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LEARNING, INSTRUCTION, AND COGNITION

Assessing Science Identity Exploration in Immersive Virtual Environments: A Mixed Methods Approach

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ABSTRACT
Despite increasing calls for science education that utilizes immersive technologies and authentically model scientific inquiry, little is known about how well curricula leveraging these technologies impact students' science identity. This paper presents a mixed-methods study of identity exploration in 7th grade science students using a three-week immersive virtual world-based curriculum. Data sources include interviews and pre-post assessments which are compared to see how one can best assess science identity exploration. Students had statistically significant gains in scientific self-efficacy, and interviews showed an increasing awareness of what it means to be a scientist and how inquiry and argumentation skills can be used across different disciplines.

KEYWORDS
Science identity; identity exploration; self-efficacy; science interest; growth mindset

Problem

EMPLOYMENT IN SCIENCE, technology, engineering, and mathematics (STEM) careers grew by 10.5% from 2009 to 2015 compared to 5.2% growth in non-STEM jobs, and the average national wage for STEM jobs is nearly double that of other occupations (Fayer, Lacey, & Watson, 2017). Despite this, employers report difficulty filling these positions due to a lack of sufficiently qualified candidates (Langdon, McKittrick, Beede, Khan, & Doms, 2012). Research suggests one possible reason for this gap is a discrepancy between how science is taught in schools and the reality of what these jobs require (National Research Council, 2011). Utilizing authentic scientific inquiry activities can give students a clearer picture of the nature of science and how fields operate in practice. Instead of focusing on memorization and "cookbook"-style lab activities, "… learners can investigate the natural world, propose ideas, and explain and justify assertions based upon evidence and, in the process, sense the spirit of science" (Hofstein & Lunetta, 2004, p. 30). This style of authentic instruction may help ameliorate the "leaky pipeline" often discussed in STEM education in which qualified candidates (often women and underrepresented minorities) stop pursuing STEM careers for a wide variety of reasons (Blickenstaff, 2005). Even for non-scientists, authentic scientific inquiry activities advance goals of scientific literacy by which students can understand the nature of science and become more informed citizens (DeBoer, 2000).

For students to become more interested in science careers or to identify as "science people," a shift in their identity must take place. While learning content knowledge is always a goal of science curricula, enabling students to adopt authentic cognitive and social practices that scientists utilize should be of equal importance. Virtual environments can situate science learning in a real-world context with an authentic problem that provides opportunities for learning as well

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Color versions of one or more of the figures in the article can be found online at www.tandfonline.com/vjxe.

as identity exploration as a scientist (Barab, Gresalfi, Dodge, & Ingram-Goble, 2010; Khan, 2012). While this identity shift is often hoped for in authentic scientific inquiry, it is rarely measured directly or set as the focus of a study. As immersive virtual worlds and games for learning become more prevalent in all subjects, more opportunities to engage in learning as identity exploration will present themselves.

This study utilizes a mixed methods approach where qualitative interview findings are compared to and contrasted with quantitative survey data, collected during a larger study of a recent implementation of an immersive virtual world-based science curriculum. This combination of methods allows for a triangulation of different sources of data, helping to accurately capture any shifts in students' identity over the course of the curriculum across several constructs, explore what characteristics of the curriculum facilitate this exploration, and see how well the survey findings reflect the more nuanced nature of the interviews.

Related research

Science identity, interest, and self-efficacy

Science identity, or "self-perception," refers to how someone sees science in relation to who they think they are, or in other words whether they identify as a "science person" (Harazi, Sadler & Sonnert, 2013). This identity is closely related to several non-cognitive aspects of science learning, including sense of belonging, interest in science or particular fields of science, and self-efficacy or beliefs about one's ability to learn or perform well (Trujillo & Tanner, 2014). Science identity has seen a recent surge of interest in the scholarly literature due to economic concerns involving diversity and lack of interest in STEM careers, as well as concerns about stereotype threat which may impede many students from pursuing science due to negative stereotypes regarding their abilities (Steele & Aronson, 1995). Even among undergraduate students in STEM majors, underrepresented minority students and women hold low self-perceptions and are less likely to identify as "science people" than white men (Harazi, Sadler & Sonnert, 2013). Low levels of self-perception and self-efficacy have been identified as barriers to persisting with science careers and study particularly for underrepresented students who have an early interest in science (Aschbacher et al., 2010).

Authentic and situated science learning

However, education interventions and experiences can be designed to help foster positive self-perception and science identity. Middle school interest in STEM subjects is a strong predictor of STEM interest post-high school (Sadler, Sonnert, Hazari, & Tai, 2012), yet many middle schoolers already have low perceptions about their science ability and identity (Aschbacher et al., 2014), suggesting middle school science interventions can have an important impact on students' academic trajectories. One challenge in improving science interest and self-perception is that lessons often focus on memorization and "cookbook"-style lab activities, failing to mirror scenarios real scientists might face. Designing education with authentic scientific inquiry would give students "knowledge and understanding of scientific ideas, as well as an understanding of how scientists study the natural world," holding promise for increasing students' self-efficacy and self-perceptions (National Research Council, 1996, p. 23). Teaching through authentic scientific practice also aligns with situated learning theory, which contends that learning cannot take place outside of the context where that skill is used, and typically takes place in a community of practice where members can learn from each other and develop their identity (Brown, Collins, & Duguid, 1989; Lave & Wenger, 1991). Having authentic science learning opportunities and having connections to others in science is an important factor in helping young people persist into STEM education and careers by helping build their identity, self-efficacy, and interests (Aschbacher et al., 2010).

Promise of virtual worlds for authentic and situated learning

Authentic inquiry and situated learning opportunities are difficult to implement and assess in a traditional classroom setting. Inquiry and problem-based activities require sufficient support to maintain motivation, reduce cognitive load for learners, and facilitate collaborative learning in complex domains (Hmelo-Silver, Duncan, & Chinn, 2007). Many teachers' attempts at these activities result instead in simplistic inquiry tasks, engaging less complex cognitive processes and utilizing less powerful epistemologies than real scientists employ (Chinn & Malhotra, 2002). However, virtual learning environments are promising alternatives, which provide a wide variety of simulated settings in which to situate the learning of any subject, complete with interactions with simulated people, objects, and processes as well as with other participants, and in which supports can respond dynamically to input from the users (Dawley & Dede, 2014).

Virtual environments are therefore well-suited for providing "thick" authenticity with activities that are personally meaningful to learners, relatable to the real world, engage students in thinking in the modes of a certain discipline, and provide opportunities for reflection (Shaffer & Resnick, 1999). In science education, virtual worlds can situate users with non-player characters (NPCs) that emulate a community of practice through interactions with expert scientists and stakeholders whose perspectives are difficult to convey in the decontextualized classroom. Games and other simulations can synthesize the "situated understandings, effective social practices, powerful identities, and shared values that make someone an expert" (Shaffer, Squire, Halverson, & Gee, 2005, p. 107). Virtual worlds are also uniquely able to let students interact with authentic environments not otherwise possible in the classroom, enabling a powerful distribution of knowledge in simulated real-world contexts and settings (Greeno, Collins, & Resnick, 1996).

Virtual worlds and identity exploration

These more authentic and situated learning opportunities therefore also hold promise for improving students' self-perceptions and identification with science by allowing students to investigate authentic science problems, trying on new identities as scientists. This kind of identity exploration through personal computers and virtual worlds has been an area of interest since digital technologies emerged (Turkle, 1984; Kafai, Fields, & Cook, 2010); however, science identity is rarely the focus of studies on virtual worlds and games for science education. The theory of transformational play describes how games can position person, content, and context to lead to deep, meaningful learning (Barab et al., 2012). By allowing students to try on new identities and tackle problems they could not otherwise do, games for learning can empower students and show them new possibilities for their futures.

