Developing Science Identities through Games: An Analysis of Game Design Features that Support Identity Exploration

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Abstract: This paper presents an in-depth examination of three exemplary virtual environments for science learning (*Land Science*, *River City*, and *EcoMUVE*) to identify and conceptualize game features that support student identity exploration. The work showcases findings obtained from Years 1-2 of an NSF CAREER project (DRL#1350707) undertaken to support the study, design, and implementation of games and curricula that enhance science learning and teaching to promote intentional student learning as identity change (Foster, 2014). The examination was guided by Projective Reflection (PR), a theoretical framework that explains and facilitates learning as identity exploration in immersive play-based environments such as games (Foster, 2014). PR characterizes identity exploration as intentional changes in a) knowledge, b) interest and valuing, c) self-organization and self-control, and d) self-perceptions and self-definitions in a given domain. The Playing Research Method (Aarseth, 2003; Foster, 2012) informed the game data collection and analysis processes. A hybrid process of inductive thematic analysis and deductive coding of game features in the three environments illustrated their capacity to support student growth along PR constructs. Findings reveal both unique and overlapping game features that support identity exploration related to STEM careers, while implications detail the future development and utility of a game feature repository to support researchers, educators, and designers

Keywords: Identity exploration,projective reflection,game-based learning,game features

Introduction

American youth between ages 8 and 18 play games for over 365 hours each year (Rideout et al., 2010). In response, educators and educational advocates (e.g., MacArthur, Digital Promise Project) have acknowledged the potential of leveraging children's motivation to play games to promote academic motivation and learning (Kenny & Gunter, 2011). Notable organization leaders have argued that schools and teachers should use digital games to support learners (Kelly, 2005). While research has demonstrated the potential of gaming to promote motivation (Young et al., 2012), comparatively little work has explored the mediating processes by which gaming affects educational outcomes. Some evidence connects gameplay to students developing content knowledge; however, there is a paucity of research about how gaming influences students' motivation and development of "self."

Game-based Learning and Science

Theory and research have highlighted digital games as contexts with the affordances to facilitate “situated understandings, effective social practices, powerful identities, shared values, and ways of thinking of important communities of practice” (Shaffer et al., 2005, p. 6). The National Research Council (2011) committee on science learning and computer games argues that games have the potential to catalyze new approaches for science learning, but acknowledge that research on simulations and games for science learning has not kept pace with the rapid development of these new learning technologies. Few empirically developed and tested digital games exist (e.g. *EcoMUVE*, *Land Science*) that present opportunities to situate science content and practices in contexts that are of interest to learners. This domain is still in its infancy, and requires research to develop theoretical understandings, theory-driven design principles for game-based learning (GBL), pedagogical approaches, and teaching practices, in order to fully enact the potential of this medium.

Recently, researchers have developed and refined more nuanced methods by which games can promote transformative learning experiences – for example, by facilitating epistemic frames (Shaffer, 2006) and identity development (Chee & Lim, 2009), and investigating how these impact learners (Author, 2014). However, much remains unclear about the mechanism of learning in game worlds. These include questions about: 1) the process by which individuals progress within and across game-based learning - “the what of learning”, 2) the ecological context of the learning – “the where of learning”, 3) how the learning is influenced by characteristics of the learner along biological, cognitive, experiential, and affective lines – “the who and the why of learning”, and 4) how the frame of learning changes across time and space due to changes in the learner – “the when of learning” (Alexander et al., 2009; Geary, 2009).

Games and Identity Exploration

Comparatively less research has explored the effects of games on player identity, despite the clear affordances of the medium for identity exploration (Shaffer 2006; Chee, Gwee & Tan, 2011). For instance, epistemic games explore learners’ development of epistemic frames as ways of thinking, valuing, and knowing about professional praxis such as engineering or urban planning (Chesler et al., 2013). Similar to epistemic games, if game-based learning is to make a difference in informing education research, a more nuanced understanding of learning for the 21st century is needed. This understanding must expand beyond content knowledge to a more generative comprehension that considers what learners know, how they think, how they see themselves, what they care about, what they would like to become, and what they expect to become (Foster, 2014). Thus, learning with games should include a process of identity exploration that focuses on the “when of learning.” Examining learning as a process of change involving identity exploration is crucial, as the frame of learning changes with time and space due to changes in the learner (however inconspicuous) from one moment to another. Understanding this mechanism to achieve identity development within a domain (i.e. science) is to advance theory and research on games and learning. In our work, we explore learning as a process of identity exploration in digital games through Projective Reflection, which explains and support the integration of the temporary identity of a student playing a game (the student’s projective identity) with the student’s possible future identity (a possible self) outside the game (Foster, 2014).

