

Who I Am, What I Know, and What I Want: An Epistemic Network Analysis of Student Identity Exploration

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Abstract: This paper reports outcomes of 57 students' exploration of urban planning and environmental science identities through Virtual City Planning, a course implemented in a science museum that leveraged a virtual learning environment supported by in-class play-based experiences. Identity exploration trajectories were assessed using the Projective Reflection framework, which consists of constructs that capture cognitive, affective, and behavioral features of the self in addition to learners' self-perceptions and definitions. Researchers constructed a parsimonious epistemic network that was supported by in-depth qualitative interpretations to a) visualize students' general trends of student self-reflection across the course experience and b) highlight which Projective Reflection constructs were highly nascent to participants as they engaged in identity exploration. Results further theoretical understandings of how courses designed to support identity exploration influence the sophistication and content of learners' reflections on the self and illustrate the utility of epistemic networks for visualizing identity exploration trajectories over time.

Introduction

Education research has examined ways to encourage learners to engage in identity exploration, or “the deliberate internal or external action of seeking and processing information in relation to the self” (Kaplan, Sinai & Flum, 2014, p. 250). Identity exploration as a form of situated, intentional, and self-directed learning can encourage identity shifts in targeted directions over time, such as a steps toward a career in science, technology, engineering, or mathematics (STEM) (i.e. Foster, 2014). Interventions that support identity exploration may therefore be of value in the 21st century for fostering adaptive skill development and career preparation in emerging and under-accessed STEM careers (Callahan, Ito, Campbell, Wortman & Wortman, 2019).

Virtual learning environments such as games and simulations have been highlighted as useful tools for promoting shifts in domain or career-specific knowledge (cognitive), motivation (affective), and relevant behaviors (Qian & Clark, 2016). Enactment of such cognitive, affective, and behavioral shifts often centers around identification with specific roles (self-definitions) that players may not have access to in real-world settings (Turkle, 1996). While meta-reviews of game-based learning suggest that game design and implementation are increasingly influenced by education theory (i.e., Clark, Tanner-Smith & Killingsworth, 2016), research is needed in the context of identity to inform how theoretically informed interventions might shape identity exploration outcomes for students across diverse contexts. Emerging research on games for identity exploration will also 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.

To address this gap, this work leverages the Projective Reflection (PR) framework to operationalize learning as identity exploration that can result in identity changes over time, as facilitated by games and game-based learning environments (Foster, 2014). PR was used to design three iterations of Virtual City Planning (VCP), a course that leveraged a virtual learning environment (Philadelphia Land Science) and supportive in-class curriculum to promote exploration of urban planning and environmental science career identities. VCP was implemented in a museum classroom context with a diverse sample of high school students (N=57). Identity exploration is conceptualized using PR as shifts in reflection on 12 constructs that relate to cognitive, affective, behavioral, and self-definitional aspects of the self. Student trajectories of identity exploration were visualized using Epistemic Network Analysis, a quantitative ethnographic technique for modeling connections among key concepts to represent underlying longitudinal phenomena. The Parsimonious Removal with Interpretive Alignment approach (Wang, Swiecki, Ruis & Shaffer, 2021) was then used to optimize the twelve-construct model as an eight-construct network that maintains interpretive power. Epistemic networks were supplemented by qualitative case findings from the student cohorts. Results (a) illustrate how VCP supported statistically significant shifts in student conceptualizations of self over time as defined by PR, and (b) illustrated which identity concepts were more or less nascent and discussed in students' written and spoken reflections on the self. The work concludes with implications for games and education practitioners, designers, and researchers.