Research using the Projective Reflection (PR) framework has explored the connection between identity exploration and such immersive learning environments, building off work on projective identities in entertainment games and theories of motivation in learning (Gee, 2008; Kaplan, Sinai, & Flum, 2014; Shah, Foster, & Barany, 2017). Foster et al. (2018) analyzed three immersive virtual worlds to identify features that support identity development within the PR framework. They found that the different environments' real-world problems and contexts connected to students' lives helped facilitate interest and valuing, and role-playing along with presentations supported students self-perceptions and self-definitions. They also identified ways in which the virtual worlds supported students' knowledge, self-organization, and self-control through scaffolding student exploration, feedback between the learner and the world, and through both self-regulated action and socially co-regulated actions with peers and mentors. In general, however, they found the virtual worlds provided fewer supports for student interest and self-perceptions than knowledge and self-control. This work to date on how identity exploration is operationalized within virtual worlds thus raises questions about how realize the potential benefits of more authentic and situated learning in virtual worlds to increase students' self-perceptions, self-efficacy, and interest in science that may lead to more students identifying with science.

EcoXPT curriculum

EcoMUVE, the original ecosystem science curriculum designed by our group, is a multi-user virtual environment-based curriculum for middle school science classes that teaches students about ecosystems and causal patterns. In the "Pond" module, students explore a virtual representation of a typical pond and can collect observational and water quality data on it over the course of two simulated months. After witnessing all the large fish in the pond die off at the end of the two-month period, students are then tasked with figuring out what killed the fish. Use of the curriculum resulted in significant student gains in ecosystem science knowledge and in causal understanding (Kamarainen et al., 2012; Metcalf et al., 2013; 2018). Beyond content gains, studies exploring changes in student non-cognitive dimensions via surveys found that students became more self-efficacious regarding conducting authentic scientific tasks and that students with a strong science identity were more interested in science after the curriculum (Chen, Metcalf, & Tutwiler, 2014). After participating in the curriculum, students' self-efficacy increased with regard to scientific inquiry and stronger initial science identity led to higher efficacy gains. Kolodner, Said, Wright, and Pallant (2017) implemented EcoMUVE while deeply studying case study pairs, noting specific affordances in the environment that provided identity, interest, and competency entryways that encouraged students to explore these three dimensions of the curriculum from the start.

Our newly finished curriculum, EcoXPT[1], builds off the Pond module of EcoMUVE and adds experimental tools to the virtual world, based on real techniques used by ecosystem scientists. These include comparison tank experiments to test the interactions between different factors at the pond and tolerance tank experiments to see what is actually lethal to the fish. By emphasizing the tools and inquiry practices of real scientists, the curriculum is designed to promote deeper learning that can potentially prepare students for the modern job market by giving them a case-based, open-ended task that can link to personal passions and their everyday lives (Dede, Grotzer, Kamarainen, & Metcalf, 2017), and therefore may have a larger impact on dimensions of students' science identity than previous implementations of EcoMUVE. Any potential changes in student self-efficacy, science identity, and interest in science have not yet been explored with EcoXPT.

Research questions

Our research questions for this study are as follows:

1. How much, if at all, does the EcoXPT curriculum foster science identity exploration and change?

We believe that EcoXPT is well-suited to engage students in questioning their interests, what they value, and what the role of a scientist entails. The curriculum was specifically designed to go beyond teaching content and to model what being a scientist is actually like. This will likely provide ample opportunities to engage with these aspects of Projective Reflection that are often neglected in science instruction.

2. How do students describe their own science identities and what it means to be a scientist or a "science person?" How did students perceive their experience with EcoXPT, and do they describe changes to the way they think and feel about science and scientists?

We predicted that engaging in the immersive and authentic world of EcoXPT will increase students' understanding of scientists' work, and thus they will be more likely to self-identify as scientists. We captured students' descriptions of what makes someone a good scientist, how they perceive themselves in relation to science, and how they may or may not consider science in their future careers. We anticipated that students will have increased interest in ecosystem science and science-related careers as a result of the agency and relevance afforded by EcoXPT.

3. How do students' descriptions of their science identities and shifts in interests and self-efficacy through interviews illuminate patterns identified from the surveys, and how do the qualitative and quantitative data support on contradict each other?

The purpose of the survey measures is to capture broad shifts in self-efficacy and student interest in learning more about ecosystem science on average across students who participated in EcoXPT. However, the interviews allow students to more thoroughly describe their thoughts about science and how it relates to their identities. We aimed to identify potential underlying mechanisms that could explain any changes observed in these non-cognitive dimensions of the survey, as well as triangulate the quantitative and qualitative data. While neither the surveys nor the interviews measured identity exploration explicitly, we aimed to understand how our measures of self-perception, interest, and self-efficacy may relate to changes in identity through students' descriptions in the interviews.

Method

During data collection for a larger comparison-curriculum study of the virtual environment-based curriculum, this study was conducted to explore the extent of science identity change taking place and how well our survey captures the shifts in student thinking about science as it relates to their sense of self. Specifically, we aim to examine mean shifts in the constructs addressed in our surveys and compare these shifts to the qualitative findings unearthed during our interviews with students. We utilized a mixed methods approach due to the iterative and cyclical nature of our analysis, in which both theory from the literature as well as observation during implementation informed our study design. Our approach could be characterized as pragmatic and methodologically eclectic, "selecting and then synergistically integrating the most appropriate techniques … in order to more thoroughly investigate a phenomenon of interest" (Teddlie & Tashakkori, 2011, p. 286). In our case, the phenomenon of student identity change within in a virtual world could be captured quantitatively via survey instruments measuring the change in how students expressed their self-efficacy, science identity, and interest before and after participating in the program, as well as qualitatively by asking a smaller number of students to elaborate their subjective experiences within the program and illuminate some of the trends captured by the survey items. This enables our findings to speak to the average changes in students' non-cognitive dimensions, while also allowing a deeper dove into the mechanisms and student experiences that can explain those patterns. Additionally, comparing the qualitative and quantitative allows us to triangulate our findings and evaluate the relative strengths and weaknesses of the methods used. For example, the survey is easy to administer at scale and has sufficient reliability and validity results from pilot studies, but it may not capture the totality of the identity shifts students experience during the course of the curriculum. Our methods combine quantitative and qualitative data that were collected and analyzed concurrently, giving both sources equal weight and informing each other's interpretation (Johnson & Onwuegbuzie, 2004).

Participants

The study included three teachers at the same school in a high socioeconomic status (SES) suburban district in the northeastern United States. Each teacher used our curriculum in two of their 7th grade science classes, a general subject that included an ecosystems unit in the spring. There were 126 students total in our sample (20-22 students in each class) ranging in age from 12 to

13 years old. Students were grouped by the teacher in teams of 2-3 (n = 63 groups). The study was conducted with Institutional Review Board approval, as well as parent and student consent to collect research data. All teachers had prior experience with the curriculum and had pilot tested it during the previous year.

Treatment

Teachers implemented the curriculum over thirteen 50-minute class periods. A typical day of the lesson plans consisted of brief instruction by teachers at the beginning of the period followed by student-led inquiry activities using the virtual world. During this portion, the teacher walked around to provide guidance and direction to groups. Students used the software on the school's Macintosh laptop computers, with each pair of students sharing a computer. While not explicitly encouraged in the lessons, different groups were free to communicate with each other during their investigations. The final day of the curriculum had students present a concept map showing the causal connections between various biotic and abiotic factors in the ecosystem. To orient them to the curriculum, teachers either received group professional development or one-on-one guidance that walked them through the program, and teachers were provided lesson materials for each day that included PowerPoint slides, videos, student handouts, and descriptions of warm-up and wrap-up activities or discussions.