Theoretical framework

Projective Reflection informs the identity exploration process measured at repeated points over the course of a learning experience, thereby tracking student learning as identity change across four constructs: knowledge, interest and valuing, self-organization and self-control, and self-perceptions and self-definitions (see Table 1). Projective Reflection is further mapped along six sub-questions: 1) what the learner knows – current knowledge, 2) what the learner cares about – self and interest/valuing, 3) what/who the learner expects to be during the virtual experience, and their long-term future self, 4) what the learner wants to be – possible self, 5) how the learner thinks – self and interest, and 6) how the learner sees him/herself – self-perceptions and self-definitions. These questions are used to measure a learner’s initial current self, exploration of possible selves repeatedly over time, and a learner’s new self at a desired specific end point. To understand learner changes over time, researchers and educators may examine characteristics of learners’ starting selves, apply the Projective Reflection process, and then assess learners’ new selves at the end of the experience, comparing differences between starting and new selves. It is this tracking of identity exploration as incremental changes in these constructs over time, and culminating at a particular end point defined by the designed experience, that we refer to as identity change (see Shah, Foster & Barany, 2017 for more information on Projective Reflection).

Table 1
Projective Reflection constructs to frame identity exploration and change in science games

PR Constructs	Definitions	Research
1. Knowledge and game/technical literacy	Shifts in player knowledge/literacy over time: ● Knowledge of science topics, careers, and systems ● Familiarity with game tools, use of tools to meet goals	Kereluik, Mishra, Fahnoe, & Terry, 2013
2. Self-organization and self-control	Shifts in behavior, motivation, and cognition toward a goal: ● *Self-regulated learning*: managed independently ● *Co-regulated learning*: supported by real/virtual mentors ● *Socially-shared learning*: collectively managed with peers	Hadwin & Oshige, 2011
Interests and valuing	● Reframing topics as not only *societally* relevant, but *personally* relevant and meaningful ● Shifts in personal identification with game topics ● Recognizing the importance of science for personal use, and use beyond school contexts ● Shifts in caring about science	Wigfield & Eccles, 2000 Foster, 2008
4. Self-perceptions and self-definitions	● Changes in self-concept, driven by developing knowledge/literacy, self-confidence, interest/relevance ● Shifts in how participants see themselves in relation to science (i.e. future STEM career)	Kaplan, Sinai & Flum, 2014

Facilitating Identity Exploration

Growing evidence suggests that teachers can play crucial roles in augmenting the impact of GBL on students' engagement in an academic domain (Bell & Gresalfi, 2017; Eastwood & Sadler, 2013). However, research on methods for empowering teachers to facilitate meaningful learning experiences with games, and the pedagogical characteristics they may use to support learners, is still emerging (Foster & Shah, 2016a; Shah et al., 2017).

Some researchers have attempted to draw similarities between the characteristics of "good games and good teachers" (Moline, 2009). Researchers have also recently explored the dynamic pedagogical roles teachers must play to meaningfully connect students' domain-specific academic experiences, in-game curricular experiences, and personal interests in the domain (Kangas, Koskinen & Krokfors, 2016; Silseth, 2012). However, few models exist to frame teachers' GBL competencies (Shah & Foster, 2015) in designing game-based curricula and facilitating identity exploration (Shah et al., 2017), thwarting the interests of pre- and in-service teachers in adopting GBL (Ruggiero, 2013; Takeuchi & Vaala, 2014).

Projective Reflection informs the design of experiences and assessments in a game and game-based learning curriculum intended to facilitate learning as identity exploration. It can also serve as an analytical lens to guide a post-hoc examination of existing game environments. These affordances can inform how Projective Reflection (that is, learning as identity exploration over time) can be facilitated in games and GBL through interruptive teacher-led actions (Foster & Shah, 2015; 2016b) and non-teacher led actions that are non-interruptive (Foster & Shah, 2016a); this represents an emerging, but important line of research to pursue. The goal of this paper is to characterize pedagogical characteristics in games that may facilitate student identity exploration. The research question asks: "*What are the design features of identity exploration in gaming contexts?*"