The research question asks: *How did learners characterize their processes of identity exploration (cognitive, affective, behavioral, self-definitional) through participation in Virtual City Planning?*

Review of literature

Virtual learning environments and identity

Identity exploration is conceptualized by Kaplan and Garner (2017) as not only the self-perceptions and self-definitions a participant iteratively applies during a learning experience, but also the beliefs, values, goals, emotions, and actions that are central to a specified role as it emerges. This process is role-specific in the sense that a learner exploring a career in urban planning, for example, will immerse herself in a different semiotic and social system than that of an art historian. Participation in virtual learning environments can support more explicit awareness of perceptions and definitions of self due to the capacity of such spaces for offering authentic simulations of professional praxis (Shaffer, 2006). Games implemented in learning contexts have also been lauded as valuable for the expression of nested identities (i.e., student and player) as design constraints of the game space intersect with real-world roles and contexts (Gaydos & Devane, 2019).

Reviews of the growing body of research on games for learning have affirmed the potential of virtual learning environments for supporting a variety of cognitive, affective, and behavioral processes that contribute to identity exploration. Most prominently featured in games research is work that points to the efficacy of virtual media for supporting knowledge acquisition and content understanding in contexts such as primary education (Hainey, Connolly, Boyle, Wilson & Razak, 2016), informal learning settings such as museums (Koutromanosa & Avraamidou, 2014), and with computer-based and serious games and simulations (Boyle et al., 2016). Game-based learning has also been lauded as valuable given emerging theoretical conceptualizations of learning, which shifted from passive knowledge acquisition to more *collaborative* and *interest-driven* negotiation of domain-specific content (Orr & McGuinness, 2018). Virtual learning environments excel in their capacity to support student engagement and motivation around specific content (Wouters, Van Nimwegen, Van Oostendorp & Van Der Spek, 2013), and can also serve as spaces in which players repeatedly practice goal setting, self-monitoring, and self-regulation behaviors (Gabbadini & Greitemeyer, 2018). Finally, the communities of practice (Lave & Wenger, 1991) that develop in and around games (What Gee (2003) defines as affinity spaces) offer opportunities for socially mediated regulation of learner goals and activities as players collectively negotiate aspects of their identities and learn from the expertise of others. This aligns with research on coregulation (McCaslin, 2009) and socially shared regulatory processes (Hadwin & Oshige, 2011) as a part of identity work. Virtual tools, particularly those that promote active discussion and collaboration, show promise for promoting the externalization of learning processes and reflection on individual progress (Zheng, Li & Huang, 2017).

Assessing learner identity exploration

While seminal identity research has characterized identity as a developmental process that emerges over time (Erikson, 1959) as mediated by external sociocultural features (Vygotsky, 1978), contemporary researchers have further characterized such role exploration as a complex and dynamic system (Kaplan et al., 2014). This complexity represents a methodological challenge for educational researchers and practitioners looking to examine learners' identity exploration processes as they manifest over time in play-based experiences. Fortunately, reviews of game-based learning literature have highlighted the emergence of increasingly sophisticated methods for understanding learner processes (de Freitas, 2018), such as data modelling (e.g., Westera, 2017) and individual analytics (e.g., Drachen, El-Nasr & Canossa, 2013). de Freitas also argues for the use of combined quantitative and qualitative measures in forthcoming game-based learning research.

Quantitative Ethnography (QE; Shaffer, 2017) offers a method for exploring learning as a form of complex thinking by offering analytic techniques that can visualize constructs (such as facets of identity) as dynamic network models. Epistemic Network Analysis (ENA) is a QE technique in which qualitative data is quantified so that patterns of association may be visualized between a learners' developing "knowledge, skills, values, habits of mind, and other elements" (Shaffer, Collier & Ruis, 2016, p.10). ENA is validated by examining alignment between qualitative constructs and quantitative representations, defined as interpretive alignment. In addition, model parsimony, as another key concept in QE research, concerns about capturing the "right" amount of detail to explain the phenomenon from both qualitative analysis and quantitative representation. Existing studies of identity exploration that leverage ENA have only applied a priori model simplification (i.e., Barany & Foster, 2020). Generating parsimonious models of identity exploration, based on prior research, is an important next step in assessments of student outcomes that was implemented in this work.