Measures and instruments

All students were given a pre- and post-survey as part of a blended assessment strategy to determine the efficacy of the curriculum (Thompson et al., 2016). Assembled from a mixture of pre-validated instruments from science education literature, the survey contained six constructs: non-cognitive dimensions (self-efficacy, science identity, and interest), ecosystem science content, understanding of causality, correlation versus causality, use of experimental methods, and epistemology of science. The survey was administered electronically via Qualtrics during science classes immediately preceding and following the implementation of the curriculum. Complete pre-post survey data were received for 82% of students due to student absences at the pretest or post-test, or due to denial of parental permission to analyze their data. Survey data for $n = 103$ students were analyzed. Survey gains were calculated by taking the average post score minus pre score for each participant and are summarized in Table 1. The self-efficacy sub-construct of the non-cognitive survey consisted of 7 Likert scale questions adapted from a prior survey designed and validated for a prior virtual world-based ecosystem science curriculum (Chen et al., 2014) and achieved a Cronbach's alpha of 0.89 on the current sample's pre-survey. The science self-perception sub-construct consisted of 4 Likert scale questions from a study of deep engagement in a high school biology curriculum (Pugh, Linnenbrink-Garcia, Koskey, Stewart, & Manzey, 2010) and achieved a Cronbach's alpha of 0.94 on the current sample's pre-survey. The science interest sub-construct was 4 Likert scale questions taken from the interest/enjoyment subscale of the Intrinsic Motivation Inventory (Deci, Eghrari, Patrick, & Leone, 1994) and achieved a Cronbach's alpha of 0.90 on the current sample's pre-survey. The complete non-cognitive survey is included in supplementary materials, and sub-construct summary statistics can be found in Table 2.

Brief, semi-structured interviews were conducted with 14 students across the six classes included in the study following their completion of the curriculum. Students were identified by teachers based on their prior consent and parental permission, as well as their willingness to be interviewed. Interviews lasted between 10 and 20 minutes. Twelve students were interviewed individually, and two students were interviewed together at their request (pseudonyms Ben and Kyle). The study authors conducted each interview using a protocol designed to elicit student experiences that were consistent with literature from identity exploration and virtual worlds

Table 1. Summary statistics of survey performance.

Statistic	N	Mean	St. Dev.	Min	Pctl(25)	Pctl(75)	Max
non_cognitive _pre	95	3.773	0.852	1.867	3.167	4.200	5.600
methods_pre	98	3.059	0.441	1.733	2.800	3.333	4.000
content_pre	94	0.707	0.187	0.167	0.583	0.833	1.000
corrcaus_pre	99	0.604	0.185	0.208	0.479	0.750	1.000
causality_pre	95	3.243	0.376	2.400	2.975	3.500	4.600
epistemology_pre	91	2.266	0.424	0.875	2.062	2.625	3.000
non_cognitive _post	101	3.928	0.928	2.133	3.200	4.600	6.000
methods_post	102	3.276	0.521	1.000	2.950	3.667	4.000
content_post	101	0.721	0.199	0.250	0.583	0.833	1.000
corrcaus_post	102	0.686	0.205	0.167	0.542	0.875	1.000
causality_post	102	3.152	0.430	2.000	2.900	3.350	5.200
epistemology_post	99	2.347	0.439	0.750	2.062	2.625	3.125
non_cognitive _gains	93	0.204	0.755	−2.600	−0.133	0.533	3.000
methods_gains	97	0.216	0.518	−1.733	−0.067	0.600	1.333
content_gains	92	0.022	0.156	−0.500	−0.083	0.167	0.333
corrcaus_gains	98	0.089	0.176	−0.750	0.000	0.208	0.458
causality_gains	94	−0.098	0.413	−1.100	−0.400	0.150	1.400
epistemology_gains	89	0.097	0.433	−1.250	−0.125	0.375	1.375

Table 2. Summary statistics of non-cognitive survey sub-construct performance.

Statistic	N	Mean	St. Dev.	Min	Pctl(25)	Pctl(75)	Max
selfperception_pre	95	3.189	1.495	1.000	2.000	4.125	6.000
selfefficacy_pre	95	4.250	0.960	1.857	3.429	5.000	6.000
interest_pre	95	3.521	0.745	1.500	3.125	4.000	4.750
selfperception_post	101	3.252	1.614	1.000	1.750	4.500	6.000
selfefficacy_post	101	4.573	0.992	1.000	4.000	5.286	6.000
interest_post	101	3.475	0.917	1.000	3.000	4.000	6.000
selfperception_gains	93	0.110	1.144	−3.000	−0.500	0.500	5.000
selfefficacy_gains	93	0.367	1.030	−4.714	0.000	0.857	3.429
interest_gains	93	0.011	0.802	−1.500	−0.500	0.500	2.250

(Kaplan et al., 2014) and with previous findings from EcoMUVE (Chen et al., 2016). In order to delve into themes captured in the survey responses, interviews were semi-structured, and the interviewers were flexible in their line of questioning, probing students' answers for more detail or to discuss other relevant topics. While students had consented to be interviewed at the start of the curriculum, interviewers additionally reviewed information related to how interviews would be used and affirmed students' consent before recording. The protocol is included in supplementary materials. All names used in this paper are pseudonyms.

Each interview was transcribed and coded by the authors utilizing an iterative, hybrid emic and etic thematic coding procedure (Creswell, 2012; Rubin and Rubin, 2005). Initial listening notes and coding were organized by etic themes identified in the literature, such as student agency, motivation and interest, and identifying as scientists. Emic codes were then generated in discussion with four additional members of the project team who undertook grounded coding in order to describe emergent themes from students' experiences. The authors created a codebook, included in supplementary materials, and each coded all transcripts independently. Coders averaged 96% agreement across all codes and transcripts. Discrepancies included some instances in which one coder included surrounding text and the other did not, or in some instances where the code was interpreted differently. Agreement was reached between the authors by identifying passages with discrepancies and discussing their application to the codes, refining the code description, and agreeing on a final coding of transcripts that was used to identify broad themes as the main findings of the analysis. This thematic analysis is presented in the results section.

Table 3. Summary of multilevel regression models for affect and self-efficacy.

Results

	Dependent variable:			
	non_cognitive _post		selfefficacy_post	
	(1)	(2)	(3)	(4)
Non_cognitive _pre	0.683***	0.711***		
	(0.086)	(0.100)		
Attendance		0.158		0.513
		(0.990)		(1.001)
Engagement (low)		0.295		0.246
		(0.290)		(0.285)
Engagement (med)		0.170		0.015
		(0.194)		(0.196)
Reading (low)		−0.114		−1.881
		(0.352)		(1.424)
Reading (med)		−0.292		−2.107***
		(0.177)		(0.725)
English Lang. learner		0.172		0.116
		(0.315)		(0.340)
Has IEP plan		−0.166		0.002
		(0.283)		(0.296)
selfefficacy_pre:readingL				0.309
				(0.367)
selfefficacy_pre:readingM				0.410**
				(0.167)
selfefficacy_pre			0.504***	0.280**
			(0.083)	(0.123)
Constant	1.396***	1.190	2.514***	3.188***
	(0.333)	(1.033)	(0.362)	(1.091)
Observations	93	93	92	92
Log Likelihood	−98.869	−96.572	−103.981	−97.617
Akaike Inf. Crit.	207.737	217.144	217.963	223.234
Bayesian Inf. Crit.	220.400	247.535	230.572	258.540

*$p < 0.01$.
**$p < 0.05$.
**$p < 0.01$.

We provide evidence of the validity of our findings not only based on the high agreement between coders but also by triangulating findings with qualitative and quantitative data. We sought discrepant evidence within our interviews that challenged the themes we identified, subsequently revising them (Maxwell, 2010). Additionally, we open our data to the reader by presenting as many direct quotes as possible for others to judge bias in our interpretation and draw their own conclusions.