Methodology

The research showcased in this paper emerged in years 1 and 2 of an ongoing 5-year NSF CAREER grant awarded to support the study, design, and implementation of games and curricula that enhance science learning and teaching to promote intentional changes in identity and learning for students (Foster, 2014). This project used an inductive/deductive qualitative approach (Creswell, 2003) to conceptualize game features that support identity exploration in three exemplary science virtual environments: *Land Science*, *River City*, and *EcoMUVE*. Design teams from each game provided access to gameplay and game artifacts for analysis. The inductive process involved a thematic analysis of games and game artifacts, which led to the identification of game features through an analytic memoing process (Maxwell, 2012). Identified game features were then deductively coded based on their affordances and constraints for supporting identity exploration (see Creswell, 2003 for a description of pre-assigned coding practices). The Playing Research Method (Aarseth, 2003; Author, 2012) also informed game analysis procedures. The following sections introduce game settings, data collection, and data analysis in greater detail.

Setting

Three virtual environments were selected for analysis because they are exemplary in their potential to support student identity exploration. Each has been studied extensively by their respective research teams, and is backed by strong theoretical frameworks.

Land Science is a simulation game that encourages students to take on roles as urban planners redesigning the city of Lowell, Massachusetts based on the needs of community stakeholders. Students roleplay remotely as interns at Regional Design Associates, a fictitious urban planning firm that models the structure of real-world professional settings. Online mentors synchronously guide players through the process of creating zoning plans that meet the needs of Lowell's stakeholder groups. Through this process, learners engage with the skills, knowledge, values, identities, and epistemologies that urban planners develop in real-world communities (Shaffer, 2006).

River City is an online game environment that situates learners as time-traveling visitors in a disease-ridden 19^{th} century town. Students work together in small research teams, using technology to keep track of clues, form and test hypotheses, develop controlled experiments to test their hypotheses, and make change recommendations. Through engagement in the environment, players develop skills in epidemiology, scientific inquiry, and experimentation as they explore environmental causes of community health issues (Ketelhut, 2007).

EcoMUVE is a multi-user virtual environment (MUVE) that recreates authentic ecological settings that develop players' understanding and interpretation of complex causal relationships in an ecosystem. Students learn about environmental science by interacting in virtual pond and forest ecosystems populated by data, instruments, and animals in order to find problems and solve emerging challenges (Metcalf, Kamarainen, Tutwiler, Grotzer, & Dede, 2011). Each module is structured as a two-week inquiry using curriculum built around the virtual ecosystem.

Data Collection

To conduct an analysis of design features, the following data was collected and/or shared with us by the games' respective research teams:

1) *Land Science* data consisted of in-game play data, including records of a past cohort's chat logs, in-game written responses to activities (notebooks), player survey data, and final completion reports. The developers also shared secondary information on the design, rules, and mechanics of the game. Finally, researchers collected a repository of academic articles written by the primary research team on *Land Science.*

2) The *River City* research team shared student outcome data from a prior gameplay implementation. In addition, researchers collected a repository of research publications and reports on game development from 2002 – 2007.

3) The primary research team for *EcoMUVE* was able to make the game available for direct play, which allowed for the primary collection of observations on in-game design features.

Data Analysis

Data analysis was informed by the Playing Research Method (Aarseth, 2003; Author, 2012) for analyzing games, which suggests that game research can be approached three ways: 1) observing gameplay to understand how players interact, 2) playing the game directly to explore game design and rules, and 3) examining game ecosystems (aesthetics, history, gameplay and game rules) through a combination of observation and play. Data may be collected through interaction with designers, and artifact-collection from secondary sources (i.e. research, player data), but optimally occurs from direct play. As such, researchers analyzed their own observations and direct play where possible (*EcoMUVE*), and analyzed secondary sources when it was unavailable (*Land Science*, *River City*).

During the analysis process, researchers approached each game as a self-contained curriculum with technological features, pedagogical characteristics, and embedded content as design decisions made to facilitate the intended learning goals (Foster, Katz-Buonincontro & Shah, 2011). Researchers first engaged in inductive thematic analysis of games and game artifacts (Creswell, 2013), involving the identification and iterative development of game features through analytic design memoing (Maxwell, 2012) (see Table 2). Individual game feature lists were then compared and synthesized to final list of features for each game. Finally, the three lists were deductively coded based on the extent to which each feature supported one or more Projective Reflection constructs. The results of this analysis are summarized in findings below.