Theoretical framework

This study leveraged Projective Reflection (Foster, 2014) as a research-informed theoretical framework to structure the design of the course (Virtual City Planning) and the virtual learning environment (Philadelphia Land Science). The model was also used as an analytical tool for conceptualizing how learners engage in identity exploration in play-based and virtual learning environments. Identity exploration is captured through individuals' reflections on the self in one moment, which is meaningfully connected to how they conceptualized themselves across prior moments longitudinally. This way, identity change can be assessed over time as participants project forward and reflect back on (a) their current knowledge of a topic, (b) what aspects of the topic they care about, (c) how they think and the processes they use to make choices and take actions, (d) what they want and expect to be in the future, and (e) how they see themselves in the present (Foster, Shah, Barany & Talafian, 2019). PR leverages twelve theoretical constructs to conceptualize identity in game-based learning contexts (see Table 1) under four features of identity exploration: (1) knowledge (i.e., Kereluik, Mishra, Fahnoe & Terry, 2013), (2) interest and valuing (i.e., Eccles, 2009; Hidi & Renninger, 2006), (3) self-organization and self-control (i.e., Hadwin & Oshige, 2011), and (4) self-perceptions and self-definitions (i.e., Kaplan et al., 2014). Constructs were developed and refined through in-depth review of literature on identity, learning, motivation, and individual and socially mediated change to capture the role-specific cognitive, affective, behavioral, and self-definitional features of self that shift over time through participation in identity exploration processes.

Table 1: Projective Reflection theoretical constructs

	Constructs	Construct manifestations
1. Knowledge (awareness of <i>cognitive</i> capabilities)	1.1 Foundational knowledge	<ul style="list-style-type: none"> • Describing knowledge of a domain-specific topic • Defining domain-specific terms or concepts
	1.2 Meta knowledge	<ul style="list-style-type: none"> • Describing awareness of how to use or apply foundational knowledge in context. • Enacting domain-specific processes/applying concepts
	1.3 Humanistic knowledge	<ul style="list-style-type: none"> • Knowledge of the self and its location in a broader social, global, and professional context
2. Interest and valuing (awareness of <i>affect</i>)	2.1 Interest	<ul style="list-style-type: none"> • A predisposition to re-engage with a domain or topic over time, psychological state of engagement. • Describing a domain or concept as interesting
	2.2 Subjective task valuing	<ul style="list-style-type: none"> • Values attached to a domain, topic or concept that motivate the choice to engage. • Describing a domain, topic, or concept as valuable
	2.3 Relevance	<ul style="list-style-type: none"> • Awareness of a domain, topic or concept's importance for the self, a learner's community, or society broadly
3. Self-organization and self-control (awareness of <i>behaviors</i>)	3.1 Self-regulation	<ul style="list-style-type: none"> • Describing one's strategic and metacognitive behaviors aimed at achieving a goal (i.e., goal setting, self-monitoring, outcome assessment)
	3.2 Coregulation	<ul style="list-style-type: none"> • Regulatory behaviors that are supported by a more knowledgeable peer or mentor
	3.3 Socially shared regulation	<ul style="list-style-type: none"> • Regulatory behaviors that are negotiated and enacted collectively by a group
4. Self-perceptions and self- definitions	4.1 Self-efficacy	<ul style="list-style-type: none"> • Confidence in one's ability to achieve goals/results. • Engaging in self-monitoring and self-evaluation
	4.2 Current self-concept	<ul style="list-style-type: none"> • Descriptions or labels applied to the self in the present. • Careers/roles a learner is enacting currently
	4.3 Possible selves explored	<ul style="list-style-type: none"> • Future role/career a learner wants or expects to have. • Roles a learner has tried, but may not wish to pursue