Results

Quantitative results

In our analysis of the survey findings, we conducted paired *t*-tests to answer whether student gains on the non-cognitive survey were statistically significant and what sub-constructs were most changed by the curriculum. We then utilized pairwise *t*-tests to determine if scores or gains on any of these sub-constructs varied by teacher or class. We next conducted two-way analysis of variance (ANOVA) testing with interaction terms to see if any student-level covariates might have impacted student gains, then we fit a multilevel model to predict student non-cognitive gains for the diverse range of students that might interact with our curriculum. Throughout this section, our analyses increase in complexity. We feel that this eases the reader into the analysis of our data and scaffolds our eventual findings. For those who wish to see the final results quickly, the most important findings from our quantitative analyses are shown in Figure 4 and Table 3.

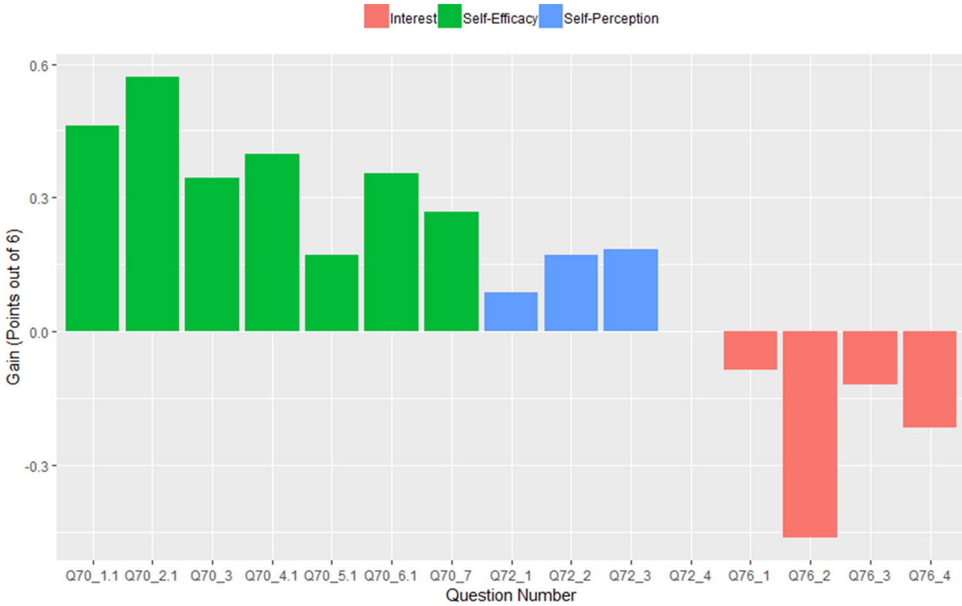

Figure 1. Gains on the non-cognitive survey by question and construct.

To get a sense of the general increase in student scores on the non-cognitive survey, we used a paired *t*-test to examine the statistical significance of student gains. On average, students gained 0.20 points out of 6 (a 3.3 percentage point increase) from pre- to post-survey across all sub-constructs ($t(92) = 2.60$, $p = 0.011$, Cohen's $d = 0.18$). By looking at gains on the sub-constructs individually, we find that the non-cognitive score gains are driven by increases in self-efficacy (Figure 1). When examining gains by subconstruct, students on average gained 0.37 points out of 6 (a 6.1 percentage point increase) on the self-efficacy sub-construct ($t(92) = 3.44$, $p < 0.001$, Cohen's $d = 0.33$), while gains on the self-perception and interest sub-constructs were not statistically significant. The largest gains were seen on questions asking about students' confidence that they could "do the kinds of things scientists do," "investigate the relationships between organisms and their environment," and "investigate what causes change in an environment," suggesting students learned most regarding how ecosystem scientists work. Pairwise *t*-tests revealed that pre-scores, post-scores, and gains did not differ significantly by teacher or by class. The lack of teacher effects on gains were confirmed via ANOVA models with teacher as a categorical variable and via Tukey's honest significance testing. Neither scores nor gains statistically significantly differed by teacher across any sub-construct.

Next, we asked whether a student's gain on the non-cognitive score depended on that student's pre-score on any other construct. We used a two-way ANOVA to test how non-cognitive gains interacted with initial scores across all survey scales. To model this effect and any possible interactions, a series of models were fit with a subconstruct's post-score as the independent variable and that subconstruct's pre-score as an independent variable along with their pre-score on a different survey (e.g., the science content knowledge survey). As expected, students non-cognitive pre- and post- scores are highly correlated ($F(92) = 13.51$, $p < 0.001$), however the interaction term between initial scores on the other constructs and initial scores in non-cognitive domains were not statistically significant. We found that non-cognitive gains did not statistically significantly differ by initial student knowledge of science content, causality, epistemology, or correlation versus causation. The lack of any statistically significant interaction terms indicates that the relationship between non-cognitive pre- and post-scores does not depend on any other constructs explored by our survey.

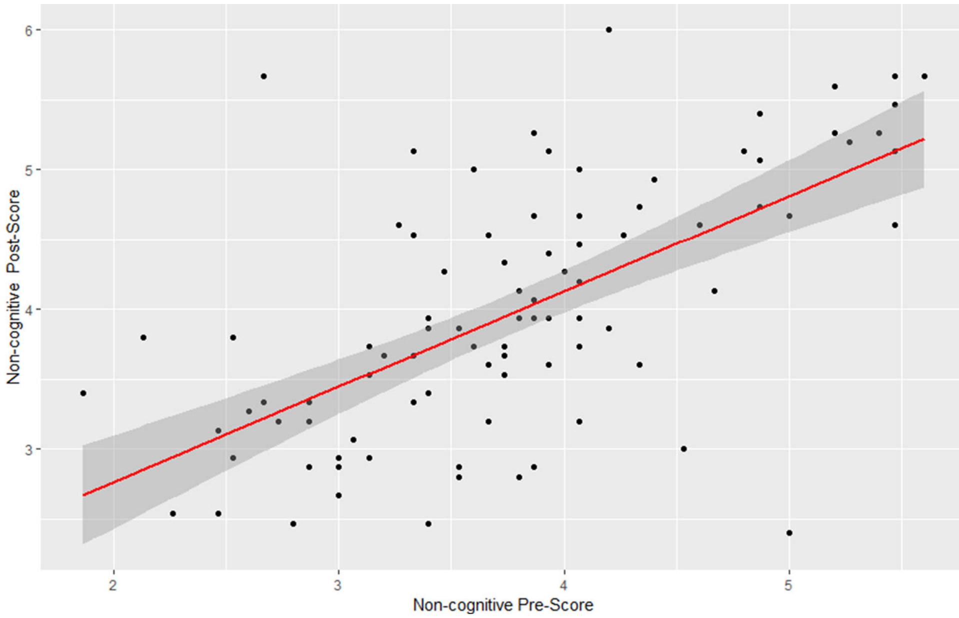

Figure 2. Non-cognitive post-scores versus affect pre-scores. Shaded area represents standard error.

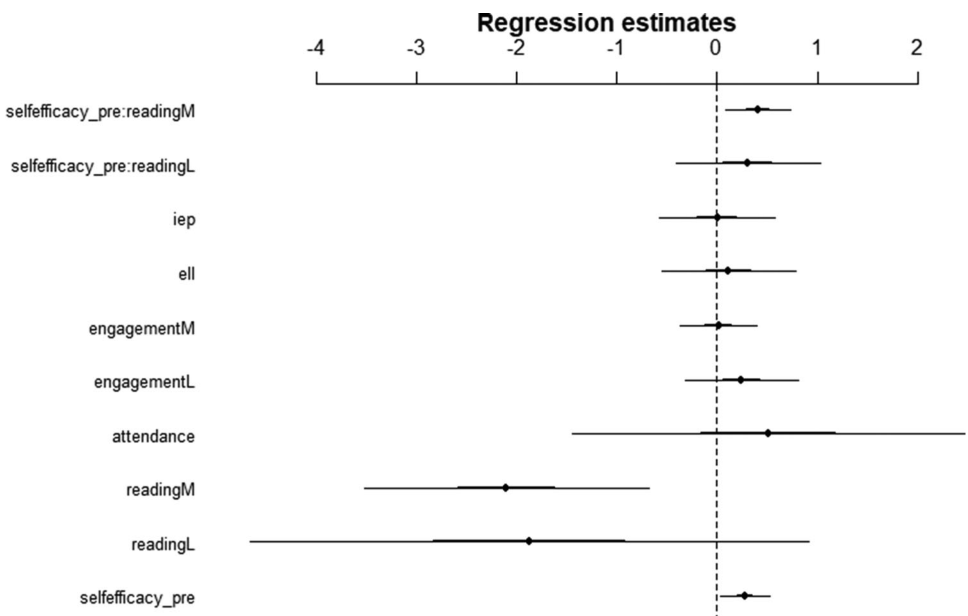

Figure 3. Regression estimates for student-level covariates.

