inform the design of games and game-based learning curricula to facilitate intentional change in learners' (a) knowledge, (b) interest and valuing, (c) self-organization and self-control, and d) self-perceptions and self-definitions in academic domains/careers. Change is tracked from a learner's initial current self, through exploration of possible selves (measured repeatedly), to a learner's new self at a desired specific end-point (Shah et al. 2017). PLS was constructed through the modification of the virtual internship *Land Science*, and capitalized on the strengths of its design features, which were informed by the Epistemic Frames Theory (Shaffer 2006). The paper introduces two iterations of *PLS* and concludes with implications for design and implementation of games for facilitating identity change. Implications are discussed for advancing research on learning and identity in immersive virtual environments.

Keywords: Projective reflection · STEM · Game-based learning
Game design · Identity exploration · Identity change

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1 Introduction

In recent years, the role of identity research in education has proliferated as an increasingly important aspect of learners' development in a globalized and technologically connected society (Brophy 2008). Kaplan et al. (2014) argue that the goals of educational opportunities should focus on allowing students to engage in exploration and construction of their identities as they consciously mature in these learning contexts in and out of school. Such experiences have relevance for students' overall development as learners. This is so because, through guided and intentional exploratory experiences, learners can develop the adaptive skills to find, pursue and redefine interest in new domains, become conscious in their actions and commitments, and leverage resources in the context to advance in their activities (e.g. a career) purposefully (Flum and Kaplan 2006). This process is conceptualized as identity exploration (Kaplan et al. 2014), whereby students intentionally reflect on a starting self, then shift through possible selves as facilitated by a learning experience and emerge as a new self at the end of a determined period of time (long or short) (Shah et al. 2017). We argue that digital immersive tools that are designed to enable identity exploration in students may prove useful, especially in light of the new and developing 21st century careers for which student preparation and mentorship may be limited or unavailable. Specifically, there is a need for learners to develop personal agency and reflexive skills that will allow them to reflect on their current positions and adapt towards changing contexts, interests, and careers; this can be achieved by designing and leveraging technologically-enhanced educational experiences (Foster 2014).

Virtual learning environments (VLEs) such as games and simulations have garnered the attention of educational researchers as these media forms have been shown to provide effective contexts for learning through students' enactment of the player role to inform personal identities (Shaffer 2006; Barab et al. 2010; Kafai et al. 2010). There is growing evidence to support the claim that games are indeed conducive to identity exploration (Bagley and Shaffer 2015; Foster 2011; Khan 2012), and in turn, the resulting identity change contributes to academic learning, motivation, and interest (Flum and Kaplan 2012; Oyserman et al. 2004). However, this area of research is still in its infancy, lacks empirically-tested theories and processes that can illuminate (a) characteristics for designing identity exploration opportunities, (b) how learners can progress through a trajectory of identity exploration, change and development, and (c) the role of educators and contexts in supporting learners' role identities (Shah et al. 2017).

In this paper, we begin addressing the aforementioned issues in order to advance the burgeoning field of games, learning and identity. We introduce Projective Reflection, a theoretical and analytical framework to conceptualize learning as exploration of possible selves in targeted academic domains and professional careers in play-based learning environments, resulting in identity change over time. We then discuss the application of Projective Reflection in the iterative redesign of the urban planning virtual environment *Land Science* into a new experience, *Philadelphia Land Science*. In this paper, we address the following research question:

"How can Projective Reflection inform the iterative design of the virtual environment Philadelphia Land Science to support student identity exploration and change around urban planning and environmental science careers?"

2 Games as Conducive Environments for Learning and Identity

A growing body of research suggests that gaming affects motivation and learning through processes of identity exploration (Foster 2008; Shaffer 2006; Squire 2006); however, few research studies have demonstrated this. In Whyville, Kafai et al. (2010) found that tweens learned science and explored identities through self-representations using their avatars. In another study by San Chee (2013), the design of Statecraft X, a game-based curriculum, facilitated the development of connections between citizenship and governance by encouraging players to act as citizens with a sense of national identity (via agency and social cohesion). Furthermore, an examination of engineering virtual internships *Nephrotex* and *Rescushell* by Chesler et al. (2015), demonstrated how games can offer authentic virtual environments that emulate professional settings, thereby facilitating player acquisition of situated content knowledge and exploration of domain-related identities. Lastly, Silseth (2012) described the learning trajectory of one student in a game-based course that explored geopolitical conflicts from multiple perspectives; the study offered insight into the student's experience as he engaged in the game and in discussions with his teacher and peers, and drew upon his local cultural experiences.