Methods

Study context

This research was conducted as part of a CAREER project awarded to support the study, design, and implementation of virtual learning environments and curricula for promoting Projective Reflection (Foster, 2014). To enact this process in a meaningful real-world learning context, the primary investigator and his team of researchers partnered with a local science museum in Philadelphia. The museum offers weekly science-related learning opportunities to middle school students from a local school. The research team also partnered with the Epistemic Analytics Group at the University of Wisconsin-Madison to redesign the existing virtual internship Land Science (Barany et al., 2017) to support identity exploration and match the needs of the science museum context. Philadelphia Land Science built on the strengths of Land Science as an immersive environment but was informed by Projective Reflection to position learners collaborating in-person during VCP as interns at a fictitious urban planning firm. The virtual learning environment and in-class mentors roleplaying as urban planners guided participants through the process of creating zoning plans for downtown Philadelphia, an area with which students were familiar. Students worked in groups of five to (1) learn about the process of creating a city rezoning proposal, (2) research specific environmental and economic needs of city stakeholders, and (3) rezone a virtual map of downtown Philadelphia to enact desired changes (e.g., decrease air pollution). Students concluded by writing a final rezoning plan outlining their city's needs and the nature of their zoning changes.

The play-based course titled Virtual City Planning was developed and implemented across three consecutive courses held at the museum between the academic year 2016 and 2017 with 57 racially diverse middle school participants. Virtual City Planning involved weekly use of the virtual learning environment supported by in-class opportunities for role-play, self-reflection, and discussion with peers. Examples of in-class activities included supplementary materials (e.g., a documentary video), group discussions on activities and processes of identity exploration, and analogous paper activities designed to support students with less technical literacy (i.e., rezoning the city by drawing on paper maps). Design of each weekly session included virtual and in-class opportunities for individual reflection and collaborative discussion on each facet of students' identity exploration processes (the 12 constructs), in addition to periods uninterrupted play and group engagement in activities. For example, in one class, students rezoned areas of Philadelphia in small groups, negotiated with other design groups to create a map that met everyone's needs, then collaboratively discussed what it felt like to act as an urban planner.

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 student'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"), and (b) short answer questions (e.g., "describe your interests in learning about cities and the environment").
- Responses to writing prompts in Philadelphia Land Science, framed as emails to the design firm.
- Written posts made on an online forum website as a curricular activity.
- Digitized copies of handwritten reflections from paper handouts and notebook annotations, etc.
- 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 were 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, with agreement reached by two coders. Lines were coded for the occurrence (1) or non-occurrence (0) of the Projective Reflection 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 the construct '2.1 Interest.'

We applied ENA (Shaffer, 2017) to our data using ENA1.5.2 Web Tool. ENA assumes that a single piece of student data (written, observed) may be representative of individual change in one or more codes (the PR identity constructs), but also that the data has local structure and that an important feature of the data is the way codes are connected. Based on this assumption, ENA generates network visualizations of the co-occurrence of codes within a moving stanza window, which means that all codes applied to a single 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 sessions 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 be 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 within and across them over time. In addition, two sample t-tests were completed to test whether changes from Time 1-2 in each session were statistically significant along the top two dimensions explaining the most variances. The results also reference themes identified from qualitative studies of the data (i.e., Foster et al., 2019) to close the interpretive loop and provide deeper understanding of the modeled phenomena. After the 12-construct epistemic network was developed, we applied Parsimonious Removal with Interpretive Alignment (PRIA), which reduced the network of students' identity exploration to an eight-construct model without losing interpretive alignment (Wang et al., 2021). PRIA takes an existing ENA model and finds a model with the fewest codes that retains high goodness of fit, correlations of ENA scores and correlations of node positions between the simpler model and the original.

Results and discussion

To answer the question "How did learners characterize their processes of identity exploration (cognitive, affective, behavioral, self-definitional) through participation in Virtual City Planning?" The parsimonious epistemic network model of eight Projective Reflection constructs is presented in a difference model (see Figure 1). Two cognitive constructs (foundational knowledge and meta knowledge), three affective constructs (interest, subjective task valuing and relevance), no behavioral constructs, and three self-definitional constructs (self-efficacy, current self-concept, and possible selves explored) were identified as highly nascent to students' reflections on the self as they engaged in any of the three sessions of VCP. In the difference model, red lines are associations between constructs that were more prevalent in the first half of each course (Time 1), and blue lines represent associations that were more prevalent in the second half (Time 2). Nonparametric Mann-Whitney test showed that Time 1 associations were statistically significant from Time 2 associations along the X-axis at the $\alpha=0.05$ level (Mdn=0.21, N=214 U=10863.50, $p=0.00$, $r=0.48$). This suggests that students' processes of identity exploration were enacted in meaningfully different ways over time, to be discussed further below.