To examine how gains differ based on initial non-cognitive states and to explore the possibility of interaction effects more deeply, we fit a three-level random intercept multilevel model (students in groups in classes) to predict non-cognitive post-scores based on pre-scores. Also included in the model were student-level covariates pertaining to attendance during the curriculum, reading level, English language learner (ELL) status, and the presence of an Individualized Educational Plan (IEP) or a 504 plan. On average, a one-point increase in pre-score corresponded

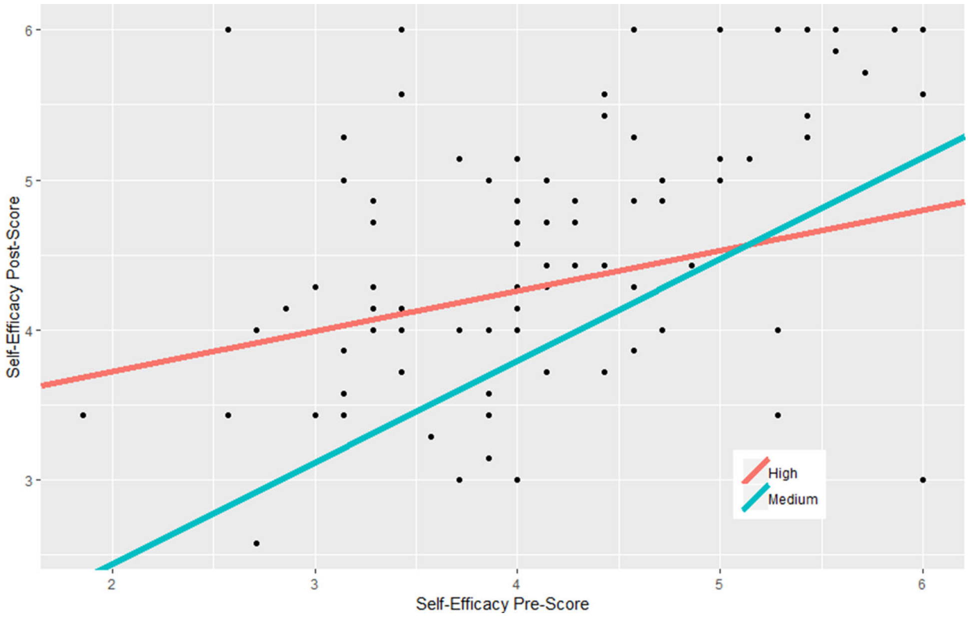

Figure 4. Self-efficacy post-scores versus self-efficacy pre-scores for high and medium readers.

to a 0.71-point increase in post-score with all other factors held constant ($t = 7.12$, $p < 0.001$; see Figure 2). In general, students who had lower levels of science interest and efficacy increased more than those with higher levels at the outset. None of our covariates significantly impacted the relationship between pre-score and gain (see Figure 3). No interaction terms were found to be statistically significant with the non-cognitive pre-score, indicating that overall non-cognitive student gains did not vary by initial knowledge of other constructs measured by the survey nor by any student-level covariates.

Because self-efficacy gains drove the increases in overall changes in non-cognitive, we fit a similar multilevel model on solely the self-efficacy construct of the non-cognitive survey to explore how our covariates and interaction terms might affect gains on the portion of the construct found to be most effective. On average, a one-point increase in self-efficacy pre-score corresponded to a 0.28-point increase in post-score for "high" readers with all other factors held constant ($t = 2.34$, $p = 0.026$). However, this main effect was qualified by an interaction with participant reading level. "Medium" readers earned on average 2.1 fewer points on their pre-surveys than "high" readers (t = -2.92, $p = 0.0068$) and their post-score increased 0.40 points more for every one point increase in pre-score ($t = 2.48$, $p = 0.019$), with all other factors held constant (Figure 4). The relationship between low reading level and post-score was not statistically significant due to a small amount of low readers in our sample (8 out of 92 students with complete self-efficacy pre- and post-scores.) Model statistics are summarized in Table 2.

Qualitative results

Here we examine interview findings around three main themes. First, we describe how students changed the way they think about science and what scientists do, and how EcoXPT helped to demystify how scientists work and think. Second, we present how students talked about what makes someone good at science or a good scientist, including the skills, ways of thinking, and passions required to be a "science person." Third, we discuss how students did or did not identify themselves as future scientists and science people, and the nuanced ways students connected their abilities, interests, and career aspirations. Finally, we explore how students perceived their agency within the program and its relevance to their lives as important factors to support identity exploration and projective reflection.

Participating in EcoXPT served to demystify how scientists work and think

When asked to describe how participating in EcoXPT changed the way students think about science and the work of scientists, most students described changes in what they thought scientists did for their work and the ways in which scientists approach problems they want to solve. The clearest instance of this was the way Samuel described the experience of being in a scientist's shoes, and how that opened him up to the work of professional scientists:

> "Overall it was really cool and it really helped me learn how scientists … It put me in a position like I was a scientist. I felt like I was a professional scientist, like I was researching ecosystems … I enjoyed the part where you got to experience stuff, not just in the lab but you could go outside and try to find evidence for your conclusions in the game … I used to think that all scientists were in labs with lab coats but now I think that they actually experience it themselves and that's one of the big parts of being a scientist."

Other students did not so explicitly discuss being in the position of a scientist, but many students discussed the tools and approaches that they now understand scientists use, such as half of the students interviewed who mentioned that they did not previously know that scientists conduct experiments or do research outside in real ecosystems. For example:

> Daniel: "[I] used to think scientists used to only do experiments in the lab but now I know that they go to the outside world and do experiments in nature."

> Maya: "Yeah, first of all, I learned that scientists didn't just do experiments indoors, they went outdoors and looked around and tried to find answers to clues and things."

Relatedly, students emphasized the hands-on nature of scientists' work in relation to the tools they use and the experiments they conduct:

> Kyle: "Yeah it's more hands-on, I guess. In the lab it's more like what I thought it was but the stuff where you go around and take the population data and stuff. I didn't really think that part was science but it is."

> Mike: "Yeah it changed the way I think about it since it made me realize how many hands-on jobs there are. And what you can do, and it's solving problems not just conducting research and handing the research to someone else."

Students also mentioned specific tools they were surprised to learn that ecosystem scientists used and which they enjoyed using themselves. This included the fact that scientists collect and graph data, that they investigate across time, and that they use tolerance tanks in which they experiment with different factors that may harm fish. For example:

> Maya: "They use tolerance tanks, I didn't know they use tolerance tanks … the fact that the fish died was overwhelming."

> Kyle: "I didn't exactly know that the collecting data was part of being a scientist."

> Jenny: "I had an idea, of how they would make graphs and put together things to find out a problem, or a solution, to a cause. I kind of had an idea, but I got deeper into the idea when we did this."

In addition to where and how scientists work, students also discussed how scientists think and approach problems they want to solve. In particular, students expressed their surprise at the amount of experimentation and work scientists have to do in order to test their hypotheses and solve problems, often due to multiple possible explanations:

> Simon: "Scientists don't know all the answers, it's not like they are taking it out of a magic hat. They really have to work hard to figure things out. I used to think the scientists were any random smart person."