While the aforementioned examples are revealing of the potential of games for learning and identity, few empirically-tested theories exist that operationalize how learning relates to identity in gaming contexts. For instance, Shaffer (2006) introduced the Epistemic Frames theory that supports the design of epistemic games. Epistemic games support pedagogical praxis and facilitate the acquisition of basic skills, knowledge, identity, values, and epistemology in a community of practice. Epistemic games facilitate learners in developing epistemic frames as ways of thinking, valuing, and knowing about professional praxis such as engineering (Chesler et al. 2013). The Epistemic Frames Theory informed the design of exemplary games such as *Land Science* (*LS*) that helps players think and act like real-world urban planners and environmental scientists (Chesler et al. 2015). Similarly, the multi-user virtual environment EcoMUVE (Kamarainen et al. 2015) illustrates the existence of additional exemplars in the field of immersive environments which excel at offering three-dimensional experiences (as defined by the National Academies of Sciences, Engineering and Medicine, 2017) in which implicit identity exploration and change could occur; however, the need for tools and curricula that can not only support student knowledge development and acquisition of scientific practices, but also connect to students' personal contextualized interests, values, and developing identities, has become increasingly apparent (Shah et al. 2017).

We argue that a unifying theoretical framework is needed to guide the design, implementation, and assessment of game-based learning for identity change, as

facilitating identity exploration through game-based learning is essential to advance an emerging and promising line of research.

3 Projective Reflection

The Projective Reflection (PR) framework conceptualizes learning as a process of self-transformation, or identity change in immersive interactive environments such as games and virtual worlds (see Fig. 1). Kaplan and Garner (2016) operationalized identity exploration through the Dynamic Systems Model of Role Identity (DSMRI). DSMRI consists of four constructs: (a) ontological and epistemological beliefs, (b) action possibilities, (c) purpose goals, and (d) self-perceptions and definitions of self. Projective Reflection analogously operationalizes these four constructs for use in game-based learning as changes in (a) knowledge (Kereluik et al. 2013), (b) interest and valuing (Foster 2008), (c) manifestations of self-organization and self-control (regulated actions; Hadwin and Oshige 2011), and (d) self-perceptions and self-definitions (Kaplan et al. 2014) in a targeted academic domain (Shah et al. 2017; Foster and Shah 2016) (see Table 1). The framework informs the process of identity exploration as it is measured at repeated points over the course of students' learning experiences, thereby tracking learning as identity change across four constructs (knowledge [meta, humanistic, and foundational], interest and valuing, regulated actions, and self-perception and self-definition) in specific domains.

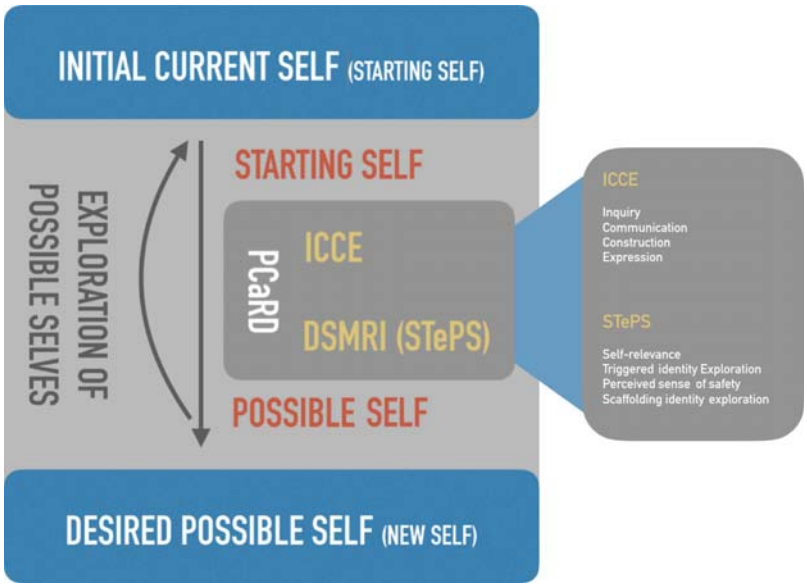

Fig. 1. Projective reflection

This framework integrates a focus on content and on the self through a view of learning as inextricably tied to the self. At least two complementary facets support identity change that inform game-player experiences and gaming identity processes. The first is the confluence of the student's prior knowledge and perceived competence, social/peer networks that influence interest development, and opportunities to occupy roles that provide opportunities to experience and identify with certain roles and their associated knowledge in the domain. The second is the strong contribution of intentional student reflection on a new-formed game-based self, and connecting it to possible current and future real-world selves.

Projective Reflection can serve as an analytical lens to design curricula or retroactively examine identity exploration in completed play experiences. It can also inform game design for identity change by connecting learning mechanics to game mechanics (LM-GM) (Arnab et al. 2015). To conduct a more fine-grained analysis or application of identity exploration, the four PR constructs may be examined in greater detail along six sub-questions (See Table 2). Instructors may design to facilitate Projective Reflection through the Play, Curricular activity, Reflection, Discussion (PCaRD) play-based pedagogical model and in turn both trigger and scaffold players' explorations of academic domains or possible career roles (Foster and Shah 2015, 2016).