Though associations between student reflections on *foundational* and *meta knowledge* were strongest compared to other associations for Time 1 and Time 2, students were slightly more likely to make connections between these two cognitive features in Time 1. Qualitative examinations of the data revealed they were often able to describe or discuss perceived knowledge of urban planning and its relevant topics throughout the course. Discussions of knowledge typically began with more binary judgments on requisite knowledge and expertise early in the course; for example, Zola (pseudonym) wrote "I have experience with urban planning through my mom" while Megan wrote "I can definitely tell you I don't know much about urban planning." Towards the end of the course, discussions of knowledge trended toward more sophisticated use of situated definitions, terms and processes as students gained experience with the urban planning role; for example, Jake initially did not know what a stakeholder did, but was later able to explain that "A stakeholder is a rich person who has interest in what urban planners do. Stakeholders can make change in our neighborhoods that positively or negatively."

All associations between PR constructs and students' current *self-concepts* were stronger in Time 1 than in Time 2. This result is at first counterintuitive, but an in-depth examination of qualitative reflections reveals that students were initially more likely to affirm concrete descriptions of self, but that these self-definitions were often distanced from environmental science and urban planning. For example, Kevin wanted to be a "professional dancer because I'm a great dancer" and then shared that he had never considered urban planning as a future career because he didn't "really know how good urban planning is." As the VCP course progressed, however, student reflections on the self became less concrete, but also more connected to urban planning roles they had explored. For example, Ellen wrote "Urban planning could contribute to the job I hoped to have because I learned a lot about the importance of high density housing and compacting space for where people live." These more nuanced reflections on the self meant that learners at the end of the course were more often unsure whether or not they might consider urban planning as a future role, where before they may have dismissed the role outright.

While the location of the eight PR constructs on the three-dimensional plane are positioned to allow for model comparison, positionality of the overall means for Time 1 and Time 2 (the red and blue squares) can be interpreted in relation to the constructs and in relation to each other. For example, the overall mean of associations for Time 2 in the model is skewed to the right compared to Time 1, toward the affective and motivational factors

of identity. Prior research on this data found trends toward interests and valuing more broadly (Barany, Talafian & Foster, 2020), but this parsimonious eight-code model reveals the specific processes driving this shift: (1) increased learner associations between *foundational knowledge* and *relevance*, and (2) *self-efficacy* and *interest*. These trends play out qualitatively, as learners were more likely to explain why urban planning and environmental science were relevant for themselves or their communities over time. Consider Emil, for example, who connected new knowledge of urban planning concepts to his awareness of climate change issues: “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.” As students gained confidence in their abilities as urban planners, they were more likely to affirm interest in the topic as well. Ali reflected that he enjoyed taking on the role of an urban planner: “[it felt] good because its my responsibility to actually take part of helping my community out by planning things or seeing what things look like in the modern world”. He then described confidence (self-efficacy) in his ability to enact urban planning changes in his community: “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.”