Nicole: "I think that I didn't realize they had to test exactly everything to really look at which can affect what. I somehow in my mind was thinking that the first thing they tested worked out and I hadn't really looked at that before and I think I may have been able to realize that wasn't true if I'd really paid attention but EcoXPT is what made me pay attention to that."

Emma: "I thought science was just make hypotheses and just did experiments but I found out that they do a lot of thinking and they have to do a lot of stuff to get the right idea … I learned many different methods that scientists use to observe. I thought they use just one or two and I learned … a ton of different methods to think deeply and observe deeply what happens."

Mike: "[I used to think] science is easy and it's more like one branch, and that it only goes one direction. Now I'm more realizing that it's able to go off in different hypothesis, hypotheses, different areas you can go to."

Other students gave more mixed answers about how their thinking changed regarding science and scientists. For example, Amina initially focused on the content she learned from the program about what affects fish in the environment. When talking about the job of scientists, she explained that she already thought scientists' jobs were to find evidence for "new ideas about the world," but that EcoXPT helped her confirm this is what they do, and that she didn't know they "learned new things along the way." Three other students said "not really" initially when asked if they see anything differently about science after participating in EcoXPT, but subsequently mentioned things they learned such as how scientists do experiments in the outdoors. This implies there may have been variation in how EcoXPT was experienced by students and what they took from the program. Some who said they did not change their views on science or think differently about how scientists work were those who said they already knew some of the things others mentioned learning about ecosystem science, and some were more focused on content they learned within the curriculum. However, overall most students described what they learned about how scientists work and think.

Students describe being good at science through knowledge, skills, ways of thinking, and passion

When asked to describe what makes a student or a scientist good at science, students described several characteristics they associate with being a "science person." Some of these characteristics were based on the types of knowledge or skills that a scientist must have. In addition, most students also emphasized being a good scientist as a way of thinking and approaching problems through experimentation and hard work. This may be characterized as students being mastery-focused and having a growth mindset orientation toward being good at science (Dweck, 2017). Finally, some students also emphasized having a passion or strong interest in science as a crucial characteristic of good scientists.

Several students talked about people who are good at science as those who are smart, who have studied something, or have memorized a lot about a specific topic. When asked what makes someone good at science, these students responded:

Michelle: "they are good at science … [*What makes them good at science?*] Being smart."

Amina: "I think they have just learned about many different parts of science, different chemicals or certain parts to it, or they have practiced things like EcoXPT many times."

Leila: "They have to be able to draw their own conclusions from evidence, they have to study a lot. They have to be good at memorizing stuff and thinking out of the box of different things.

Many students discussed being good at science from a growth mindset perspective, emphasizing that being good at science takes hard work and an approach to solving problems or specific ways of thinking, rather than simply being smart. For example, when asked what makes a person good at science, these students described working hard over being smart:

Sasha: "You don't have to have a high IQ or anything like that. You just have to be interested and willing to pursue it on your own … "

Simon: "They really have to work hard to figure things out. I used to think the scientists were any random smart person."

Students also emphasized ways of thinking and approaching problems, being curious, creative and persistent:

Emma: "They think deeply. They don't just take a very quick glance at something and take down a quick note. They look at it really deeply and they think about what's happening."

Nicole: "If they're curious about learning different things and they really try to find all the information, if they are able to connect different things to each other and sort of build a web that explains how things work, then that makes them a scientist."

Mike: "Well, creativity … somebody that is really creative."

Maya: "Finding solutions to problems and not giving up"

Daniel: "If they can understand how to do it, like how to make inferences I think they could be good."

James: "Wanting to know more … Having questions that they want to answer … Instead of just saying "I wonder why this is true," you can actually try and find the answer by looking it up and asking people.

Sasha: "I think the core thing is being able to ask questions and having good questions be answered with more questions."

Some students also emphasized the role passion and interest play in being a scientist or being good at science in tandem with other skills and ways of thinking. For example, Sasha said being good at science takes "really just kind of having a passion," in addition to working hard and having good questions to answer. Michelle identified people who are good at science as those who are smart and said "people who are good at science are people who like science." Jenny emphasized having a passion for science along with studying hard, and discussed the way role models and adults may play in whether a student is a "science person":

"They probably study it a lot, and have a passion for it, and are into it. They might have a mom or a parent who is into science who talks to them about science and that's why they're into it. Kind of like how my mom is a PT and always talking about working out and all that, and I'm into sports and all that … I feel like school and your parents have something to do with what you like."

The ways in which students describe what being good at science means to them helps reveal the varied ways young people may also define their identities as scientists. Their discussion shows that how students perceive science people and scientists entails a nuanced combination of skills and ability, ways of thinking, and passions. Importantly, many students exhibited a growth mindset, discussed science as hard work, and articulated an aptitude for science as a way of thinking rather than a fixed skill. Increases in students' self-efficacy may be indirectly related to their identities through how they perceive themselves as good at science or capable of thinking like a scientist.

Students are more likely to say they are good at science than they want to do science

Having a science identity could mean identifying as someone who is good at science, likes science as a school subject, is a scientist, or wants to pursue a future career in science. In interviews, we asked students not only to describe what they think makes someone good at science, but also whether they would consider becoming a scientist themselves. While students discussed learning a lot about the work of scientists from EcoXPT, few students discussed the experience as having changed their affinity toward science. A number of students discussed their definite interest in science careers, largely those who had high interest in science prior to engaging in the curriculum. More students said they might consider science careers, and generally students described themselves as good at science and as enjoying science, whether or not they connected science with their future aspirations.

Most of the students interviewed expressed some interest or at least an openness to careers in science. However, only three students explicitly discussed the role participating in EcoXPT played in shaping their interests. For Nicole, she knew from her previous interests and the work of her scientist parents that she wants to be a scientist, and the curriculum helped spark an interest in her in studying nonliving influences in the environment in addition to living organisms. Maya discussed how, in addition to her interest in chemistry, EcoXPT helped pique her interest in biology and studying the environment as well. Amina discussed her aspirations to become an author but talked about her interest in incorporating science in her writing, and how EcoXPT made her like science more. When asked if they want to be a scientist, they replied:

> Nicole: "Yeah I even wanted to be one before this experiment. Both my parents are scientists and I want to look into biochemistry … [*Did anything change about what you want to study or do based on your experience here?*] I really have to look into the nonliving things because I've mostly been looking at plants and animals but there are so, so many other variables that come into this that I hadn't completely realized before."

> Maya: "It's an idea, maybe … Either a chemist or a biologist … well, EcoXPT kind of influenced me to want to learn more about biology and causes for things in nature happening, and animals."

> Amina: "Probably, like if I do- whatever I do I definitely want to include some part of science or math or something. I don't know if I want to be just a scientist but I want to have it be a part of it … [EcoXPT] definitely made me like science more. Science has never been my favorite subject but it was more fun … "

Other students discussed wanting to be scientists but did not point to EcoXPT enhancing or changing their aspirations, emphasizing their previous interests and dispositions toward science. Sasha talked about her interest in bees and desire to study bees, saying "I've always been interested in science"; she indicated that she found EcoXPT "very interesting … very educational," but it did not change her interest in science. Similarly, Daniel aims to be an astronaut and work as a scientist, but the curriculum didn't change what he wants to study or how he thinks about scientists. Kyle also wants to be a scientist, and emphasized science as his favorite subject, but features of EcoXPT did "not really" change his thinking about scientists, just that "it definitely helped me see what's happening."

More students talked about their enjoyment of science and described themselves as being good at science without necessarily aiming for a career in science. For some, this is because they see science as one of their interests in balance with other career goals or academic subjects. Four students talked about their interest in being a lawyer over working as a scientist, and two mentioned that they prefer other subjects. However, these students still expressed enjoyment in science and with EcoXPT, but perhaps not strongly enough to consider it as a career goal. For example, Ben described enjoying science and being good at it, but not as much as his desire to be a lawyer:

> Ben: [on ecosystem science in EcoXPT] "I probably wouldn't do it for a job, but it was fun … Maybe [I would be a scientist] … [but] I want to be a defense attorney for criminal justice … [Kyle and I] are both good at science and it's kind of fun."