Table 1. Projective reflection constructs to frame identity exploration and change

Projective reflection constructs	Description
Content knowledge and game/technical literacy	Shifts in what a player knows about science (environmental science), urban planning, and urban systems from the beginning to the end of an intervention
Self-organization and Self-control	Shifts in behavior, motivation, and cognition toward a goal • Self-regulated learning – conducted independently • Co-regulated learning – conducted with real/virtual mentors • Socially-shared learning – conducted with peers
Interests and valuing	• Shifts in science (environmental science) and urban planning as being just globally relevant to personally relevant and meaningful as well • Shifts in identification with science (environmental science) • Seeing need for science (environmental science) for self and for use beyond school contexts • Shifts in care for science (environmental science)
Self-perception and Self-definition	• Shifts in confidence in self, shifts in self-concept, shifts in science (environmental science) knowledge • Shifts in how a participant sees himself/herself in relation to science (environmental science)

Table 2. Sub-questions for elucidating student identity exploration as it changes

Reflection/discussion questions to measure identity changes – asked/assessed repeatedly over time	Definitions
What do learners know?	Knowledge of science (environmental science) from beginning to end of an intervention
What do learners care about?	• Identifying with or seeing the need and personal relevance for science (environmental science) for themselves, and for use beyond school contexts • Engagement in science content for science understanding as increased social capital from peer interactions, and confidence based on new knowledge about the essential role of science in their lives for personal use • Understanding the roles science plays in their lives
How do learners think?	Seeing science not only as globally relevant, but also personally meaningful
How do learners see themselves?	• Changes in self-concept (i.e. increased self-confidence and motivation) • Resulting changes in behavior are more socially acceptable in class and among peers
What do learners want to be in the future?	Aspirational goals or expressed desires around science-related careers as a possible self
What do learners expect to be in the future?	Perceived expectations about science-related careers based on their current life circumstances, even with an expressed desire to view science-related careers as important, valuable, and a possible self

4 Methods

Philadelphia Land Science (*PLS*) was designed, developed, and implemented from 2014–2017 as part of an ongoing 5-year NSF CAREER project undertaken to advance theory and research on promoting identity exploration and change in science through interactive and immersive environments such as games (Foster 2014). Overall, through PLS we strived to design and facilitate opportunities for high-school students to (a) construct foundational-meta-humanistic knowledge for urban science which were aligned with the Next Generation Science Standards (NGSS) for high school environmental science, (b) generate/trigger and sustain interest in environmental science,(c) enable global and personal valuing in environmental science, and (d) explore multiple identities related to environmental science in an urban context.

Early phases of the project involved characterizing the processes of identity change in known exemplary science games/virtual learning environments (*EcoMUVE*, *Land Science*, and *River City*) that aim to develop science-related user identities. These environments were selected because of the strong line of research and theoretical grounding that influenced their development, testing, and refinement over several years. From 2014–2016, the process involved (1) conducting an analysis of the design of the environments for affording identity exploration and change, and (2) examining existing data from complete studies of participants in the environments to learn science and explore science identities. The analysis was guided by identity change constructs as defined by the Projective Reflection framework: knowledge, interest and valuing, self-organization and self-control, and self-perception and self-definition (see Table 1). The procedure for analysis and the designed affordances and constraints for *Land Science* were identified as a result (Foster and Shah 2016).

From 2016–2017, the Principal Investigator and his team of researchers collaborated with the Epistemic Games Group (EGG) to design an iteration of *Land Science* using the Virtual Internship Authoring (VIA) tool. This iteration of *Land Science*, named *Philadelphia Land Science*, capitalized on the game's existing technological, pedagogical, and content characteristics to support greater alignment with Projective Reflection constructs. Furthermore, *Philadelphia Land Science* was customized to reflect Philadelphia, the context of implementation (see Fig. 2). Collaborative efforts involved visits to the EGG and weekly meetings to receive training in the use of VIA, creating land parcels for Philadelphia, and playtesting the frameboard over a period of 18 months. The EGG also hosted *Philadelphia Land Science* on their server and online platform (WorkPro Banner), which logged player data. Additionally, some EGG personnel offered real-time technical support during the implementation of *Philadelphia Land Science* at a Science Museum from October 2016-March 2017.

Fig. 2. Philadelphia Land Science in-game interface

4.1 Research Design

Philadelphia Land Science was developed, implemented, and refined using a design-based research (DBR) methodology (Cobb et al. 2003). DBR supported cycles of design, enactment, analysis, and redesign as the authors implemented the game in a classroom where the game's technological, pedagogical, and content characteristics were adjusted by subsequent interventions. Each time we used *Philadelphia Land Science*, we examined classroom artifacts (e.g. student survey responses and written reflections) and reviewed researcher observation notes to inform game and classroom modifications that could enhance learner identity exploration and change related to environmental science. While modifying the game during interventions was not possible, external aspects of facilitating identity exploration were improved based on insights from the application. That is, the Play, Curricular activities, Reflection, and Discussion (PCaRD) (Foster and Shah 2015) opportunities were modified as needed in response to participants' experience with the game to better support the process of identity exploration. Thus, game improvement occurred in successive cycles of application.