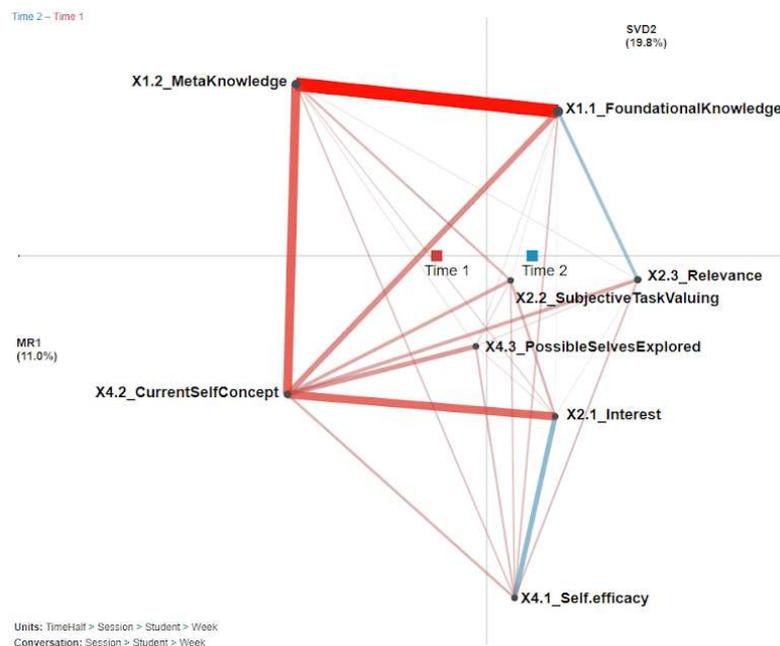


Figure 1. A parsimonious difference model of student identity exploration in which strength of construct associations in Time 2 (blue) were subtracted from the strength of construct associations in Time 1 (red).

In addition to the removal of humanistic knowledge as a construct in the networks, the parsimonious model with the best goodness of fit advocated for the removal of all constructs related to behavioral features of identity (self-regulation, coregulation, and socially shared regulation). While regulated activities remain a highly important and relevant feature of learners’ identity exploration processes, students in VCP were more likely to connect their emerging perceptions and definitions of self (who I am), to their developing interest and perceived relevance of the topic (what I want), to their increasingly specific knowledge of the topic (what I know). While the behavioral ‘what I do’ piece is important from a theoretical perspective, students were less likely to meaningfully integrate discussions of their behaviors into reflections on their identity exploration processes. This could result from students’ newness to identity exploration processes, a lack of self-awareness of their own behaviors or a lack of intentionality when enacting them or could be a result of design choices in curricular design that limited student reflection on behavioral features. Further research is needed to understand why behavioral features emerged as less nascent to students’ reflections on the self in VCP.

Conclusions and implications

Results illustrate the potential of educational experiences designed to facilitate Projective Reflection (Author, 2014) as a way to develop learners’ skill in enacting situated, targeted and intentional identity exploration related to STEM domains (i.e., environmental science and urban planning). Though characteristics of the designed experience (VCP) and features of the student cohort may have influenced how students reflected on their identity

exploration processes, trajectories of identity exploration over time shifted from an emphasis on more concrete and simplistic discussions of initial knowledge and self-concepts to a more nuanced conceptualization of self that was grounded in emerging interests and perceived relevance of the topic. These findings align with summary reports on the acquisition of STEM careers, which suggests that identity exploration may be closely linked to students' developing interest and motivation around a topic, resulting in closer and deeper engagement with the topic over time (CAISE, 2018). Given these findings, designed virtual learning environments such as Virtual City Planning have potential to serve as particularly valuable avenues for promoting the exploration (and potential future acquisition) of STEM identities. Further work is needed to address limitations of this study design, such as (1) examinations of student change across longer time periods and with a more diverse group of students, (2) assessments of the influence of specific curricular design features (see Author, in press for preliminary work on this topic), and (3) the application of the PRIA model to identity exploration processes across more contexts.

Quantitative Ethnographic (QE) (Shaffer, 2017) techniques such as Epistemic Network Analysis (ENA) served as a valuable and innovative approach for understanding whole-group trajectories of identity exploration as operationalized by Projective Reflection. The parsimonious epistemic network not only allowed researchers to examine large quantities of student data related to identity exploration by providing a nuanced view of the relationships between the most nascent identity constructs, but also supported comparison of group characteristics over time (Time 1 to Time 2). 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, Joksimović, Eagan & Shaffer, 2019) to examine identity exploration as both an individual/developmental and collective/situational process of change over time.

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