Table 2
A sample of design memoing conducted during game analysis

Game Feature	Description/Function	Design Notes
Notebook	Allows the student to review what they have previously explored and build upon what they have learned.	Feels more like personal email reminders than an actual notebook. Perhaps a notebook formatting would be nicer.
Chatboard/Chat Archive	Chatboard allows student to connect and communicate with one another immediately.	It is easy to miss information. Is there a way to send important chat information to offline members? Add a memos tab perhaps
Resources	Similar to that of a textbook. The content is there for the student to read.	Needs to have more images. Better formatting in general. Also some things are download links. Why?
Emails	Straightforward	Unused to send emails due to the chatbox. Find another use or omit the emails.

Findings

We present a summary of the design features of *Land Science*, *River City*, and *EcoMUVE* that support identity exploration and change toward STEM careers, as defined by Projective Reflection (see Figure 3).

Features that support knowledge and game/technical literacy

The design features in *Land Science*, *River City*, and *EcoMUVE* were analyzed for the extent to which they support 21st century knowledge and skills, conceptualized as foundational knowledge (i.e. core and cross disciplinary knowledge, information literacy), meta-knowledge (i.e. critical thinking, problem solving, collaboration and communication), and humanistic knowledge (i.e. knowledge of self in a broader social community) (Kereluik, et al., 2013). Features that support student technical literacy, or developing understanding of how to conduct gameplay, are also identified in this category.

Game features identified as supporting student development of foundational knowledge typically presented key science information in an organized and consolidated location, such as *Land Science*'s Resources Tab, which provided concise write-ups of key urban planning issues for players to explore. Multiple features were identified in each game as opportunities for meta-knowledge development. In particular, game features such as *River City*'s Environmental Health Meter and *EcoMUVE*'s Population Tracker allowed for causal feedback between students' in-game actions/experiments (i.e. removing a variable, time) and the effects of these changes on the given environment.

The three environments offered comparatively few features that could support player development of humanistic knowledge. Although *Land Science* encouraged students to empathize with different stakeholders within the game, the original game lacks features that prompt players to relate their developing empathy to a knowledge of self. Similarly, in *River City*, players were encouraged to empathize with the residents who became ill, but game features did not explicitly prompt players to connect this empathy beyond the game context.

All three games offered multiple technical and design supports to scaffold players' developing literacy with gameplay. The most notable game features in *Land Science* included the Help Icon, which offered information about the function of different pages, and notification bubbles that appeared periodically on game screens to remind players of tasks and deadlines. Based on the player data we examined, we determined that players also relied heavily on the real-time virtual mentor, who was available throughout gameplay to answer questions and support game use; players also regularly used the game's two-window feature to view multiple different game elements at once.

Features that support self-organization and self-control

The three environments were examined to identify design features that supported self-organization and self-control along three conceptual features: a) co-regulated actions conducted with the support of a more-knowledgeable mentor, b) socially-shared regulation of activities toward a goal that is negotiated among a group of peers, and c) self-regulated actions that are driven and organized by the individual (Hadwin & Oshige, 2011; Vygotsky, 1978).

River City offered co-regulation in the form of non-player character (NPC) supports, such as avatars and computer-based agents that provided information and guidance to players. The design of *Land Science* also offered multiple rich features that supported co-regulated actions between players and more knowledgeable others. Two features of particular note were the presence of virtual mentors, and the notebook entry submission system. Students completed the full *Land Science* experience with the ever-present guidance of real-time game mentors, who virtually monitored each player's progress from a visualization system known as the mentor dashboard, and would also communicate with players (individually and communally) via the chat log. Through this system, mentors provided direct support when needed, and players could request support. Students also submitted written documentation of their urban planning activities through the notebook entry feature; game facilitators could respond with both personalized feedback and pre-set options (e.g. "all elements are completed," "please revise and resubmit").

All three games included at least one design feature that supported socially shared regulation with peers, such as seeking guidance, co-constructing knowledge, and problem solving. In *River City*, students collaborated with team members in the View and Action Space to solve the problem of disease-spread, collectively negotiating complex choices and conducting experiments to understand causal relationships in the virtual world. *Land Science* also heavily featured the use of the chat log, where students collectively conducted virtual meetings, discussed in-game decisions, and sought assistance from peers. The game also featured the Customer Input Map, an annotation tool that allowed students to collectively share notes on environmental or economic findings.

Finally, features in all environments facilitated self-regulated activities and goal-completion. For example, *EcoMUVE*'s calendar and data view features encouraged individual scientific inquiry into environmental causal relationships over time – players were expected to engage in scientific data collection, analysis, and interpretation by paying attention to feedback and actively reflecting on experimental results. In *EcoMUVE*, players also used the field guide, population tracker, and camera to evaluate and monitor their own progress within the game.