4.2 Participants and Settings

Two 8-week courses titled "Virtual City Planning" were offered at a popular science museum in Philadelphia in 2016–2017 to 9th grade students from a local magnet school emphasizing science learning. The museum partnered with the school to offer 4–8 week long enrichment courses during an academic semester. Courses were held for 90 min on Wednesday afternoons.

Thirty-five 9th grade students participated across the two interventions. Student groups consisted of 19 girls, 14 boys, and 2 non-identifying students; 34% identified as African-American, while other students identified as Caucasian-American, Latino/a, or other. Students played the game in a museum classroom using laptops provided by their school. Class structure typically consisted of an overview of activities, followed by engagement with *Philadelphia Land Science* or other curricular activities until a scheduled 15-min break, at which point mentors would provide in-game feedback. Students then completed related curricular activities for the second part of class, or continued longer projects.

4.3 Roles and Procedure

The team of researchers included the PI, a postdoctoral scholar, three doctoral students, and nine undergraduate students. The PI and the postdoctoral scholar guided all aspects of the project; students modified game content to reflect the Philadelphia context, pedagogical structures to further align with PR, and assessments to track identity exploration over time.

Game-based learning environments consisted of (a) internal aspects: in-game experiences informed by game mechanics, and (b) external aspects: activities that occur in designed spaces outside of the game, but as a result of gameplay. The Play, Curricular activity, Reflection, Discussion (PCaRD) model informed the design of both

internal and external aspects to facilitate the intentional process of identity change. Thus, it was essential to design both the internal-external aspects of the study concurrently, ensuring they were in sync.

Below we describe two design iterations of *Philadelphia Land Science* as a tool for facilitating learning as identity exploration and change in environmental science. *Land Science* is described to familiarize readers with original game structure, then characteristics of *PLS* are discussed for iterations one and two.

5 Land Science

Land Science development was conceptualized by the Epistemic Frames theory, which introduces learners to basic skills, habits, and understanding related to urban science (Chesler et al. 2015), such as scientific modeling and real-world problem solving. *LS* was designed to serve as a virtual internship for students exploring urban planning, and related environmental, economic, and engineering concepts. Students digitally role-play as interns at the fictional urban planning firm Regional Design Associates, which models real-world professional settings. Interns engage in research surrounding city history and structure, analyzing community stakeholder needs, and translating these needs into city zoning changes while working to create a comprehensive rezoning plan for the city of Lowell, Massachusetts. As players work to understand and meet stakeholder needs, they develop contextualized understandings of diverse economic (e.g. housing density) and environmental issues (e.g. wildlife protection).

Land Science features include: (a) a notebook entry tool where players summarize and justify actions through professional emails to a virtual supervisor, (b) a resources page that offers content knowledge about the city, stakeholders, and environmental and economic issues, (c) an interactive city map connecting player rezoning choices to environmental and economic effects, (d) a chat log that hosts cooperative mentor-peer meetings, and (e) intake and exit surveys that gather intern feedback. The design of *Land Science* is typical of immersive virtual environments developed around pedagogical praxis or epistemic frames theory (e.g. Nephrotex, EcoMUVE) that emphasize the thinking (cognitive), being (civic), and doing (practical) that is essential to all complex learning (Shaffer 2006).

6 *Philadelphia Land Science* - Iteration 1

The design goals of iteration one of *Philadelphia Land Science* (*PLS1)* were the intentional facilitation of identity exploration through designing for changes in what the players know and think, what they care about, how they see themselves, and what they want and expect to be in relation to urban science and environmental science careers. *PLS1* included changes that personalized the game experience for students, and optimized affordances of the museum implementation context. The following list synthesizes *PLS1* design changes, to be discussed in further detail in the following sections:

- Significant changes occurred in the development of *PLS1* to shift game content and setting from Lowell, Massachusetts, to reflect Center City, Philadelphia – a more meaningful and personalized context. Non-player character changes reflected diversity characteristics of the Philadelphia area.
- *Land Science* gameplay consists of twelve "rooms" that iterate student actions and corresponding notebook "deliverables." *PLS1* added seven additional deliverables across the twelve rooms to enhance PR constructs.
- *PLS1* intake and exit surveys included a subset of original *LS* questions that aligned with PR constructs, with additional questions prompting reflection on student identity exploration.
- *Land Science* provided players with example notebook entries as a game resource. *PLS1* replaced these with 1–2 line prompts embedded in the notebook text boxes reiterating notebook entry goals.
- In-class curricular activities emphasizing reflection and discussion were designed with the goal of supplementing game affordances to create an integrated learning experience.
- *Land Science* embedded team discussion in the game's virtual chat log to accommodate remote players. *PLS1* made use of the classroom context at the museum to host in-person meetings facilitated by mentors roleplaying as urban planners.
- An online blog was developed where students could synthesize elements of game experience for later review by themselves and by peers.