Similarly, when asked if they wanted to be a scientist:

> Jenny: "Not really … I like science, but I wouldn't see myself being a scientist … I'm not bad [at science], but I don't love it. I love English and History, but [science] is not the worst thing."

> Michelle: "Well, I'm more interested in law, but science is cool … It's like math, you're always solving problems and I like solving problems … [but] it seems like a hard job."

> Simon: "I'm actually pretty set on being a lawyer because my dad is a lawyer and I really like when I listen to him talk about the law … [But] you never know, my career choice could change."

Despite their openness to careers in science and enjoyment of science class, students expressed a nuanced relationship between being interested in and good at science versus being a "science person." The students like Sasha and Nicole who affirmed they want to be scientists tended to describe themselves as good at science, having a passion for it, and having an interest in a science career. But for other students, they may be open to a career in science without necessarily claiming a passion for it, as they balance what they see as the most interesting academic subjects and careers in which they might be interested.

For example, Mike said he might consider working as a scientist and he thinks he is good at science but, when asked if he considers himself a science person, he responded, "yeah, although science isn't really too much my thing… it doesn't interest me as much as it interests other kids." Similarly, Michelle said she thinks "science is cool," but "I wouldn't really consider myself a science person… science isn't my best subject, I'm not great at it."

Even for Samuel, who clearly articulated that EcoXPT made him feel like he was a professional scientist and put him in those shoes, said "I haven't really thought of [being a scientist]," and that while he thought it could be an interesting job, "at this time I'm not really interested in science." This illustrates how students think about what their interests are, and that identifying with a specific subject or career aspiration may be quite ingrained, while they may be more flexible about enjoying or being interested in some aspects of a job or future study. An experience as short as EcoXPT may not be able to accomplish the former, but opening students' minds to being scientists may achieve a deeper interest in the long term. There is also evidence that some students do not have an interest in science, and EcoXPT did not change their interests. One student stated that she thinks science is difficult and complicated. When asked if she would want to be a scientist:

> Leila: "Not really, it's complicated and I'm not good at things that are very complicated… I feel like studying history would be really easy because you just have to learn facts, doing math you have to just memorize stuff, you don't have to think extra."

The student interviews reveal the nuanced ways in which students connect their abilities, interests, and career goals. On the one hand, it appears that students came into EcoXPT with strong feelings about their career goals and their orientation toward science. This is evident both from the students who see themselves as science people and future scientists as well as those who described the other subjects or careers they prefer over science, influenced by their interests and role models in their lives. However, they also discussed a complex relationship between their science ability and interests, implying that being good at science is one important factor in enjoying science among other options, but that seeing themselves as science people may require a strong passion as well.

Students felt a sense of agency within EcoXPT, and many perceived the curriculum as relevant for their future study or work

In addition to the ways in which students described what they learned about scientists, what makes someone good at science, and whether they are interested in science careers, we were interested in what features of EcoXPT and virtual worlds may help facilitate identity exploration. According to the projective reflection framework and triggering identity exploration, increasing students' agency by providing opportunities for self-organization and self-control as well as making learning relevant and connecting content to students' interests and real-world contexts are key mechanisms through which students may engage in identity change (Kaplan et al., 2014; Foster et al., 2018). When asked what they enjoyed about EcoXPT and what made it different from other curricula and assignments, students indeed pointed to their agency and ability to explore as important features. Additionally, students found different aspects of the curriculum relevant for their lives in terms of future study or careers, both in and outside science. These features of EcoXPT can help explain how affordances of well-designed curricula in virtual worlds can increase students' self-efficacy and understanding of scientists' work, and perhaps their identities as well.

In terms of agency, most students mentioned exploration and having greater independence when describing what they enjoyed most about participating in EcoXPT and what made EcoXPT different from other units and assignments they have done in science classes. For example, when asked what they liked or found interesting in EcoXPT:

> Sasha: "I really liked how we could go to different places and we had to figure out things on our own. Sometimes we got different things like we got to go into that blue house but we really had to figure out what would happen all by ourselves so we didn't have it all laid out for us all. We had an option."

> Daniel: "The free roam part, you can walk around and do the best stuff, if It feels like you're actually there."

> Leila: "I liked how we could take a couple days and look around with her partner and just make conclusions with ourselves instead of having someone micromanage us."

> Samuel: "It was exciting and fun, and I really liked it because every day I want to go to science class so I could use the computers and really explore the world of EcoXPT. It was really exciting because you could always find new things."

In addition to describing the independence and exploration within EcoXPT as one of the features they enjoyed most of the curriculum, students also identified the freedom they had to explore and experiment as an important difference between EcoXPT and its virtual world from other work they do in school and in science class. For example, when asked how EcoXPT is different from other assignments, or how what they can do in EcoXPT is different, students responded:

> Maya: "Usually we sit in class and learn about it, take notes, watch videos, but in EcoXPT we can actually explore and find out by ourselves."

> Simon: "it's not traditional where they are setting you up for a test. They're setting you up so that you can figure things out on your own. Not giving you all of the answers. They're letting you teach yourself."

> Sasha: "In other classes we aren't really able to explore things on our own. We have a path set out for us and we aren't really playing a game over time or trying to figure out what happened. You know what happened and then we have to figure out why or how."

> Jenny: "…for a math test for example they give it to you and you have to solve it. But what we would do [in EcoXPT], [the teacher] would give us a lesson on what we would be doing today and how to use the materials, she would show the materials, how to use the concept map. Then we did it, and we had our own thoughts about what killed the fish and we were on our own."

Additionally, students perceived many ways in which they could apply what they learned within EcoXPT to their lives, emphasizing the relevance of the curriculum to future academic work or potential careers. When asked what they would use that they had learned, a few students pointed to the content of the program, but more often students discussed the thinking moves that related to making observations and gathering evidence for their hypotheses. Students discussed using what they learned in future studies or classes, as well as in their aspirational careers, both those who want to be scientists as well as in other types of work.

Three students mentioned the specific content from the curriculum, emphasizing what they had learned about fish or the environment and how they may find this useful in their future if they need to know something related to a pond environment:

> Jenny: "Well maybe if we were… cleaning our community and we have a pond we know how to take care of it, and we would use it for probably school… we could go back to EcoXPT to see oh, there are the largemouth bass, the minnows, the bluegill fish, and we could look at all the plants. That could have something to do with school if we do that topic again."

> Michelle: "Well, I'll know more about fishes."

> Nicole: "I can definitely use all the things in the field guide to study the world around me, I think that will be very interesting. I want to do some sort of science club in high school so this information will help me there but I'm not sure I can think of something really different that this will help me with. I won't be able

to connect this to history … it would be harder to look into exactly what happened because you can't test the pH level in a pond that was 5000 years ago."

However, more students discussed some of the strategies and thinking moves they may be able to use in their future and in their lives. In particular, students mentioned some of the scientific reasoning skills they had learned for observing their environment more deeply, seeking evidence, and testing hypotheses:

Sasha: "Yes, definitely. I'll definitely use a lot of those deep seeing moves. I also really like how we could do comparison tanks and tolerance tanks. I thought that was very interesting. I thought the mesocosm was really cool."

Emma: "Observing what happens when I'm doing science class, what's happening in the real world so I can find out what surroundings … Evidence seeking."

Amina: "I think that the way I learned how to use evidence, to back up claims and where I can find certain things, that was really helpful. So I'll remember that … Maybe for other science projects or if I end up using science in my life, this helped me learn how to take evidence and put my reasoning with it."