Features that support student interests and valuing

Fewer features in *Land Science, River City,* and *EcoMUVE* provided opportunities for students to reflect on their developing interests and values as they related to identity exploration. That is not to say that these games did not develop students' interests and valuing of their respective content and contexts, but rather that comparatively few existing features prompted players to intentionally reflect on how science may become increasingly personally relevant and meaningful for their personal use in real-world contexts, as a result of their engagement in these spaces.

The primary features in these three games that supported student interests and valuing are the simulated environments designed to reflect real-world problems, contexts, and processes, to facilitate player connection and application of science knowledge and skills beyond the game or the classroom. For example, *Land Science* situated gameplay in the real-world city of Lowell, Massachusetts; players learned about the city's unique history and structure, researched the needs of key stakeholder groups in the community, and translated these needs into zoning changes on a map of the city. As players worked to understand and meet their stakeholders' needs, they developed contextualized understandings of diverse economic and environmental issues such as housing density, job growth, pollution control, wildlife protection, and waste disposal. Players could easily draw connections between issues presented in Lowell and issues that exist in their own area of residence, although no features in the game explicitly prompt them to do so. To address this concern, *Land Science* developers at the Epistemic Games group have recently developed a virtual internship authorware feature that allows users to change the game context to more closely align with player context. As part of years 2 and 3 of the NSF CAREER grant, we utilized the virtual internship author tool to redesign the game; Our version, *Philadelphia Land Science,* set the game in our players' home city, and allowed us to include more interest and valuing prompts (for more information, see Shah et al., 2017).

Features that promote reflection on self-perceptions and self-definitions

Few game features were identified as promoting intentional reflection on players' changing self-perceptions and self-definitions over time through play. Design features from each game did support changes in how players saw themselves in relation to science over time, but did not elicit reflection on or awareness of identity shifts.

The role-play feature found in each game was identified as useful for promoting potential shifts in how learners saw themselves in relation to science. *River City* and *EcoMUVE* provided opportunities for players to take on the role of scientists engaging in professional inquiry around real-world issues (e.g. disease, pollution). Such opportunities encouraged students to "try on" the role of a scientist as a possible self (Markus & Nurius, 1986; Foster, 2008), and gain competence and confidence in this role for future use.

In *Land Science*, players assumed the role of urban planners for the city of Lowell, and documented their in-game activities in written notebook entries framed as professional emails to a virtual supervisor. In this role, players were expected to research the needs of community stakeholders and represent them by developing city design proposals. This emphasis on professional and role-play experiences was coded as a feature that might prompt students to reflect upon whether they may or may not wish to pursue urban planning as a desired future self. These features hold potential for promoting student identity changes over time toward science careers, but these benefits would be strengthened by game features that make these reflections explicit and intentional.