6.1 Internal Aspects of Content Change

Overall, the content embedded in PLS1 was explicitly aligned with the NGSS for high school environmental science (see Table 3). Given the demonstrated success of *Land Science* in promoting changes in students' content knowledge, much of the existing game content was either retained in *Philadelphia Land Science*, or mirrored to reflect a Philadelphia context. For example, *PLS1* maintained the general expression of city zoning codes and scientific/economic output variables, but made changes to represent context. Land use codes described as single-family, two-family, and multi-family residential were renamed as low, medium, and high-density housing to offer more flexible definitions of downtown Philadelphia housing density, as almost all residential areas in Center City qualify as "multi-family." New housing density descriptions aligned more closely with students' lived experiences in an urban center, and illustrated the housing density nuances more precisely.

Scientific/economic output variables on the interactive map were largely analogous to a Philadelphia context, though the unit levels (i.e. gallons of water runoff) shifted to reflect Philadelphia measurements. Environmental variables related to animal populations in Massachusetts were shifted to represent Philadelphia-native species: Eastern Bluebirds and Eastern Mud Turtles. New content descriptions emphasized the local importance of these species and illustrated how map changes might affect them.

Land Science included brochures for four fictional stakeholder groups in Massachusetts that detailed the issues these groups value, and provided brief biographies for individual stakeholders so that students could understand and address their needs.

PLS1 designer developed analogous brochures and biographies for stakeholders and groups that emphasized varying combinations of economic and environmental values:

- The Bridgeway Community Action Association supported low-income families and emphasized housing and environmental issues.
- The Environmental Council of Greater Philadelphia advised on environmental conservation issues such as wildlife protection and pollution control.
- The Philadelphia Economic Affairs Coalition supported economic growth and valued increased zoning for houses and businesses.
- The Philadelphia Institute for Neighborhood Preservation sought to improve citizen quality of life by balancing environmental and the economic change.

While *Land Science* included representative non-player characters based on gender, race, and ethnic background, *PLS1* capitalized on opportunities to demonstrate diverse employees and leaders in urban planning. Portraying urban planners with whom players can identify is key to the development of possible selves in the domain, as it encourages players to see themselves in a given role and develop domain-specific knowledge (Foster 2008). In-game diversity also addressed museum context, as the majority of players were likely to be members of groups currently underrepresented in STEM fields (women, non-white employees).

Table 3. Mapping game content with NGSS and projective reflection

NGSS for high school	What LS is designed for	What/how to meet the required standards in PLS week-wise	Application within PLS	Relation to projective reflection - What they know - How they think - What they care about - What they expect to be - How they see themselves - What they want to be
HS-LS2-6: Evaluate claims, evidence, and reasoning that the complex interactions in ecosystems maintain relatively consistent conditions, but changing conditions may result in a new ecosystem	- Manipulating the map in one neighborhood affects each of the four variables in that neighborhood, and ultimately in other neighborhoods, which leads to ecosystem changes - The research notes provide some background information on the Baltimore oriole, such as habitat requirements, migration patterns, and food sources	- The game can ask students to think about concepts like runoff, use of pesticides, and pollution - The game can ask students to predict how certain changes might affect various ecosystems: wetlands, temperate forest, etc. -The game can ask students to think about how human interactions affect ecosystems	- Prompt students to apply their current knowledge of ecosystem functions to these changes - Example: when a student zones a space such as a community garden near the Schuylkill, students should think about how runoff will be a new input variable within the ecosystem	- Students know what life is like in their current ecosystem - By exploring this standard, students will be able to understand how environmental changes can change their own living conditions - This will allow them to see value in the field of urban planning

(*continued*)

Table 3. (*continued*)