Jenny: "if we're using a lab, and the graphs, we would know how to do it … If we were doing an experiment instead of doing it one day we would do it more than once. Because if you do it once it's not as accurate as doing it more than once."

Mike: "Like how to follow a solution path and figure out answers to a problem creatively. Since in EcoXPT it shared a bunch of stuff about the fertilizer and sewage, and then eventually when you were opened up to more options you learn more about the cause and effects and stuff … it would help you always want to learn more information before making guesses and hypotheses … like in math, if you're trying to solve a problem, if it's an open ended problem and you're trying to figure out what happened then there's different ways to take it."

Ben: "I mean all the evidence seeking, all those tools, I might use in any job or in school when you're reading an essay or something … [as a defense attorney] you would take evidence for a criminal case like from the dude's house and try to piece it together."

Notably, students perceived what they had learned as relevant for work within science as well as without. Like Ben, a few students who aspire to be lawyers mentioned the ways of using evidence as important for law. While Nicole failed to make a connection to EcoXPT with history, Mike pointed to the usefulness of problem-solving strategies he learned to math as well. Simon also mentioned using his understanding of ecosystems following EcoXPT as useful in his voting decisions and supporting policies to protect the environment. Additionally, Amina described a very creative application of what she learned to her interest in being an author:

"And so maybe I could write books that have to do with science. Not factual books, but fictional books that include parts of science … maybe if there was a story where someone lost someone in the pond, or an animal in the pond and they had to learn certain things to find where the animal could have been, and then they- learned more things about the pond."

Discussion

This study aimed to investigate the affordances of virtual worlds to improve students' self-perception, interest, and self-efficacy toward science in order to support more students identifying with science. Prior research in science identity has shown that these non-cognitive dimensions can be important predictors of studying and working in STEM fields (Hazari et al., 2013; Aschbacher et al., 2010), and that the affordances of virtual worlds to provide more scientifically authentic and situated learning opportunities could facilitate the kind of identity exploration that would increase students' perception, self-efficacy, and interests (Shah et al., 2017; Kaplan et al., 2014). In this study, we examined whether engaging in a virtual world-based curriculum impacted student identity, and how its features and design may or may not have supported students in this way.

In answering our first research question, whether students experienced changes in their science identities as a result of the EcoXPT curriculum and virtual world, we find mixed results. On average, we did not estimate a statistically significant difference in students' survey responses to questions about their interest in science or whether science is an important part of their identity. However, we do find increases in students' science self-efficacy. Interviews confirmed that students primarily discussed changes in their thinking related to self-efficacy, and that working in the more authentic inquiry-based environment helped to de-mystify how scientists work and how students can approach problems. Students generally did not discuss changes in their interest in science or whether they identify as a science person, however.

As for the second research question, we find that students described their science identities as a nuanced combination of their skills and abilities, interests, and career aspirations. They also more generally discussed being good at science through the skills, ways of thinking, and passions required by someone who is a good scientist. Interestingly, students were more likely to say they are good at science, and that they enjoyed EcoXPT or science classes in general than they were to say they want to be a scientist in the future. Students weighed their interests with interest in other subjects and career options and did not necessarily see EcoXPT as an experience that changed those interests.

While students generally did not describe changing their broad interests or aspirations as a result of the program, they did discuss ways they could use what they learned in EcoXPT in creative ways. Students discussed how they could use the thinking strategies they learned about collecting evidence and supporting claims for their interests in law or other subjects, and others described incorporating the content that interested them in EcoXPT into interests like writing. For students who already strongly identified with science and STEM careers, EcoXPT appeared to provide a way to deepen or shift some of their specific interests along with giving them a clearer understanding of how scientists work. It is possible these experiences could support a persistence in science interests in the long term that many students lack (Aschbacher et al., 2010).

Therefore, to answer our final question as to how findings from the different methods compare, we find that that the two methods complemented each other and confirmed each other's findings, particularly regarding the increases in students' self-efficacy. The interviews helped illuminate how students experienced the curriculum as a way to demystify how scientists work, explaining the increased survey responses. While both sources of data also showed the curriculum did not shift students' science interest and identity broadly, the interviews showed how some students were influenced in more subtle ways regarding specific areas of science interest and creative ways they found the program relevant to themselves. The survey instruments may be too blunt to capture such shifts for a short curriculum and may not distinguish well between students who have different interests and how changes in their orientation toward science and scientific thinking differed.

These findings point to the potential for virtual worlds to support students in identity exploration, but may highlight the need for a more prolonged or intensive experience than what the EcoXPT standalone curriculum offered. On the one hand, it is clear that students of this age hold strong views of their interests and aspirations, which a brief experience, even if immersive, is unlikely to shift. On the other hand, the interviews helped to illuminate the some of the mechanisms through which more prolonged or intensive experiences could in fact help students engage in a deeper or more explicit identity exploration. In particular, the virtual world gave students autonomy to explore what they felt was relevant to them, in some cases allowing students who were already interested in science to deepen their interest in different areas, and in other cases to allow them to apply strategies from the curriculum to other interests like investigating law cases or writing novels. Additionally, the increased sense of self-efficacy they described from being able to put themselves in the shoes of a scientist may point to ways that virtual worlds could support students' exploration further with a longer or more intensive experiences.

These results have interesting implications for the affordances and limitations of virtual worlds to facilitate students' identity change. Students identified increased agency as an important benefit of EcoXPT, and they were also able to articulate many interesting ways in which the program is relevant to their lives and futures. This confirms previous research into affordances of virtual worlds that can support projective reflection and identity exploration. Regarding science identities and interests, another consideration is the role relationships and mentoring can play in helping young people identify with a professional group. While EcoXPT allows students to interact with virtual scientists, in-person mentoring and affiliating with professional groups may be more effective when changing how people see themselves (Bouquillon, Sosik, & Lee, 2005). Indeed, students discussed their parents and other role models when describing their interests in school and careers. Further, it is possible that students need more explicit reflection on their identities or intentional guidance for considering how EcoXPT may change some of their interests or identities.

Overall, we find that the mixed methods approach is useful to provide a holistic and robust assessment of student's identity change by capturing average changes across students as well as illuminating the mechanisms through which students experienced changes. However, our study does have several limitations that should be accounted for when interpreting the results. We sampled a small population of classrooms from a larger study of the EcoXPT curriculum who may not be representative of all students more broadly. Additionally, the students interviewed represented an even smaller and potentially less representative sample, as they were identified by their teachers and had parental consent to be interviewed. It is difficult to estimate the percentage gains on the non-cognitive survey in terms of something meaningful external to the curriculum, but the interviews help us contextualize what it means to students. While not much variation is seen across the categories of the student-level demographic characteristics, there is certainly variation among students revealed in the interviews. The role of reading level must be more carefully examined, as too much written content may hinder the ability of the curriculum to effectively reach all students. Knowing that interests, motivation, learning, and identity interact in complex ways throughout young peoples' development, it is possible that the impacts of EcoXPT on students' self-efficacy may help change students' interests and identities over time.

Future work could investigate some of the subtle differences that may predict variation in cognitive and non-cognitive domains and revise the survey to detect these shifts. EcoXPT is currently being deployed in several public schools in the Northeastern United States to study how it differs from EcoMUVE and how it compares with several similar curricula, and forthcoming results may offer tantalizing clues as to how it's impacts on science identity may differ from our previous curricula. This work may have important implications for understanding the potential for virtual worlds to provide students opportunities for identity exploration and change compared to improving their self-efficacy. Agency, interest, and motivation, which are affordances baked in to educational experiences in virtual worlds, may not be enough in small doses to make students rethink their identities. Either programs need to target identity exploration specifically, or perhaps the long-term implications of increased self-efficacy may impact identity. A longitudinal study of how students' self-efficacy and understanding of scientists' work changes what they learn and changes in their interests in future science classes or other experiences may reveal whether self-efficacy is an important driver of STEM career choice in the long run.

Note

1. Pseudonym for blinding purposes.

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