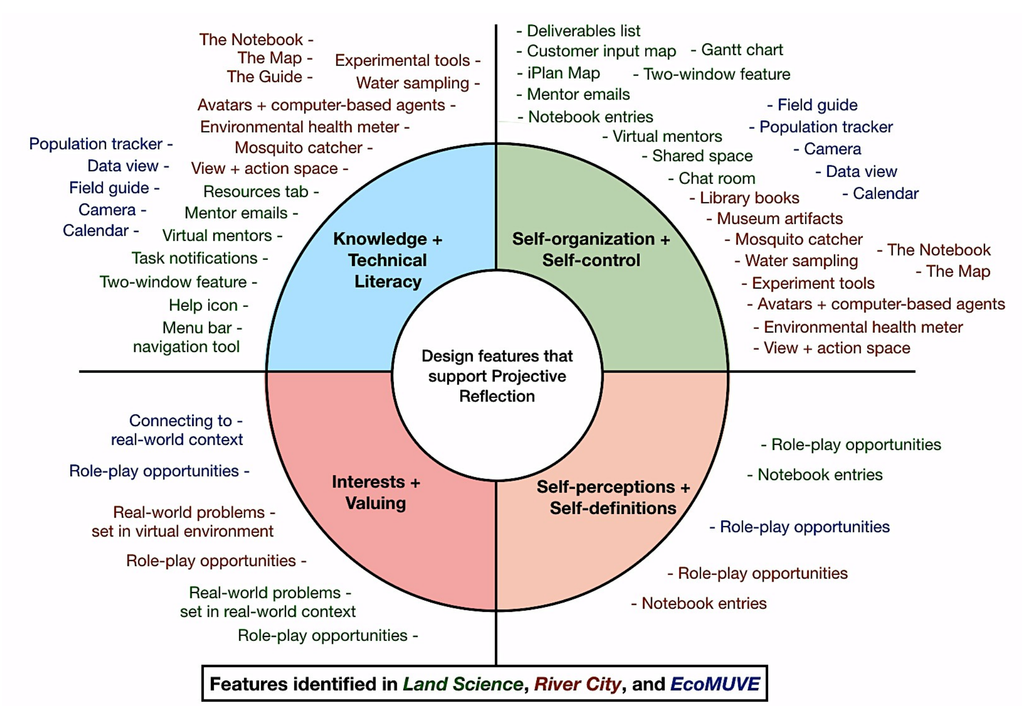

Figure 3. Design features found to support identity exploration, summarized along each of the four Projective Reflection constructs.

Discussion and Significance

Given the identified potential for games as pedagogical tools to support academic motivation and learning (Young et al., 2012; National Research Council, 2011) three game environments were analyzed to identify design features that support student identity exploration in science. Using an inductive/deductive qualitative analysis (Creswell, 2013) supported by the Playing Research Method (Aarseth, 2003; Foster, 2012) researchers examined games and game artifacts from *Land Science*, *River City*, and *EcoMUVE* to write design memos on game features, which were deductively coded to the four Projective Reflection constructs (Foster, 2014).

Findings revealed that while some elements of identity exploration, as conceptualized by Projective Reflection, are represented in existing games across a variety of features, other essential elements of identity exploration receive limited design attention. Specifically, over twenty different features were found to support student knowledge/game literacy gains, as well as development of self-organization/self-control, respectively. In comparison, only 2-3 unique design features were found to support student reflections on their changing interests and values, and emerging perceptions and definitions of self.

These findings align with existing literature findings, which suggest a limited research focus on learners' incremental changes across time and space - "the when of learning" (Alexander et al., 2009; Geary, 2009). In response to the need for increased study, design, and implementation of tools and curricula that promote intentional changes in identity and learning for students (Foster, 2014) this research seeks to further the development of a "roadmap" for the expansion and enhancement of game-based learning practices that support identity exploration. Such an endeavor also builds upon existing research qualifying the "claims of games" in terms of the medium's physiological and psychological effects on student learning (Author, 2007) by connecting the learning affordances identified in the authors' literature synthesis (i.e. motivation, cognitive skills, etc.) to specific game features.

Such a repository of game features is groundbreaking, given the lack of existing research that offers theoretical understandings, theory-driven design principles, or pedagogical approaches and teaching practices to support identity exploration through game-based learning (Mishra & Foster, 2007; Foster, 2014). A limitation of this repository is the size and scope of analysis (i.e. 3 well-designed games, limited access to direct gameplay). Ongoing access to more games and more primary game data will enhance the scope and utility of this feature list. For example, primary gameplay of *Land Science* (which occurred in later phases of the grant project) may offer increasingly rich insights into *Land Science* game features; new information from these and other games may further qualify existing features on the list, in addition to populating new ones. Continuing analysis of these game features will also distinguish between interruptive and non-interruptive characteristics (Foster & Shah, 2015; 2016b), to increase list usability for future designers.

This analysis of game features also offers many uses for the research and design of future tools that support identity exploration targeted at all four Projective Reflection constructs. Our research has implemented these game features into the design of games and game curricula with targeted science identity exploration opportunities in mind (Foster & Shah, 2016b), using the Learning Mechanics-Game Mechanics process to connect game features to desired learning outcomes (Arnab et al. 2015).

Finally, this repository may serve as a model to frame teachers' GBL competencies (Shah & Foster, 2015) in designing game-based curricula and facilitating identity exploration (Shah et al., 2017). To address teachers' need for targeted support to encourage GBL adoption (Ruggiero, 2013; Takeuchi & Vaala, 2014), continuing research in the NSF CAREER project has incorporated support for teachers' analysis of existing games for their identity-related affordances and constraints in the project's professional development praxis (Shah et al., 2017). Ultimately, the researchers' hope is that this design feature list may prove useful for educators, designers, and researchers, who may then add, refine, or leverage this information to support students' intentional exploration of identities in increasingly diverse contexts, across a wider collection of games, and using continually evolving and developing game features.

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