NGSS for high school	What LS is designed for	What/how to meet the required standards in PLS week-wise	Application within PLS	Relation to projective reflection - What they know - How they think - What they care about - What they expect to be - How they see themselves - What they want to be
	- Comparisons between the requirements and the population sizes are made, but students will need to think critically about how they are related			
HS-LS2-7: Design, evaluate, and refine a solution for reducing the impacts of human activities on the environment and biodiversity	- The game discusses the issue of carbon monoxide and the fact that the release of the gas is associated with the burning of fossil fuels - The proposed "solutions" are the use of catalytic converters in cars and the fact that photosynthetic interactions help to reduce carbon monoxide - Although these are not labeled as solutions, the resource documents explain that they may reduce the amount of CO - Students design a proposal using the community input map with consideration of the societal and environmental concerns of the stakeholders - Students work in teams using the community input map and collaborate to come up with the best possible solutions to account for the needs of the stakeholders - Effects on biodiversity are not addressed	- Students may be prompted to try either of these "solutions" or come up with their own ideas on reducing human impacts A scenario asking students to reduce carbon monoxide must be used - Connections to the impacts on biodiversity must also be drawn	- The same example of carbon monoxide can be applied, as it is also an issue in Philly - There need to be questions or activities addressing the relationship to biodiversity - Example: how can the presence of carbon monoxide either increase or decrease biodiversity?	- Environmental impacts will directly impact scenarios that students personally care about. - This standard and the activities that align with it will allow students to more fully develop their own future expectations of their own life and how they can personally control the impacts by engaging in urban planning

6.2 Pedagogical Changes

6.2.1 Internal Aspects of Pedagogy

Land Science was designed with a cyclical pedagogical structure that scaffolds student development from one "room" to the next, guiding students through the process of developing urban planning proposals. In each of the twelve rooms, students reviewed an email that explained upcoming activities, provided context, and outlined deliverables for players to complete and write about in notebook entries. Students reviewed content resources, participated in meetings, made zoning changes on the interactive map, and reviewed stakeholder feedback on map designs. Each room culminated with notebook entries where students summarized their activities, which were reviewed remotely by instructors, who accepted or returned student work for resubmission.

PLS1 maintained much of this pedagogical structure, particularly as its design authentically progressed players through urban planning processes. Seven new deliverables were added across the twelve rooms (as informed by PR) that prompted students to consider developing a) interests and values (e.g. submit "a formal summary of the changes you would make to meet your own needs as a citizen of Philadelphia"), and b) self-perceptions and self-definitions (e.g. "reflect on your role in this internship and your expectations about this role going forward").

Questions on intake and exit surveys in *PLS1* were designed to assess all four PR constructs; items consisted of short answer, multiple choice, and Likert-style questions that took about 30 min to complete. Intake and exit surveys bookended identity exploration in the game, allowing researchers to assess players' starting selves and new selves at the end of the intervention; game and classroom data tracked changes between these start and end points.

6.2.2 External Aspects - Curricular Activities, Reflection and Discussion

Supplemental curricular activities, reflection, and discussion were also designed and implemented in the classroom environment to support a more integrated classroom experience, as supported by PCaRD (Foster and Shah 2015). For example, using paper maps and markers, students drew how they would want the city to be redesigned, then explained and justified these changes in a whole-group discussion. The purpose of this activity was to foster engagement in the internship experience and offer an opportunity to construct a rezoned Philadelphia based on student interests and values. Another example involved students creating blog posts to describe the interests and values of one community stakeholder they were working to please. Posts offered advice for peers on how best to meet stakeholders' needs.

Researchers chose to leverage pedagogical opportunities afforded by the classroom space, student proximity, and existing peer relationships; Instead of virtually-facilitated meetings structured around a virtual mentors' questions, *PLS1* meetings had in-person facilitators roleplaying as urban planning professionals, who guided meeting topics and discussions around important points, and encouraged socially-shared regulation among peers.

Opportunities for student reflection were also facilitated in the classroom experience. The most notable example of this occurred when role-play urban planner shared a mid-intervention class synthesis of students' demonstrated changes in what they know,

care about, want/expect to be, and how they think and see themselves; students reflected on how they have changed in these areas. Online blog posts (external to the game) provided further opportunities for self-reflection.

6.3 Internal Aspects of Technological Change

The *Land Science* interface was designed to virtually simulate the experience of working as an urban planner, and most technological features were retained in *PLS1*. As mentioned, progression of game activities was moderated by real-world mentors situated remotely, who initiated emails from a virtual supervisor, answered questions in chat, reviewed students' work, and provided in-game feedback. *LS* included a chat feature where players held meetings and communicated with peers and mentors. Though these online meetings were translated to in-person role-plays in *PLS1*, researchers retained the chat feature so that players could communicate with online moderators if needed. When a student prematurely submitted a notebook entry, for example, online mentors coached them through its retrieval through chat.

LS included example notebook entries that students could reference as they developed skill in professional writing and speaking. Such resources are well suited for the goals of the original game, as they model ways of thinking and acting around urban planning. Review of the *LS* gameplay data showed that students recognized these examples as optimal responses, but some would copy sections of sample text to construct their notebook responses. Given the emphasis on personal reflection and regulated learning practices in *PLS1*, redesign shifted supportive texts from *how* a notebook is written towards *what* players should write in their entries. *PLS1* instead included statements reiterating the deliverables needed for each entry (e.g. "please include a short summary of your experience completing the Entrance Interview").

7 *Philadelphia Land Science* - Iteration 2

Gameplay and classroom data from *PLS1* were collected and analyzed to inform the iterative design of the internal and external aspects, and further align with the goals of the museum context. *PLS1* built upon existing gameplay structures to add increased opportunities for in-game and in-classroom self-reflection and discussion around possible selves. Nonetheless, the game with these additions proved to be too long and cumbersome to offer a complete and engaging experience to students in eight class periods. Hence, modifications were designed into iteration two of *Philadelphia Land Science (PLS2)* that simplified and streamlined gameplay narratives and processes, while upholding original *LS* goals and developing more targeted intentional shifts in across PR constructs. The following list offers an overview of the changes made in *PLS2,* to be discussed in further detail in the following sections:

- *PLS2* included readability changes to in-game text but retained existing content.
- *PLS1* gameplay consisted of twelve "rooms" that iterated student activity through over 50 distinct "deliverables". *PLS2* streamlined game processes to include 31

deliverables across eight rooms, while maintaining intentional alignment with Projective Reflection constructs.
- Further in-class curricular activities emphasizing reflection and discussion were created with the goal of supplementing game affordances to enhance personal connections, develop contextualized content knowledge, and provide opportunities for student self-reflection. Curricular activities from *PLS1* were also redesigned with this goal in mind.
- To accommodate Internet connectivity issues in the museum, paper versions of all in-game resources, surveys, and activities were developed and included in personalized student work binders.
- Weekly PowerPoints outlined class structure, detailed class activities, and shared technological information.
- Online blog use was discontinued due to time and connectivity constraints.
- Classroom features such as open space, SmartBoard access, and video streaming capabilities were leveraged to enhance student engagement and identity exploration.

7.1 Internal Aspects of Content Change

Analysis of *PLS1* data showed students were able to connect in-game content to their contextualized values and interests. Internal content in *PLS1* was retained in *PLS2*, though text resources in-game were modified to fix errors and streamline readability. Content elements were expanded through the use of additional curricular activities to further align game activities with the Philadelphia context. One example of this shift included use of the 1940 documentary "A Place to Live", which detailed the struggle for safe, affordable housing development in early 20th century Philadelphia. The alignment with the following NGSS was retained in PLS 2:

- *HS-LS2-6:* Evaluate claims, evidence, and reasoning that the complex interactions in ecosystems maintain relatively consistent conditions, but changing conditions may result in a new ecosystem.
- *HS-LS2-7:* Design, evaluate, and refine a solution for reducing the impacts of human activities on the environment and biodiversity.
- *HS-LS4-6:* Create or revise a simulation to test a solution to mitigate adverse impacts of human activity on biodiversity.
- *HS-ESS3-3:* Create a computational simulation to illustrate the relationships among the management of natural resources, the sustainability of human populations, and biodiversity.
- *HS-ESS3-4:* Evaluate or refine a technological solution that reduces impacts of human activities on natural systems.
- *HS-ESS3-6:* Use a computational representation to illustrate the relationships among Earth systems and how those relationships are being modified due to human activity.
- *HS-ETS1-1:* Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants.

- *HS-ETS1-2:* Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.
- *HS-ETS1-3:* Evaluate a solution to a complex real-world problem based on prioritized criteria and tradeoffs that account for a range of constraints, including cost, safety, reliability, and aesthetics, as well as possible social, cultural, and environmental impacts.

7.2 Pedagogical Changes

7.2.1 Internal Aspects of Pedagogy

The most significant changes to *PLS1* occurred as pedagogical revisions to game processes, as students struggled to conceptualize what they needed to do in-game, and complete in-game tasks within necessary time frames. In addition, students demonstrated gaps in development of their urban planning knowledge and processes; researchers determined that an abundance of in-game text and deliverables may have overwhelmed players and contributed to this disconnect. Difficulty maintaining universally functional Internet connections across users exacerbated these issues, and further demonstrated the need for a streamlined pedagogical approach.

PLS1 was designed with a cyclical pedagogical structure in which students used their developing knowledge and skill as urban planners to create city plans that meet stakeholder needs. Players received stakeholders' fictional feedback tailored to their design choices. Additionally, players were prompted to incorporate suggestions into a new iteration of map design and ultimately in their final proposal. In *PLS1*, elements of this process repeated 3–4 times; by iteration four, players with well-developed skills and knowledge were finished and off-task, while those continuing to work expressed increasing frustration. In *PLS2*, one iteration of map design was dropped, resulting in a map design exploration phase, followed by a single progression through map creation, feedback, and map redesign. This change, plus the synthesis of two other rooms, resulted in a reduction of 4 "rooms" and several in-game deliverables, while not detracting from the game's intentional facilitation of Projective Reflection constructs.

Other deliverables were synthesized, removed, or streamlined in remaining rooms to enhance pedagogical clarity. For example, deliverables such as records of meeting dates and times were dropped, as their affordances for modeling professional practice were supported by other game elements. In addition, deliverables added in *PLS1* to enhance identity exploration (e.g. personal reflections) were reorganized across existing rooms so that no more than one extra task was assigned to each room in *PLS2*.

7.2.2 External Aspects - Curricular Activities, Reflection and Discussion

PLS2 saw an increase in the design and inclusion of curricular activities. This afforded greater opportunities to develop and personalize content knowledge and promote reflection and discussion, as supported by the Play, Curricular activity, Reflection, and Discussion curricular implementation model for game-based learning (Foster and Shah 2015). The following examples offer a redesigned curricular activity from *PLS1* to *PLS2*, and a new curricular activity, both of which offered opportunities for reflection and/or discussion.

- In *PLS2*, paper maps were printed on large poster board with added visual detail. Using markers, students color-coded how they would want the city to be redesigned on day 1 and day 8 of the intervention. Day 1 class discussion emphasized description and justification of map design, while day 8 discussion focused on how and why their designs had changed. This activity supported increased personalization of urban planning issues, and reflections on how students changed.
- Stakeholder Walk. A balanced list of economic and environmental values affirmed by stakeholders was compiled. The classroom was segmented by tapelines, and values were read off; students stepped left (environmental) or right (economic) from neutral center based on what they found important. Class discussion centered on explanations for their choices and affective exploration of the experience.

7.3 Internal Aspects of Technological Change

Analysis of *PLS1* data demonstrated that students were able to develop game literacy over time and access internal technological features to achieve game goals when given adequate peer and mentor support. During *PLS1*, Internet connectivity problems became more and more pronounced in the museum space, precluding some students' participation with content and pedagogy. Though this issue was ameliorated somewhat through the enhancement of external pedagogy in *PLS2*, paper handouts of all in-game emails, surveys, notebook deliverables, and resources were designed to support student engagement when online connections could not be established.

The use of the online blog site proved useful in *PLS1* to encourage reflection and peer knowledge sharing, however overhead site literacy development, coupled with limited online access, resulted in its discontinued use in *PLS2*. Technological features of the external environment were increasingly leveraged in *PLS2* for external curricular activities that supported student identity exploration, including classroom open spaces (stakeholder walk), SmartBoard access (PowerPoints), and video streaming capabilities (documentary), which offered varying opportunities to enhance student engagement.

8 Discussion, Conclusion and Implications

This paper described the iterative development and implementation of Philadelphia Land Science (PLS), a virtual experience intended to support high school students to experience projective reflection (Foster 2014) in the context of environmental science in an urban context. Projective Reflection is a theoretical framework that facilitates the process of exploration of specific roles identities (e.g. a career role) in play-based environments. Identity exploration is scaffolded through opportunities for learners to develop foundational-meta-humanistic knowledge, to cultivate regulated actions, to promote interest and valuing, and to reflect on ones' self-perceptions and self-definition in relation to the roles (Foster 2014; Shah et al. 2017). This paper was one demonstration on how game platforms that involve immersive and virtual reality simulations can be designed to emphasize both learning subject matter knowledge as well as the development of personal and interpersonal competencies and skills that are required for

successful functioning in the increasingly volatile, uncertain, and ambiguous 21st century world of work (Flum and Kaplan 2006; Foster 2014).

Scholars are increasingly investigating the role of games in facilitating identity construction and reconstruction, particularly in the sciences to spur alternatives to the 'mile-wide and inch deep' canonical teaching methods, which are disconnected from many students' experiences (Beier et al. 2012; Khan 2012; Silseth 2012). However, this area of research is still in its infancy and requires the development of theories of change mechanisms, and evidence-based measurement and design principles for virtual learning (games, virtual realities, simulations) experiences that affect learners' knowledge, identity processes, and career paths. Frameworks such Epistemic Frames theory (Chesler et al. 2013; Chesler et al. 2015; Shaffer 2006) and Projective Reflection are few empirical processes that allow educators, researchers, and designers to conceptualize, facilitate, and examine learning and identity in virtual environments such as games. Further theoretical and practical advancements are required to reinvigorate students' motivation and commitment particularly in STEM and STEM careers (US Congress Joint Economic Committee 2012).

Philadelphia Land Science was designed for players to explore the role of an environmental scientist in an urban setting, a context personally meaningful to the participants. PLS was designed by modifying Land Science, an epistemic game (Shaffer 2006). The technological, pedagogical, and content features were modified over two iterations to ensure that the game (internal aspects) and the supportive game-based curricula (external aspects) were designed to offer and support identity exploration opportunities as intended by the projective reflection framework. PLS was largely text-based; however, future iterations will involve more immersive experiences such as (a) a 3D environment for players to explore their roles in, (b) the incorporation of a map of Philadelphia that updates to reflect real-time zoning changes, (c) map and game development around specific city sections and/or of the entire city, and (d) the inclusion of more land use codes and variables to develop value-driven, personalized learning as identity change.

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